

Proceedings

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Conference

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MESSAGE OF THE CHANCELLOR, RIPHAAH INTERNATIONAL UNIVERSITY



Mr. Hassan Muhammad Khan
Chancellor, Riphah International University

Having participated in the 8th International Water Conference titled "Valuing Water for Sustainability", I am filled with pride and gratitude for the collective efforts that contributed to its remarkable success. Hosted in collaboration with the Pakistan Council of Research in Water Resources (PCRWR) and international partners, the conference has underscored the critical importance of sustainable water management in today's world.

Graced by the presence of distinguished experts, scholars, policymakers, and practitioners from across the globe, the conference has fostered invaluable discussions and knowledge sharing. The diverse range of sessions and panel discussions, meticulously organized, have explored innovative solutions and strategies to address water scarcity, urban flooding, and climate resilience. These dialogues have been pivotal in advancing our understanding and commitment to sustainable water practices.

Appreciation is extended to all participants, speakers, and organizers whose dedication and expertise have made this conference a beacon of hope and progress in the field of water sustainability. The discussions held and the knowledge exchanged have been instrumental in shaping a more resilient and sustainable water future for Pakistan and beyond.

With the insights gained and the relationships forged, we remain committed to advancing the cause of sustainable water management. The outcomes of this conference have fortified our resolve to continue our efforts in education, research, and community engagement, ensuring that the value of water is recognized and preserved for generations to come.

Thank you for your unwavering support and contribution to the success of the 8th International Water Conference.

MESSAGE OF THE WASH EXPERT, UNICEF



Ms. Kiran Qazi
WASH Officer, UNICEF

Nearly half of Pakistan's drinking water is unsafe, worsening water scarcity, a crisis that demands immediate action. Particularly the situation in schools, where 24% of schools lack basic water and sanitation facilities, compromising children's health. Water is essential for sustaining communities, economies, and ecosystems. We should prioritize sustainable water management, innovation, and collaboration. Let's unite to secure clean water access for all, safeguarding our environment for future generations.

MESSAGE OF THE DIRECTOR GENERAL PCRWR



Dr. Hifza Rasheed
Director General PCRWR

Water is indispensable for life and plays a pivotal role in sustainable development worldwide. However, climate change is placing unparalleled stress on our water resources. The escalating temperatures, erratic precipitation, and heightened frequency of extreme weather events are disrupting water availability and quality globally. Consequently, vulnerable communities in developing countries are grappling with water scarcity, economic hardships, and social instability.

Pakistan faces significant challenges related to water resources, including scarcity, unequal distribution, deteriorating quality, and inefficient management, exacerbated by rapid population growth, urbanization, and climate change. To address these, we must focus on improved governance, enhanced infrastructure, conservation, monitoring, climate adaptation, community engagement, and integrated management. These efforts are crucial for managing water resources effectively, ensuring water security, and building resilience to climate change. Addressing climate change in Pakistan requires innovative solutions to mitigate its effects and enhance resilience.

Both the government and academia play crucial roles in addressing the challenges related to water security and climate change. The government is responsible for policy formulation, investment in infrastructure, regulation of water use, monitoring and reporting, and capacity building. On the other hand, academia is responsible for conducting research, educating the public, promoting innovation, building partnerships, and providing policy support. By fulfilling these responsibilities, both sectors can contribute to ensuring water security and climate change adaptation for current and future generations. The Eight International Conference is a joint venture of Riphah International University, PCRWR and UNICEF Pakistan that has acted as a forum for addressing the challenges related to water security and climate change. It has enabled the exchange of ideas and the formulation of practical recommendations for implementation by stakeholders in the water sector, including policymakers and decision-makers. It is with great pleasure that we present the proceedings of the 8th International Water Conference. This proceeding encapsulates the rich discussions, valuable insights, and innovative solutions shared during the conference, highlighting our collective efforts towards sustainable water management.

The proceedings reflect the breadth and depth of topics covered during the conference, including innovative technologies for water treatment, best practices in water conservation, and strategies for enhancing water resilience in the face of climate change.

We hope that this proceeding will serve as a valuable resource for all those working in the field of water management, inspiring further research, policy development, and action. Together, we can make a meaningful impact and ensure a sustainable water future for generations to come.

Thank you to all the participants, students, organizers and sponsors (UNICEF Pakistan) who made the 8th International Water Conference a resounding success. We look forward to continuing our collaboration and building on the momentum generated during this conference

MESSAGE OF THE VICE-CHANCELLOR, RIPHAH INTERNATIONAL UNIVERSITY



Prof. Dr. Anis Ahmed
Vice-Chancellor, Riphah International University

It is with great pride and honor that I reflect upon the successful conclusion of the 8th International Water Conference, entitled "Valuing Water for Sustainability," which was held three months ago. This conference, having been meticulously organized and passionately attended, has underscored the critical importance of sustainable water management in the face of escalating global challenges.

Having been convened by the collaborative efforts of the Pakistan Council of Research in Water Resources (PCRWR), the Riphah Institute of Public Policy (RIPP), and the dedicated organizing committee, this event has brought together leading experts, policymakers, researchers, and stakeholders from around the world. The invaluable insights and innovative ideas shared during the sessions have significantly contributed to our understanding and appreciation of water as an essential resource for sustainable development.

We have been privileged to have engaged in profound discussions, witnessed groundbreaking research presentations, and participated in thought-provoking panel discussions. These exchanges have illuminated the multifaceted dimensions of water sustainability, from technological advancements in water management to policy frameworks that ensure equitable and efficient water distribution.

It is through such collective endeavors that we can forge a path towards a future where water is not only valued but also managed with the utmost care and responsibility. The diverse perspectives and solutions presented have provided a robust foundation upon which we can build resilient water management strategies tailored to our specific regional and global contexts.

I extend my heartfelt gratitude to the organizers, speakers, and attendees who have made this conference a resounding success. Your contributions have been instrumental in advancing the dialogue on water sustainability and have reinforced the imperative of interdisciplinary collaboration.

Thank you once again for your participation and dedication.

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Executive Summary

The 8th International Water Conference (8IWC) – 2024 on “**Valuing Water for Sustainability**” jointly organized by Faculty of Public Policy-Riphah International University, , Pakistan Council of Research on Water Resources (PCRWR), United Nations Children's Fund (UNICEF) and partner universities/institutes; University of Balochistan (UoB), Comsats University (CU), U.S.-Pakistan Center for Advanced Studies in Water (USPCAS-W) Mehran University, United Nations agency for human settlements (UN-Habitat) and Institute of Research Promotion from 6-7, March 2024 at Islamabad.

The conference provided a vibrant podium for the dissemination of scientific ideas of scientists, academic scholars, researchers, policy actors, technocrats, and the development sector. The platform also provided a paved research pitch to civil society members and progressive students who are very enthusiastic and passionate to dig out the effective and viable scientific solutions, plans, and intervention for the blue sustainability of Pakistan’s water sector. The conference comprises of six sessions extended over two days including inaugural and five technical sessions. The two panel discussions-based sessions were i) Tech for Tap - Leveraging Innovation for Sustainable Pakistan’s Water Future and ii) Rainwater Harvesting to Manage Urban Flooding. The other thematic sessions of the conference are as follows: a) Water, Sanitation and Hygiene (WASH), b) Climate Change Adaptability, Water Governance & GLOF and c) Water Productivity: Water, Energy, Food Nexus & Hydro Diplomacy. The inaugural session was pursued by the 60 research papers presented by different scholars and scientists in accordance with the nature of sub-themes of the conference.

In the inaugural session, after the recitation of Holy Quran and National Anthem, the opening remarks on the importance of water in terms of availability and the sustainable preservation of insufficient resources were given by the Dr. Hifza Rasheed, Director General, PCRWR. Dr. Rashid Aftab, Director RIPP gave an overview of the water conference and its background. Further, experts, researchers, academicians and representatives of the development sector enlightened their perspectives with various lenses of logical rationalization and highlighted the challenges and way forward for the water sector. Prof. Dr. Anis Ahmad, Vice Chancellor, Riphah International University, Islamabad focused on the concept of drop of blue and how it is the basis of creation according to Quran and Islam. The Keynote Address was delivered by Ms. Kiran Qazi, WASH expert UNICEF, who appreciated the initiative of conference, she reiterated that UNICEF support collaborative efforts and will extend future support in respect of WASH sector. She also emphasized the importance of water in terms of its provision for safe drinking water to the populace as well as observing the sanitation and hygiene which is directly related for a healthy society.

Prof. Dr. Athar Hussain, Head of Department of Meteorology, COMSATS University interestingly related the atmospheric effect and water on earth and specifically in Pakistan and the key factors which have enormous potential to deviate the atmospheric phenomena and water level

in Pakistan. Dr. Muhammad Ashraf, Advisor IWMI, highlighted significant factors associated with water governance and its distribution to the users i.e. agriculture, municipality and industry. He emphasized the unveiling of game-changing water accounting framework to monitor water sources, consumption and availability.

Dr. Muhammad Abid T.I, UNESCO Chair, Comsats University, was the last Speaker in the inaugural session. He asserted that blue regime has broader footsteps, and it spread over diversified crossings in the world because it is linked with the phenomena of climate change which is an alarming issue at global level in general and Pakistan in particular. Pakistan is facing several episodes of extreme climatic events that have produced the devastating impact on the growth of the country, therefore on this platform, existing challenges of climate change which make Pakistan Flood prone country and climate vulnerable country may be account for.

During invaluable technical sessions, key areas which were addressed, included; a) Inadequate Water Availability, b) Dependence on Single River System, c) Low Water Productivity, d) Overuse of Groundwater, e) Vulnerability of the country due to Climate Change, f) Climate resilience and adoptability g) Limited access of the population to safe drinking water and h) Waste water management and treatment, i) Model for climate change in Pakistan, j) Factors associated with GLOF, k) Incompetent hydro diplomacy network and paradigm shift, l) Non-nexus approach and independent approach of water management.

In the conference, the pivotal point of discussion was “**WATER FOR SUSTAINABILITY**” so the WATER can be dealing as “**Energy Savior for Generation**” The speaker emphasized that due to extreme Climate Change Scenarios, Unavailability of Safe Drinking Water and Lack of Sanitation Facility, Climate Resiliency, GLOF and Pattern of Blue and Green governance and its trend. In the crux, productive control of blue output with consistent pattern of water systems for energy and power savior intelligently.

Water needs specific attention by relying on the holistic, integrated nexus approach to bring together all vulnerable sectors of interest for community wellbeing. Water is becoming an “**engine of national security**”, because it is affecting the normal citizens by putting the burden on the food security (less agriculture productivity due to water- intensive practices), untenable energy utilization (non-availability of small and large dams to store wasted water in the Arabian Sea). The inclusive demand- driven model was proposed to be considered as an operative way to buffer the impact of water as strategic acid.

There is a need to re-manage the whole paradigm of the water sector by evidence creation, echoing and modelling of available water resources in the hydro-sector. This can be done by focusing on applied and innovative water resources systems, generation of real time data, plans of actions, thus it is high time to revisit the blue strategy with the geo-economic approach and it should be re-orient with green nexus -to save the country from ultimate devastation.

Technical Session Reports

Session I

Tech for Tap - Leveraging Innovation for Sustainable Water Future of Pakistan

Organized by the Institute of Research Promotion (IRP) as part of the 8th Annual Water Conference by the Pakistan Council of Research in Water Resources (PCRWR) and the Riphah Institute of Public Policy (RIPP) on March 06, 2024, at PCRWR, Islamabad

Brief of Session

Using innovation to secure Pakistan's water future was the main goal of the "Tech for Tap" session. Key strategies to promote local research, development, and investment in water-related technology were discussed in the panel discussion. These programs attempted to encourage local solutions to water problems and lessen Pakistan's reliance on imported water technologies.

Panel Speakers

- Dr. Tariq Bashir, PCST
- Dr. Mirza Habib, PSF
- Dr. Muhammad Abid, COMSATS
- Moderated by Rahmat Ullah Gill, Executive Director IRP.

Description of Key Proposed Initiatives

1) Topic Bank for Water Research Projects

A unified "Topic Bank" for water research projects was suggested by the panel. The purpose of this repository is to facilitate collaboration among academics, institutions, and funding agencies by identifying major study areas and themes related to Pakistan's water challenges.

2) Networking Platform for Water Stakeholders

All parties involved in the water sector would be connected through the creation of a networking platform. By providing a regular forum for the sharing of concepts, insights, and best practices, this platform will promote cooperation in the fight against water-related problems in Pakistan.

3) Funding Stream for Water Research

The panelists underlined the necessity for government funding organizations and venture capital firms to establish specific funding streams for water research. These grants would help with research and development projects meant to create regional answers to water-related problems.

4) Promotion of Local Technologies

Universities in Pakistan were urged to start an initiative to create indigenous technologies for a range of water management applications. Water treatment, conservation, distribution, consumption, quality assurance, recycling, and reuse are all included in this. Pakistan's reliance on imported water technologies would be lessened and local innovation would be encouraged.

- Water treatment: refers to the development of economical and effective methods for making water fit for human consumption and other uses.
- Water conservation: refers to the application of technology to minimize water waste and encourage effective water use in homes, businesses, and agriculture.
- Water Distribution: To efficiently distribute water to various locations, smart technology and improved infrastructure must be used.
- Water Consumption: Endorsing methods and technologies that cut down on water use across a range of industries, including families, businesses, and agriculture.
- Monitoring Water Quality: Creating cutting-edge methods to check water quality at various distribution and treatment stages.
- Water recycling and reuse: refers to the application of technologies for the treatment of wastewater and its subsequent reuse for a variety of uses, including industrial activities and irrigation.

5) Venture Capital for Water Technologies

The relevance of venture capital in fostering innovation in water technology was underlined during the discussion. Venture capital businesses are essential sources of investment for early-stage companies developing solutions related to water. Venture capital firms can stimulate growth and innovation in the water sector by assisting in the commercialization of new technology through their investment in these businesses.

6) Creation of Office for Advisory on Water Research Commercialization (WRC)

The creation of an office for the Advisory on Water Research Commercialization (WRC) inside PCRWR was suggested at the session. Members of the business sector and specialists in water technology and research would make up this office. With an emphasis on commercialization, the WRC office's main responsibility would be to offer direction on themes and the conduct of applied research in the water sector. Incorporating the private sector would allow the office to guarantee that research endeavors are in harmony with market demands and have a direct route to commercialization, thereby propelling innovation within the water industry.

7) Creation of Water Technology Park

The creation of a Water Technology Park was suggested during the session as a means of giving a complete ecosystem for the advancement of water-related solutions and the founding of businesses that provide water solutions. By bringing together academics, businesspeople, and industry specialists to foster innovation, this park would act as a center for water sector innovation, research, and commercialization.

Modern research facilities, including testing grounds and labs, would be available at the Water Technology Park to aid in water technology research and development. Additionally, it would allow early-stage and startup businesses developing water-related solutions access to incubation facilities, which would give them access to capital, mentorship, and other resources they need to develop and prosper.

The Water Technology Park would also encourage cooperation between government, business, and academia, creating a vibrant environment for innovation in the water sector. In addition, it would provide a stage for exhibiting and advancing regional water technology, assisting Pakistan

in becoming less reliant on foreign water technologies and encouraging local creativity in the water industry.

Conclusion

The need of using innovation to address Pakistan's water concerns was emphasized during the discussion. By encouraging indigenous research, development, and investment in water-related technology, the suggested programs hope to secure Pakistan's water supply for the future.

Session II

Rainwater Harvesting to Manage Urban Flooding

Background

Climate change poses a significant threat to sustainable urban development. During recent years, heavy rainfall events have led to severe urban flooding, disrupting human life and causing widespread damage. Urban flooding is a pressing issue in many metropolitan cities of Pakistan, exacerbated by rapid urbanization, inadequate infrastructure, and changing climate. Metropolitan cities in Pakistan face recurrent urban flooding, leading to significant economic loss, infrastructural damage, and threats to public safety. The inflow is unprecedented and urban sprawl has constrained the drainage systems rendering it insufficient to manage the high volume of rainfall runoff. An integrated approach to rainwater harvesting with urban landscape management can offer a sustainable solution by utilizing rainwater as a resource rather than allowing it to contribute to flooding.

UN-HABITAT, Pakistan office is implementing, and Adaptation Fund (AF) project titled “Enhance community, local and national-level urban climate change resilience to water scarcity, caused by floods and droughts in Rawalpindi and Nowshera, Pakistan”. The collaborating partners include The Ministry of Climate Change and Environmental Coordination, National Disaster Management Authority (NDMA), Pakistan Council of Research in Water Resources (PCRWR), Water and Sanitation Authority (WASA), Rawalpindi and Tehsil Municipal Association, Nowshera. This project is aimed at raising the awareness among the masses for the importance of integrated approaches to harness full potential of rainwater harvesting system indispensable for the mitigation of urban flooding in the cities of Pakistan. This will not only encourage the communities to enhance their resilience to the climate extremities but also help to mitigate the risks of urban flooding in changing climate scenario. It is imperative for the farmers to share the findings of this project with the relevant stakeholders such as academia to re-define the policy guidelines and prepare the future professional accordingly. In this regard, PCRWR joined hands with Riphah International University to organize a specialized panel discussion as a part of the 8th International Water Conference. The discussion was held on 6th March 2024 from 2:00 to 4:00 pm at PCRWR auditorium. The target audience of this session were national and international academics as well as the policy experts. The objectives of the discussions are as follow:

- To discuss the different plausible solutions to mitigate the urban flooding in the wake of climate change.
- Raise awareness and promote community involvement in rainwater harvesting initiatives to create a sense of ownership and sustainability.

List of panelists

- i. Dr Rashid Aftab, Riphah Institute of Public Policy, Riphah International University, Islamabad.
- ii. Ms. Almas Shakoor, Executive Director, Shehresaaz Foundation, Islamabad.
- iii. Engr. Dilshad Arshad, Director (Hydrology), Pakistan Council of Research in Water Resources (PCRWR)
- iv. Mr Abdul Qayyum, Architect, UN Habitat, Pakistan Office
- v. Engr. Bareerah Fatima, Deputy Director (PCRWR) (moderator)

Key Questions of the panel discussion

- What are the current challenges in urban flood management in Pakistan, particularly in densely populated urban areas?
- What kind of approaches do you think may be applied for rainwater harvesting in the urban areas to avoid urban flooding?
- How are climate change and urbanization exacerbating flooding risks in Pakistani cities, and what proactive measures can be taken to address these challenges?
- What role do urban planning and infrastructure development play in mitigating flood risks in Pakistani cities, and how can they be improved to enhance resilience?
- What are the financial implications of implementing integrated flood management strategies, and how can sustainable funding mechanisms be established to support long-term resilience efforts?
- How can the government collaborate with communities and stakeholders to develop comprehensive flood management strategies that integrate both structural and non-structural measures?
- What is the role of green infrastructure, such as rain gardens, permeable pavements, and wetlands, in reducing urban flood risks, and how can they be integrated into urban planning frameworks in Pakistan?
- How can public awareness and community engagement be improved to foster a culture of preparedness and proactive involvement in urban flood management initiatives?

Proceedings

The composition of panel discussion was comprised of seasoned professionals from academia, civil society organization, UN-HABITAT and PCRWR. The discussion was attended by many students and professionals having diverse backgrounds in the field of public policy research. The panel discussion started with a brief presentation by PCRWR explaining the concept of the panel discussion that surrounded the subject of integrated urban flood management with rainwater harvesting as a possible solution. In this presentation so possible solution for rainwater harvesting to curtail urban flooding were also explained, these include rooftop rainwater harvesting for domestic use, rainwater harvesting for managed aquifer recharge, rainwater harvesting in parks and green belts through landscaping. Few such interventions are shown in figures 1-4.

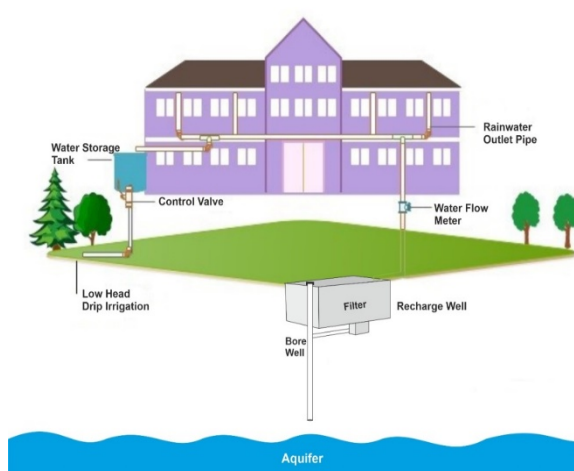


Figure 1. Urban rainwater harvesting in system approach



Figure 2. Rainwater harvesting for managed aquifer recharge in the green belts



Figure 3. Rainwater harvesting in parks



Figure 4. Rainwater harvesting in public building through soakway recharge pit

The presentation stressed the need for resolving the practical difficulties in the way of implementing the interventions keeping in view the scenario of urban flood as the consequences of climate change. In this regard, integrated thinking approach was explained keeping in view the policy tools, community awareness, decision support system tools, green buildings, capacity building and lastly the adaptation to climate change (figure 5).

External Factors that influence the integrated approaches;

- Financial allocations for implementing adaptive approaches
- Organizational policies
- Institutional collaborations
- Compatibility of solutions
- Perpetual growth and sustainability of solutions
- Ownership by the communities
- Availability of well tested solutions

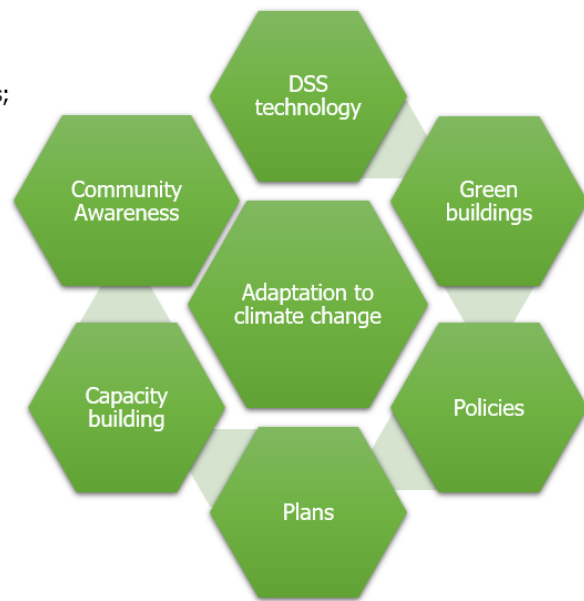


Figure 5. A composition of intrinsic and extrinsic factors for the implementation of integrated urban flood management solutions

The discussion began with deliberation on well-tested solutions, the ice-breaking question was floated to the panelist from PCRWR, Engr. Dilshad Arshad, Director (Hydrology), regarding possible methods and techniques for rainwater harvesting in urban areas. He responded that in urban areas infrastructure is categorized according to their attributes and likewise rainwater harvesting options may be proposed accordingly. In urban areas the limiting factor includes space, the private and public ownership of land, high cost of land and the urbanization being the umbrella factor. Therefore, solutions of smart scale in larger number may yield fruitful results. For instance, any rainwater harvesting intervention installed in the premises of a public or private building do as the potential to conserve at least 50% of the rain rainfall. Therefore, redesign the magnitude of urban flooding by half.

On a question regarding the existing challenge of urban flooding with reference to urban development. The representative from UN-HABITAT and disaster management expert Mr. Abdul Qayyum, explained in detail the provision of urban flood management solutions according to the space in urban planning and development. He further apprised that it is awful to note that all the new urban sector development being made is without provision of rainwater harvesting even though Islamabad is planned according to the availability of rainwater for ensuring urban water supply directly or in directly. He noted that at the design stage of the Islamabad, it was presumed that the rainwater will be harvested at domestic level for water usage at the domestic level for diversified usages such as car washing, gardening and other usages for cleaning purposes. It was adopted initially but did not continue till today. Just imagine in the present scenario, in the absence of domestic rainwater harvesting where the rainwater is allowed to rush through the streets which seldom accumulate solid waste on its way to a nearby natural drainage. Ultimately it is going to chock up that drain leading to a disaster of high magnitude. In this regard, unplanned urban development is not to be blamed only but the ownership of the communities of this issue is also an important factor to be considered.

On a question regarding bridging policy gap for urban planning and flood mechanism, Dr. Rashid Aftab, Director, Riphah Institute of Public Policy, Riphah International University, first took sometimes to set the context of climate change and its relationship with urban planning and flooding, keeping in view the presence of many students in audience. He stressed that a **need for integration of rainwater harvesting in urban planning** is a key element of this discussion and for its sustainability institutions should respect and understand the perspective of each sector. He further remarked that fortunately in Pakistan there is a large setup of institutions and a new set of policies have been set up in recent decades. It is high time to put this development to the best use. Urban department is the symbol of progress of a nation because in Pakistan 10 big cities contribute need national GDP by 80%. Therefore, increasing the resilience against natural disasters for big cities is critical for nation growth as well as.

It is notable to mention here that urban areas are also surrounded by the peri urban and informal settlements that are often deprived of facilities associated with urban development. Therefore, a question was posed to Ms. Almas Shakoor, Executive Director, Shersaz Foundation that why the issue of such informal settlements may be addressed. She explained that first it is important to note that what are these settlements in Islamabad and Rawalpindi? She explained Bara Kahu in Islamabad and colonies associated behind Nallah Lai are highly representative of such areas. Lack of planning and development of such settlements has already compromised their sustainability towards the supply of fresh water. In these areas household units in these settlements are much smaller compared to any well-planned sector in Islamabad, likewise roads and green belts are almost negligible. Therefore, in 2,3 and 4 marla houses there is a limited space to harvest rainwater. Moreover, the water and sanitation issues become more pronounced during the abundant rainfall period and prolonged dry period. She highlighted that with the support of UN-HABITAT and Adaptation Fund communities are being trained for rainwater harvesting and such units are being established at the household level. Sheharsaz foundation is helping people in installing roof top rainwater harvesting system in schools, households and mosques. The impact of these rainwater harvesting systems on the water flow system of these areas is such that the beneficiaries are being contacted by their relatives to set up these systems in other areas as well. Since there is a severe crisis of drinking water supply in these areas, we are also putting some efforts into making this harvested rainwater be treated in a way that it can be made drinkable.

A question was posed to Engr. Dilshad Arshad, Director (Hydrology), PCRWR, regarding the possible integration of green infrastructure into urban planning framework of Pakistan. He apprised that there are two ways to do this firstly, to include these provisions in the building regulation of Pakistan and secondly by piloting such intervention in the urban spaces. He further said that PCRWR, UN-HABITAT and PEC had jointly worked for developing the building codes for rainwater harvesting. If this provision is approved and implemented in letter and spirit the rainwater harvesting may be incorporated in the urban infrastructure by legislation. Now in response to the second option PCRWR has piloted different methods for rainwater harvesting in urban areas for instance roof top rainwater harvesting technologies followed by water storage in portable tank, surface rainwater harvesting for groundwater recharge. Therefore, inverted well and development of soak way pit as well as recharge well in the parks and green belts. PCRWR has implemented a model site in Kachnar park of Islamabad where a lake is developed to store and convey water into recharge pit. Moreover, there is a potential to develop more 1000 of such sites

in Islamabad only. PCRWR has successfully supported CDA in the developing 100 such sites in Islamabad. During the discussion it was highlighted that policy and technology is important but the financial resources to implement this intervention is required to realize the benefit.

On a question of sustainable financial mechanism Dr. Rashid Aftab, Director, Riphah International University, remarked that we talk about capital resources whereas human capital pertains to 70% of that financial capital. Therefore, ideas generated by this human capital are worth much to generate economic activity for the financial sustainability of a society. For instance, if ideas are valuable to such an extent that a private sector entity is willing to pay for its extension seeking the mutual benefits of this organization and the public. In this regard, public/private partnership is the most suitable sustainable financial mechanism. The representative of civil society organization Shersaz said that the informal community are very poor that they cannot be contributed financial need physical intervention for rainwater harvesting but they will do that through in-kind contribution. This could be in the form of share in labor during the construction and maintaining development in the long run. The only way for the successful implementation of this method is through effective community mobilization and engagement.

The feat of public awareness of community engagement can only be achieved through multi-tier projects, such as inclusion of rainwater harvesting and possible options in the curriculum starting from primary education level to the university level, promulgating rainwater harvesting as potential urban flood management solution through national television and social media. In this context religious channels may also be availed by convincing Mosque Imams to shed light on the importance of rainwater harvesting system in the light of Quran and Sunnah. Organizations like PCRWR and the academia should join hands to develop such knowledge products that are available to any person who is willing to install a rainwater harvesting system at their house with ease.

Theme 1

WATER, SANITATION & HYGIENE

Valuing Water for Sustainability: Water Sanitation and Hygiene (wash)

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Abstract

As the world grapples with escalating water challenges and their impact on sustainable development, the theme of "Valuing Water for Sustainability" emerges as a critical paradigm shift. Within this overarching theme, the sub-theme of Water, Sanitation, and Hygiene (WASH) stands as a linchpin for achieving holistic environmental, social, and economic sustainability. This abstract delves into the significance of valuing water within the context of WASH, emphasizing the interdependence of clean water access, sanitation infrastructure, and hygiene practices for thriving and resilient communities. Adequate and equitable access to water resources is explored as a fundamental human right and a prerequisite for achieving the United Nations Sustainable Development Goals (SDGs). Recognizing the intrinsic link between water and sanitation, the abstract underscores the need for integrated WASH strategies that go beyond infrastructure development. It delves into the behavioral and cultural dimensions of hygiene practices, highlighting the transformative potential of education and community engagement in fostering sustainable habits. Moreover, the abstract addresses the economic implications of valuing water in the WASH sector. Investments in water and sanitation infrastructure are positioned not only to prevent waterborne diseases but also as drivers of economic growth and resilience, particularly in marginalized communities. The abstract emphasizes that investments in water and sanitation infrastructure are not only crucial for preventing waterborne diseases but also serve as catalysts for economic growth, particularly in marginalized communities, creating opportunities for employment and fostering resilience in the face of broader economic challenges." The global water crisis requires a paradigm shift from viewing water as a limitless resource to recognizing its finite nature and the importance of conservation. The abstract concludes by advocating for a collaborative and innovative approach to valuing water within the WASH framework, acknowledging its pivotal role in achieving a sustainable and equitable future for all.

Key words: Sanitation Infrastructure, Hygiene Practices, Sustainable Development Goals, Economic Growth, Equitable Approach

Exploring Aquifers Dynamics in the Quetta Valley through Artificial Neural Networks (ANNs): A Comprehensive Analysis for Predictive Modeling

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Abstract

In recent times, there has been a growing interest in monitoring and comprehending the dynamic shifts in groundwater levels (GWL) within the Quetta Valley. Precise forecasting of GWL is crucial for the effective management and preservation of groundwater resources, mitigating the risks of overexploitation, degradation of water quality, and land subsidence. In this study, we employ an Artificial Neural Network (ANN) as a data-driven model to anticipate fluctuations in aquifers. We make use of data gathered from 14 GWL monitoring stations, spanning from 1980 to 2020, encompassing a spectrum of dynamic fluctuations, including both increases and decreases, in GWL. For the development and assessment of our model, we divide the dataset into two subsets: allocating 70% for model training and the remaining 30% for testing. The model's performance is evaluated quantitatively using established metrics, such as root mean square error (RMSE), coefficient of determination (R^2), and mean absolute error (MAE). Furthermore, we present a qualitative assessment through visual representations like time-series line plots and scatter plots, providing a comprehensive perspective on the model's predictive capabilities. This investigation enhances our comprehension of GWL dynamics in the Quetta Valley and illustrates the potential of ANN models as valuable tools for the prediction and management of GWL.

Keywords: Aquifer fluctuations; Artificial Neural Networks (ANNs); Quetta Valley; model evaluation.

1. Introduction

The aquifer forms the principal and vital water sources for ecosystems and human societies. In arid and semi-arid areas, the major source of water to the mentioned uses becomes the aquifer. The Quetta valley is a semi-arid climate area where rainfall is both very little and erratic. This, therefore, leaves the area in a position of depending upon its aquifers in order to satisfy water needs both to support the growing population and farming demands of this area. Dynamic operation of the aquifer systems, be it natural or anthropogenic, poses serious challenges toward their sustainable management. This gives dynamic aquifer dynamics a management application through progressive predictive tools that can bring out changes in water flow and storage with different scenarios clearly with very few margins of errors.

This study is a very robust model recently proving to be the Artificial Neural Networks (ANNs) in the field of hydrology. These models have a very strong predictive capability; therefore, aquifer understanding, and management will be made easier and more effective (Smith and Eli, 2017; Khan et al., 2019). The ANN proves competent for capturing the non-linear relations defining the

aquifer parameters and exterior influences; therefore, it comes out very suitable for dealing with the complexity defining the interaction within the aquifer system. (Doe and Rahm, 2020)

This study intends to apply ANN to get the dynamics of the aquifers in the Quetta Valley. The development of such a holistic predictive model has the eye to the provision for efficient management of water resources within this region.

This study has its added value, in that it contributes not only to a better scientific knowledge of the aquifer systems but also to the intrinsic interest in their sustainable water resources management in semi-arid regions. Thus, this is an important support tool for planners and decision-makers to avail of a reliable predictive tool that can help them chalk out appropriate strategies of the aquifer conservation and its effective use to lead toward long-term viable water resources in the Quetta Valley.

2. Study Area

The selected study area is Quetta, serving as the capital of the Balochistan province in Pakistan. The Quetta valley covers a total area of 603 square kilometers and is situated between the latitudes of 30°0' to 30°30' N and longitudes 66°40' to 67°15' E (Khair et al., 2012) It is in a valley at an altitude of 1,680 meters (5,511 feet) above sea level. (Fig 1).

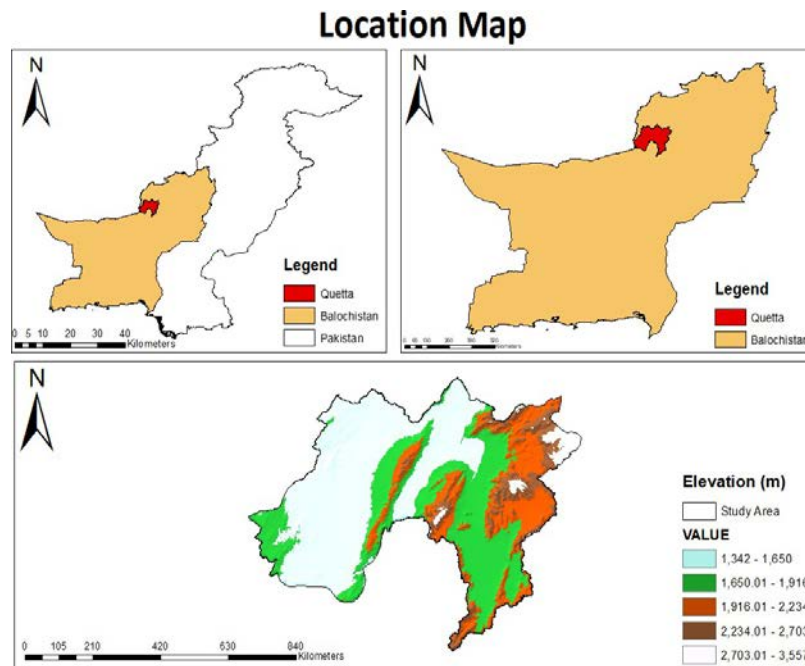


Fig. 1: Location Map of the Study Area

2.1. Hydrogeology

There are two aquifers beneath the Quetta valley. The unconfined alluvial aquifer, which is the top layer and makes up the valley floor, is composed of a combination of gravel, sand, and clay. It is between 150 ft and 300 ft below the surface. The thickness of the alluvial aquifer increases gradually from the valley shoulders to the center and from the southern to the northern part of the valley (Aftab et al., 2022). The second aquifer, a restricted aquifer made of limestone formation, ranges in depth from 350 ft to 1,200 ft (Imran et al., 2021). Due to the active tectonic of the Chaman Fault System, hard-rock formations of limestone and conglomerates are heavily

jointed and fractured with well-developed secondary porosity and permeability. Direct replenishment of the aquifers occurs along mountain slopes through exposed limestone formations from precipitation and surface runoff (Table 1).

Table 1: Principal hydrogeological units' classification

Aquifer Types	Lithology	Depth (m)
Shallow Aquifer	Gravel, sand, and silt	45 to 91
Deep Aquifer	Limestone	106 to 365

3. Literature Review

3.1. Aquifer Dynamics in Arid and Semi-Arid Regions

Understanding aquifer dynamics in arid and semi-arid regions has been a critical area of research due to the challenges of water scarcity and the increasing demand for water resources (Ahmed and Umar, 2018). Studies focusing on these regions have highlighted the complexities of groundwater flow, recharge mechanisms, and the impacts of human activities on aquifer sustainability (Jiang et al., 2016).

3.2. Artificial Neural Networks in Hydrology

The application of Artificial Neural Networks (ANNs) in hydrological studies has grown significantly over the past few decades. ANNs have been recognized for their ability to model nonlinear systems without the need for detailed a priori knowledge of the system's internal processes (Maier and Dandy, 2000). This characteristic has made them particularly useful in predicting groundwater levels, quality parameters, and aquifer responses to various stimuli (Smith and Eli, 2017).

3.3. Predictive Modeling of Aquifer Systems

Predictive modeling has become an indispensable tool for the management and planning of water resources. Recent advancements have focused on integrating machine learning techniques, such as ANNs, to improve the accuracy and reliability of predictions (Khan et al., 2019). These models are capable of assimilating large datasets, including precipitation, land use changes, and extraction data, to forecast aquifer behavior under different scenarios (Doe and Rahm, 2020).

3.4. Case Studies and Applications

Several studies have successfully applied ANNs to model aquifer systems in various geographic settings. For example, a study by Lin and Chen (2018) demonstrated the efficacy of ANNs in predicting groundwater levels in Taiwan, while Al-Bitar et al. (2020) applied ANN models to assess the impact of climate change on aquifer recharge rates in Jordan. These case studies provide valuable insights into the practical applications of ANNs in aquifer management and highlight the importance of tailoring models to specific regional characteristics.

3.5. Challenges and Future Directions

Despite the proven capabilities of ANNs in hydrological modeling, challenges remain in terms of data quality, model interpretability, and the generalization of models to different hydrogeological contexts. Future research directions include the integration of ANNs with other modeling approaches, such as physically based models, to enhance understanding and predictions of aquifer dynamics (Singh and Gupta, 2021).

4. Methodology

4.1. Data Collection

The study utilized groundwater level, precipitation, and temperature as input variables. Groundwater level fluctuations were assessed using piezometer data from the Quetta Valley, obtained from the Water and Sanitation Agency (WASA) for the period 1990 to 2022. Monitoring frequency ranged from monthly to annual, with nine observation wells providing a total of 492 data points. See Fig 2 for the location map of observation wells.

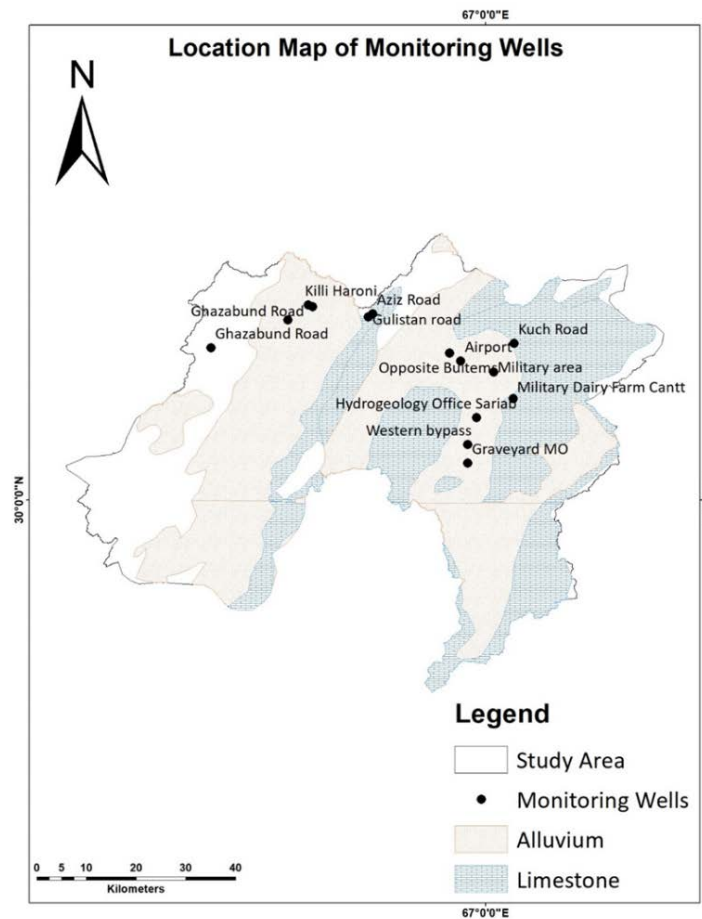


Fig. 2: Location map of monitoring wells

4.1.1 Model Deployment (Artificial Neural Network)

The empirical, data-driven Artificial Neural Network (ANN) model is employed for making groundwater level predictions. The ANN structure consists of three layers: the input layer, hidden layer, and output layer. In this study, a widely used technique for hydrological parameters, the feed-forward multilayered perceptron (MLP), was employed to train and test the ANN model. The utilization of MLP within the ANN framework highlights the model's capability to handle complex, nonlinear relationships between variables in hydrological forecasting and analysis. This approach underscores the potential of machine learning techniques in enhancing the accuracy and efficiency of water resource management and prediction models.

The MLP, employed in this study for predictions, learns relationships between inputs and outputs using a large volume of data and is well-suited for nonlinear modeling. An MLP comprises multiple layers of neurons, with each node (neuron) in a layer connected with a certain weight to every node in the following layer (Fig 3 for the ANN architecture for the prediction).

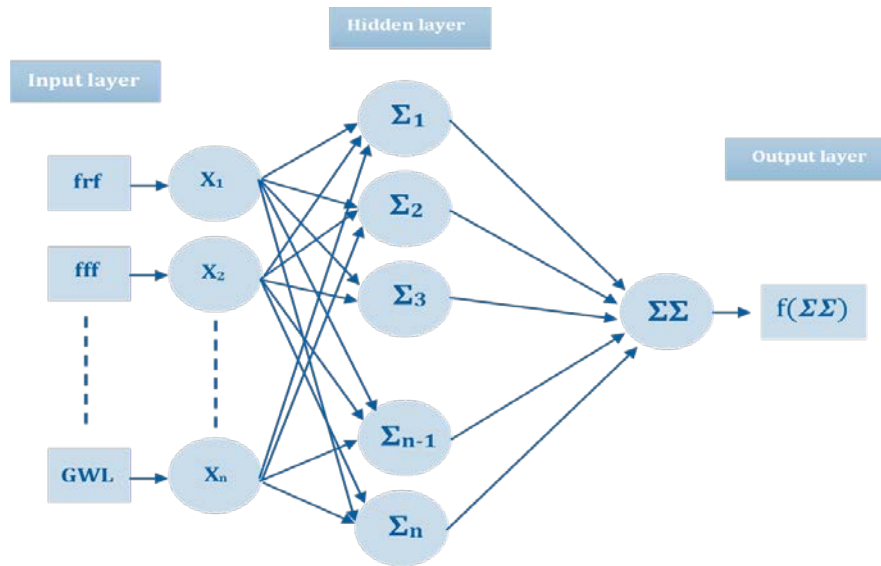


Fig. 3: ANN architecture for prediction.

4.1.2 Training and Testing of data

For appropriate training and data testing, the type and preparation of data play an important role. The dataset was divided into two parts: 77.23% for training and 22.76% for testing and validating the developed model.

4.1.3 Model Calibration

In the training phase initially, the Rectified Linear Unit (ReLU) was used as an activation function in the hidden layers. The ReLU activation function is applied element-wise to each neuron's output. The formula for ReLU is:

$$\text{ReLU}(x) = \max(0, x)$$

In the context of an ANN for groundwater level prediction, if x represents the output (or weighted sum of inputs) of a neuron in the network, the ReLU function will output x if x is positive and 0 otherwise. Mathematically, it can be expressed as:

$$\text{ReLU}(x) = \begin{cases} x, & \text{if } x > 0 \\ 0, & \text{otherwise} \end{cases}$$

This activation function introduces non-linearity to the model and helps the network learn complex patterns in the data. It's worth noting that ReLU has been widely used in deep learning models, including those applied to time series prediction tasks such as groundwater level forecasting.

4.1.4 Model Validation

After deploying and calibrating the model, we conducted validation using various statistical indices, including the Coefficient of Determination (R^2), Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE) to assess the reliability and predictive performance of the deployed model (Table 2). The R^2 ranges from 0 to 1, where 1 indicates the perfect model, while values above 0.8 indicate an acceptable model with good prediction. Values below 0.5 indicate an unacceptable model with poor predicting ability. But for RMSE and MAE, there is no fixed range; smaller values are considered better for a model's performance, and values near 0 or just 0 indicate a perfect model.

Mathematical precision formulas for different statistics used in measuring prediction precision are provided below.

Table. 2: Metrics for model performance evaluation of ANN

Performance criteria for evaluation of ANN model		
RMSE	Root Mean Squared Error	$\sqrt{\frac{1}{n} \sum_{i=1}^n (h_i - h_i')^2}$
MAE	Mean Absolute Error	$\frac{1}{n} \sum_{i=1}^n h_i - h_i' $
R^2	Coefficient of Determination	$1 - \frac{\sum_{i=1}^n (h_i - h_i')^2}{\sum_{i=1}^n (h_i - h)^2}$

Where n = the number of observations or data points, h_i = the actual groundwater level for the i^{th} observation, h_i' = the predicted groundwater level for the i^{th} observation and h = the mean of the actual groundwater levels.

5. Results and Discussions

5.1.1. Analysis of Rainfall and Static Water Level Variations

The study presents a comprehensive analysis of the variations in rainfall and static water levels in the alluvium and limestone aquifers from 1980 to 2020 (Fig.4). This period shows notable fluctuations in both parameters, which are crucial for understanding groundwater dynamics in these aquifers.

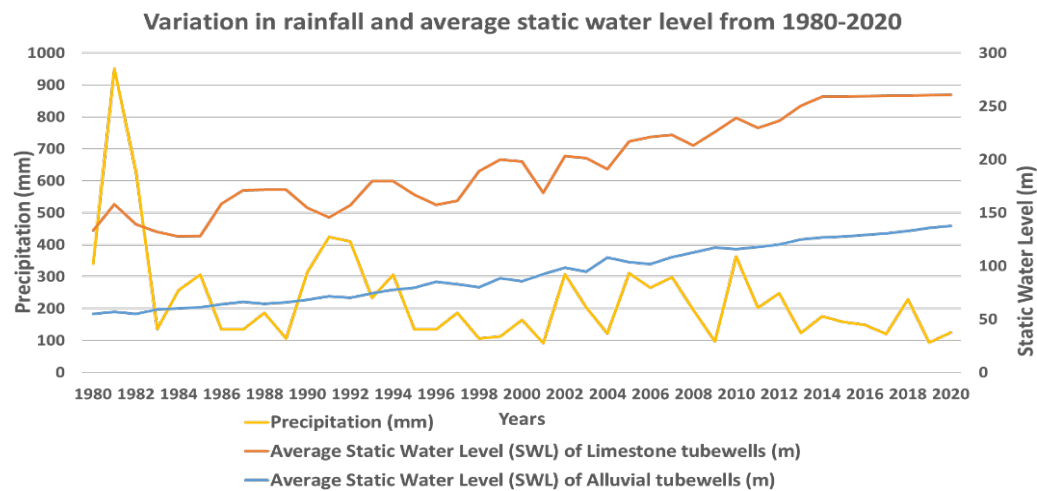


Fig. 4: Variations in rainfall and average static water level from 1980-2020 in alluvium and limestone aquifer.

5.1.2. Evaluation of ANN Model Predictions

Artificial Neural Network (ANN) models were employed to predict static water levels in both aquifer types. Figures 5 and 6 present the ANN model predictions for the alluvium and limestone aquifers, respectively. The accuracy of these predictions is critical for future water resource management.

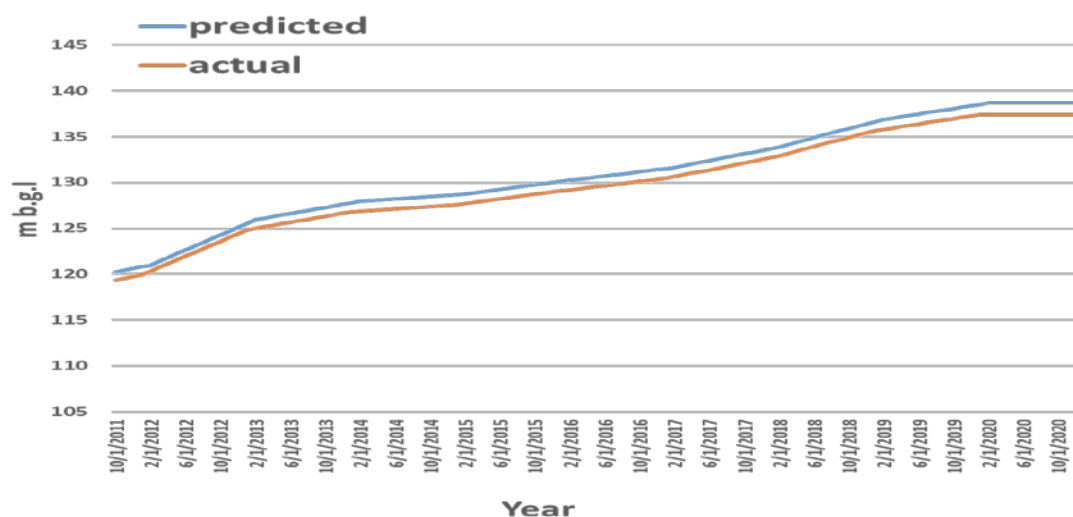


Fig. 5: ANN Model Prediction of Static Water Level of Alluvium Aquifer.

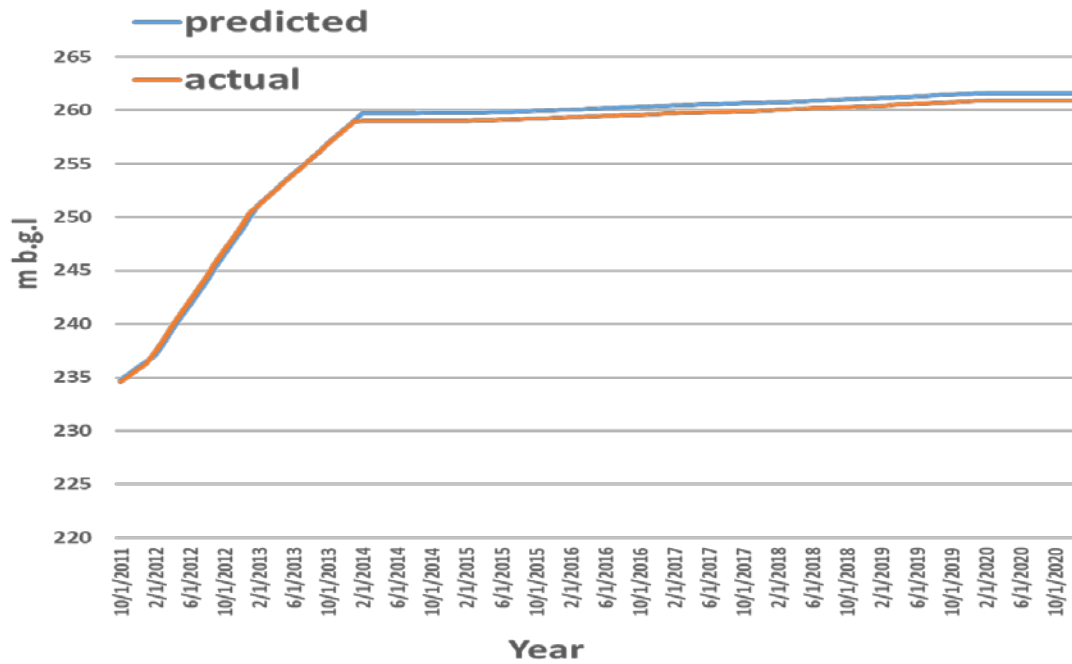


Fig. 6: ANN Model Prediction of Static Water Level of Limestone Aquifer.

5.1.3. Comparison of Actual and Predicted Water Levels

The study further compares the actual and predicted water levels for both aquifers. Figs 7 and 8 show scatterplots for the alluvium and limestone aquifers, highlighting the model's efficiency in predicting water levels over the study period.

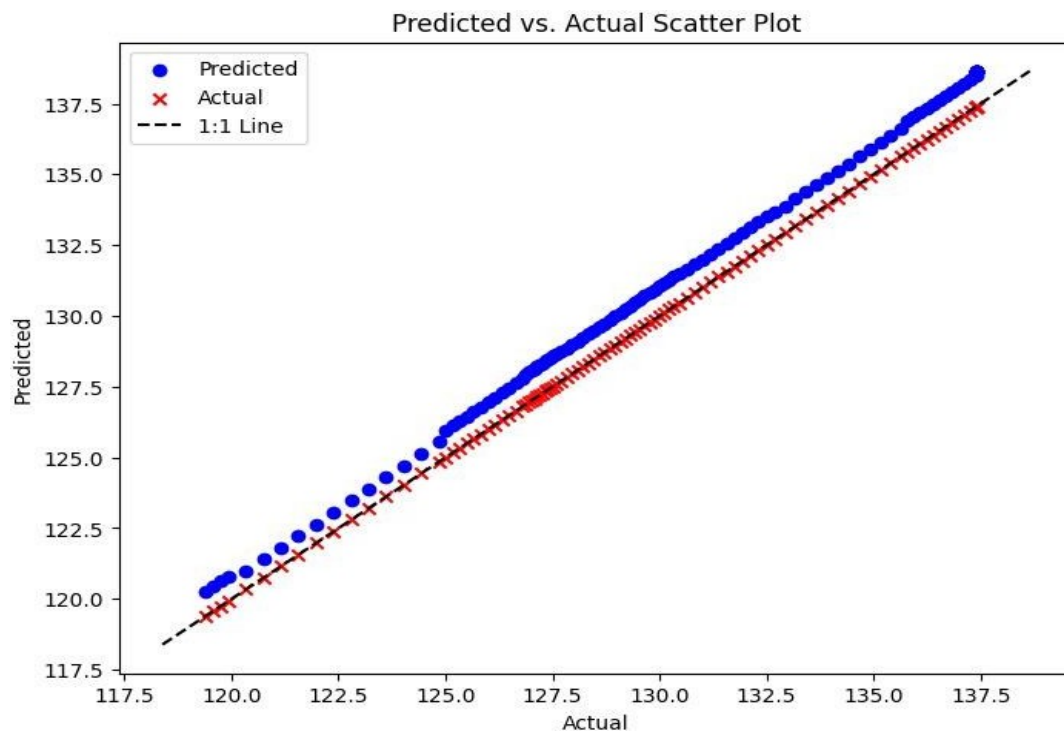


Fig. 7: Comparison of Actual and Predicted Water Level with Scatterplot of Alluvium Aquifer.

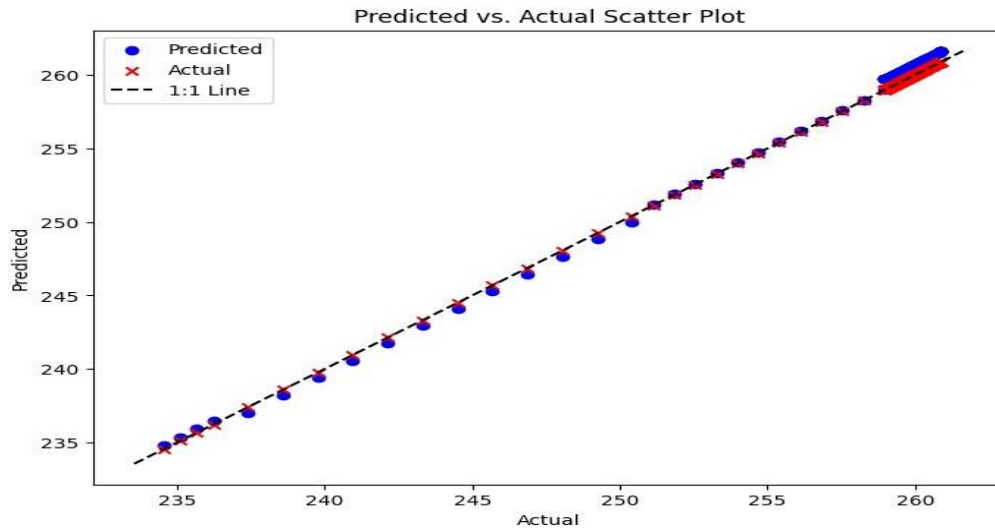


Fig. 8: Comparison of Actual and Predicted Water Level with Scatterplot of Limestone Aquifer.

5.1.4. Performance Evaluation of the ANN Model

The ANN model's performance was evaluated using statistical measures including R-squared (R^2), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE) (Table 3). The results indicate a high degree of accuracy for the limestone aquifer ($R^2 = 0.991$) compared to the alluvium aquifer ($R^2 = 0.961$), suggesting the model's better suitability for limestone aquifer predictions.

Table 3: Performance Evaluation of ANN Model

Statistical Analysis			
Aquifer Type	R2	RMSE	MAE
Limestone	0.991	0.646	0.602
Alluvium	0.961	1.013	1.003

5.1.1. Groundwater Level Decline in Quetta

Figure 9 illustrates the decline rate map of Quetta, highlighting significant groundwater level changes, especially in the central region, over the 40-year period. This underscores the critical nature of groundwater depletion in the area.

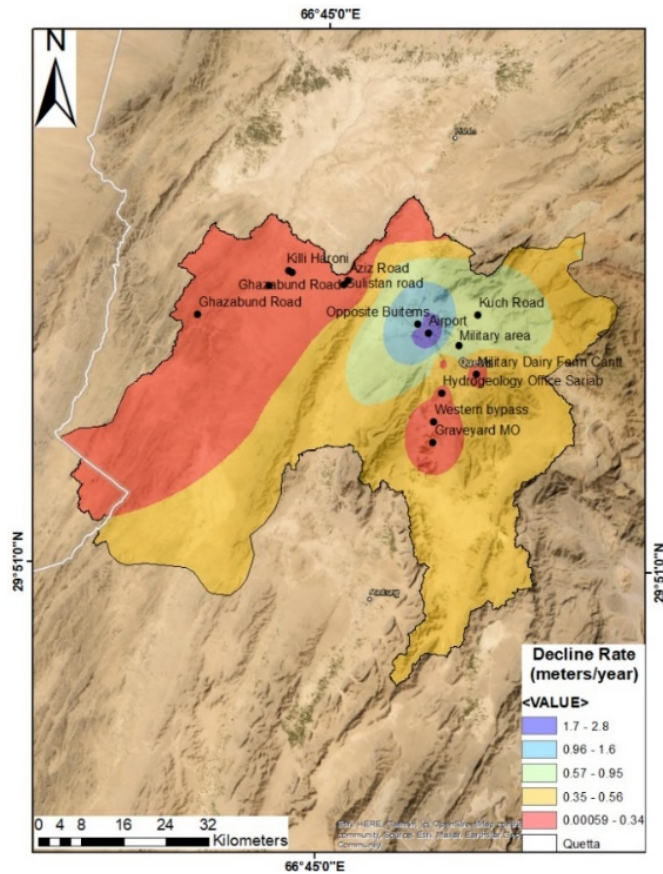


Fig. 9: Decline rate map of Quetta.

5.1.2. Longitudinal Analysis of Groundwater Level

A 40-year analysis of groundwater levels (Fig10) provides valuable insights into the temporal trends and patterns of groundwater changes, emphasizing the region's vulnerability to declining groundwater levels.

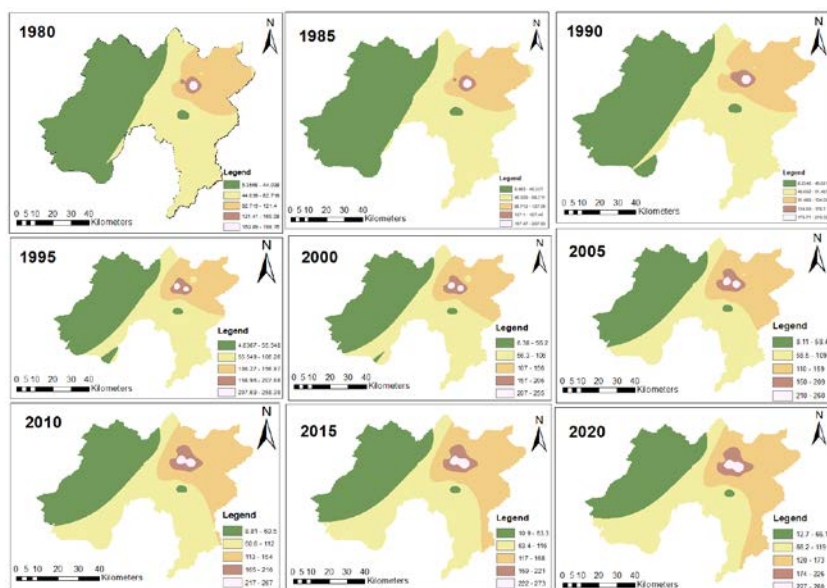


Fig. 10: Groundwater Level from 1980-2020

6. Conclusion

This study has successfully demonstrated the application of an artificial neural network (ANN) in predicting groundwater levels in the Quetta Valley of Balochistan, Pakistan, with a particular focus on two primary aquifers: the limestone aquifer and the alluvium aquifer. The ANN model exhibited exceptional predictive accuracy, as evidenced by the high R^2 values of 0.991 for the limestone aquifer and 0.961 for the alluvial aquifer, along with low mean absolute error (MAE) and root mean square error (RMSE) values. These results underscore the model's capability in effectively forecasting groundwater dynamics in complex hydrogeological settings.

Our findings highlight a concerning trend of declining water levels in both aquifers, with the limestone aquifer experiencing a decline of 2.815 m/year and the alluvial aquifer at 1.476 m/year. This decline is attributed to extensive extraction through unauthorized tube wells and agricultural wells over the past 20 years, leading to significant aquifer exhaustion. The implications of these declining levels are profound, especially considering the importance of the limestone aquifer as a vital drinking water resource.

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Evaluation of groundwater quality and its suitability for drinking and irrigation using GIS techniques in Taluka Tando Adam, Sanghar, Sindh, Pakistan

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Abstract

Groundwater quality is a major concern for water managers and policymakers, due to the increase in anthropogenic activities groundwater resources are under tremendous pressure and groundwater is depleting. The present study aims to assess the groundwater quality and map the spatial variation of water samples in terms of suitability for drinking and irrigation purposes in Tando Adam taluka of district Sanghar, Sindh, Pakistan. For that purpose groundwater survey was conducted, and 36 water samples were collected from different locations and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS) calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium, bicarbonate, sulfate, chloride, sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium carbonate (RSC), magnesium hazard (MH). A GIS-based ordinary kriging method was used for the preparation of thematic maps of groundwater quality parameters. About 25% of samples are within the WHO standards; however, 75% exceeded the WHO standards. Consequently, 80% of EC, 89.19% of TDS, and 0.75% of pH, of the total groundwater samples are not suitable for drinking purposes as per the WHO standard. The spatial distribution map of groundwater quality showed that 80% of the area was not suitable for drinking purposes; While 30% of the area has been designated for irrigation purposes, the remaining 70% is unsuitable for such use.

Keywords: Groundwater quality; GIS; Kriging, Sanghar

1. Introduction

In many regions of Asia, groundwater has become the primary resource for irrigated agriculture. Over 300 km³ of groundwater are used annually by India, Nepal, Bangladesh, Pakistan, and China combined, accounting for approximately half of the world's total groundwater consumption. (Shah et al. 2003). Groundwater is considered an essential resource since it is the world's largest freshwater reservoir (World Water Quality Alliance, 2021). For agricultural purposes, groundwater supplies 43% of the global consumptive consumption and approximately 50% of the global drinking water supply. (Siebert et al., 2010). Pakistan's main supply of drinking water comes from groundwater. Pakistan groundwater contamination necessitates substantial research funding for the sake of public health. About 44% of people in Pakistan do not have access to clean drinking water, and the situation is even worse in rural regions. With a potential of 63 BCM, Pakistan's total groundwater abstraction is estimated to be 50 BCM, and over 70% of the population relies on groundwater for household and drinking purposes. (Kahlowan and M.A., 2004). In Sindh, Pakistan, farmers are mostly installing skimming wells that are partially penetrating in relatively fresh groundwater aquifers that are overlying on highly saline groundwater aquifer lenses (Qureshi et al. 2011). Many groundwater quality studies have been undertaken in Sindh for various purposes, with the resulting picture not good for either agriculture or domestic consumption. The problems of high salinity, conductivity, sodium adsorption ratios (SAR), and excessive chloride and calcium quantities prevail in the groundwater in the southernmost coastal districts of Thatta and Badin, possibly due to seawater intrusion (Shahab et al., 2016, Solangi et al., 2017). A comprehensive study to map groundwater quality in Sindh demonstrated high electric conductivity in

approximately two-thirds of the samples collected. It also showed high hardness, TDS and solutes in the water. The samples from lower Sindh had higher than permissible SAR and electric conductivity (EC) levels for irrigation (Shahab et al., 2016). Different sets of parameters are required for the assessment of groundwater for irrigation. The Food and Agriculture Organization (FAO) has recommended guidelines for irrigation water use based on estimates of major anions, cations, electric conductivity (EC), pH, and sodium adsorption ratio (SAR). The pH is the representative of the alkalinity in the groundwater assessment. Calcium ions (Ca^{2+}) and magnesium (Mg^{2+}) ions are a determinant of hardness in groundwater (Prepas et al., 2001). High content of ions such as Na^+ and Cl^- in soil can also reduce growth and yield of certain crops (Grewal, 2010). Geographic information system (GIS) has been playing a key role in the management of natural resources, and therefore, it may offer an appropriate method to integrate physicochemical data analyses of groundwater (El Omran et al. 2014). However, the role of GIS in analyzing the spatial distribution of groundwater has been investigated by many authors (Verma et al. 2016; Gorai and Kumar 2013; Srivastava et al. 2012). Despite the large number of studies of water quality assessment, no complete assessment tool has been found in the literature that incorporates the crucial aspects of water quality analysis in the Taluka Tando Adam. The objective of this study is to evaluate the quality of groundwater in Taluka Tando Adam, Sanghar, Sindh, Pakistan, with a focus on assessing its suitability for both drinking and irrigation purposes. This has been achieved through the application of Geographic Information System (GIS) techniques to analyze various water quality parameters, enabling the identification of potential contaminants and their spatial distribution within the study area.

2. Methodology

2.1 Study Area

The Tando Adam taluka in the Sanghar district is the study's location; its latitude is 25.7682°N and its longitude is 68.6559°E (Figure 1). The region is a portion of a lush plain that is situated northeast of Hyderabad on the eastern bank of the Indus River. This city is well-known for its textile mills, food industries, and agriculture. It is also a well-known commerce hub (SIDA, 2012, WWF, 2008). Conjunctive irrigation systems are primarily responsible for the area's agricultural activity. The primary source of groundwater recharge is seepage from a well-established canal irrigation system; nevertheless, the water in these systems is highly contaminated because of the mixing of industrial and sewage effluents, which is the primary cause of water-borne illnesses in the region (Khan et al., 2018).

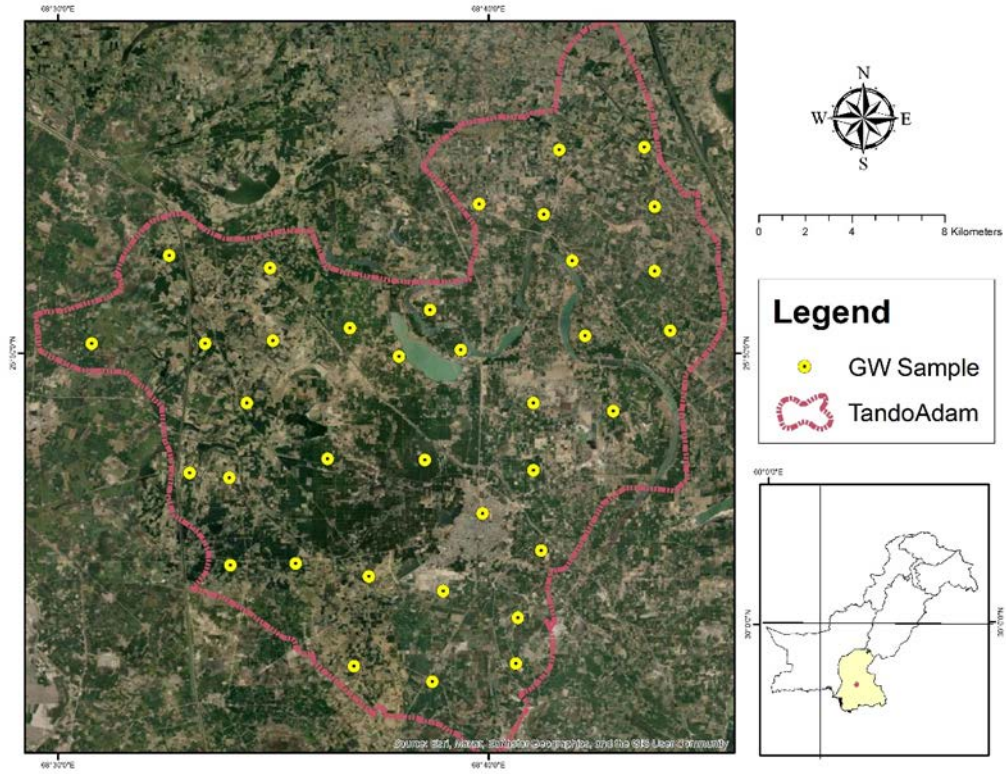


Figure 1: Study Area Map

2.2 Groundwater Sampling

Groundwater samples were randomly collected from the study area tube wells, open wells, and handpumps. Standard sampling procedures were analyzed for different irrigation and drinking parameters during 2023. The location of each sampling point was recorded by Global Positioning System (GPS) in Table 1. These samples were assembled and stored in one-liter acid-washed, well-rinsed low-density polyethylene bottles. Samples were stored in a clean and cool ice case and were brought to the Advanced Water & Wastewater Quality Control Lab in USPCASW Mehran University of Engineering and Technology Jamshoro for chemical analysis.

Table 1: Total Sample Collected from Taluka Tando Adam

SampleID	Source	Lat	Long	Elevation(m)	SampleID	Source	Lat	Long	Elevation(m)
TAD1	HandPump	25.83461	68.6559	27	TAD20	HandPump	25.87145	68.543217	28
TAD2	Tubewell	25.81094	68.7149	25	TAD21	Tubewell	25.841	68.55276	24
TAD3	HandPump	25.77133	68.66434	24	TAD22	HandPump	25.78543	68.56691	26
TAD4	HandPump	25.74734	68.62035	21	TAD23	HandPump	25.84332	68.61354	24
TAD5	HandPump	25.81443	68.5731	25	TAD24	HandPump	25.84342	68.70395	23
TAD6	HandPump	25.85945	68.58832	29	TAD25	HandPump	25.84191	68.736992	26
TAD7	HandPump	25.713332	68.6773	22	TAD26	HandPump	25.86487	68.730966	24
TAD8	Tubewell	25.70633	68.64492	22	TAD27	HandPump	25.8912	68.730911	23
TAD9	Open Well	25.71232	68.6145	25	TAD28	HandPump	25.83576	68.69854	24

TAD10	HandPump	25.75132	68.5667	25	TAD29	HandPump	25.91321	68.72754	23
TAD11	HandPump	25.74134	68.64912	23	TAD30	HandPump	25.78854	68.68432	26
TAD12	HandPump	25.73176	68.67792	24	TAD31	HandPump	25.93281	68.70543	23
TAD13	HandPump	25.75798	68.68633	25	TAD32	Tubewell	25.75254	68.59212	24
TAD14	Tubewell	25.79243	68.64142	27	TAD33	HandPump	25.80745	68.67351	24
TAD15	HandPump	25.792476	68.604376	24	TAD34	HandPump	25.89091	68.662991	22
TAD16	HandPump	25.787	68.584	27	TAD35	HandPump	25.85543	68.64432	27
TAD17	HandPump	25.88714	68.68854	26	TAD36	HandPump	25.832	68.632	23
TAD18	HandPump	25.82141	68.60802	24	TAD19	HandPump	25.8384	68.51387	21

2.3 Chemical Parameters of the Samples

The collected groundwater samples were examined for various physiochemical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl), sulfate (SO₄), Nitrate (NO₃), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K). On-site measurements of pH, TDS, and EC were conducted using a multi-parameter probe, while CL was determined through titration method), NO₃ and sulfate SO₄⁻ by a UV-VIS spectrophotometer (Analytik Jena, Germany), and Ca, Mg, Na, and K were determined by NexIon 350 Perkin Elmer (ICPMS).

2.4 Irrigation Indices Water Quality

For evaluating suitability for irrigation purposes, some commonly used indices like the sodium absorption ratio (SAR), residual sodium carbonate (RSC), Sodium soluble percentage (SSP), and magnesium hazard (MH) were computed (Vincy et al., 2015). A formula of the indices has been presented in Table 2, categories based on the criteria given in

Table 3 as prescribed by Food and Agriculture Organization (FAO).

Table 2 Water quality indices for irrigation

Indices	Formula
Sodium absorption ratio (SAR)	$Na/\sqrt{\frac{Ca+Mg}{2}}$
Sodium soluble percentage (SSP)	$[(Na+K)/(Ca^{+}+Mg^{+}+Na+K)]*100$
Residual sodium carbonate (RSC)	$(CO_3+HCO_3)-(Ca+Mg)$
Magnesium Hazard (MH)	$[(Mg^{+})/(Ca^{+}+Mg^{+})] *100$

	Range	Mean	Standard Deviation	WHO Standard
pH	6.4 - 8.4	7.5	0.6	6.5- 8.5
EC ($\mu\text{S}/\text{cm}$)	504 – 3800	1482.6	830.1	1000
TDS (mg/l)	322 – 2432	948.9	531.3	1000
Cl (mg/l)	8 - 70.09	22.1	13.6	250
F(mg/l)	0.24 - 1.8	0.9	0.4	2
SO ₄ (mg/l)	18.72 – 542	12.1	112.7	500
NO ₃ (mg/l)	9.50 – 123	57.4	24.6	50
Na (mg/l)	300 – 2001	908.0	499.7	200
Ca(mg/l)	17.10 - 223.37	78.2	57.4	75
K(mg/l)	5.90 – 154	12.3	10.4	12
Mg(mg/l)	5.90 – 154	61.8	34.8	50

Table 3 Classification of each parameter for Irrigation water Quality (Romanelli et al., 2012)

Rating	Class	EC	SAR	SSP	MH
1	Excellent	<1000	<6	<20	<50
2	Good	1000-1500	6.1 - 8	20-40	
3	Permissible	1500-2000	8.1- 15	40-60	>50
4	Unsuitable	>2000	>15	>60	

2.5 Data Analysis Utilizing Through GIS

Geographic Information System (GIS) is commonly employed in hazard evaluations, spatial mapping, and water quality assessments (Zolekar et al. 2015; Alogayell et al. 2023). The maps were illustrated using the Kriging interpolation technique from the spatial analyst tools in the ArcGIS 10.8 toolbox has been utilized to produce the spatial distribution maps (Alshehri and Abdelrahman 2023). Maps of quality parameters for evaluation of groundwater for drinking i.e. EC, TDS, pH, CL, SO₄, NO₃, Ca, Mg, Na, K, prescribed by World Health Organization (WHO) and for Irrigation viz. SAR, SSP, RSC, and MH, were prepared via kriging interpolation.

3. Results and Discussions

3.1 Groundwater's Physicochemical Properties

As [Table 4](#) show the physicochemical characteristics of the quality of groundwater. Recognizing groundwater quality is significant as it is the key feature defining its appropriateness for drinking, agricultural, and industrial purposes (Mokarram 2016). Table 4 abridges the outcomes of several parameters comprising statistical measures such as mean, standard deviation and WHO standard analysis of groundwater samples from the study area.

	Range	Mean	Standard Deviation	WHO Standard
pH	6.4 - 8.4	7.5	0.6	6.5- 8.5
EC ($\mu\text{S}/\text{cm}$)	504 – 3800	1482.6	830.1	1000
TDS (mg/l)	322 – 2432	948.9	531.3	1000
Cl (mg/l)	8 - 70.09	22.1	13.6	250
F(mg/l)	0.24 - 1.8	0.9	0.4	2
SO ₄ (mg/l)	18.72 – 542	12.1	112.7	500
NO ₃ (mg/l)	9.50 – 123	57.4	24.6	50
Na (mg/l)	300 – 2001	908.0	499.7	200
Ca(mg/l)	17.10 - 223.37	78.2	57.4	75
K(mg/l)	5.90 – 154	12.3	10.4	12
Mg(mg/l)	5.90 – 154	61.8	34.8	50

Table 4 descriptive Statistic of physicochemical Parameter

3.2 Spatial distribution of physicochemical properties of groundwater

3.2.1 Groundwater quality for drinking purpose

The World Health Organization has established drinking water quality criteria (WHO 2011). For the purpose of analyzing groundwater quality, key physicochemical parameters (pH, EC, TDS) and the behavior of main ions (Cl⁻, F, SO₄, NO₃, Na⁺, Ca²⁺, K⁺, Mg²⁺) have been examined. The appropriateness of the groundwater in the study area for agricultural and drinking purposes has been determined by evaluating the analytical data. Table 5 presents the analytical results for each parameter of the groundwater sample. According to WHO (2011), the pH range of 6.5 to 8.5 is the maximum that can be used for drinking water. The pH range in our investigation is 6.4 to 8.4, with an average of 7.5. This indicates a minor alkalinity in the groundwater. (Figure 2A) depicts the pH spatial distribution map. The findings indicated that the groundwater in the southwest of the research area is slightly acidic, whereas the groundwater in the eastern and northern regions is slightly basic.

Table 5 Descriptive statistics of chemical parameters

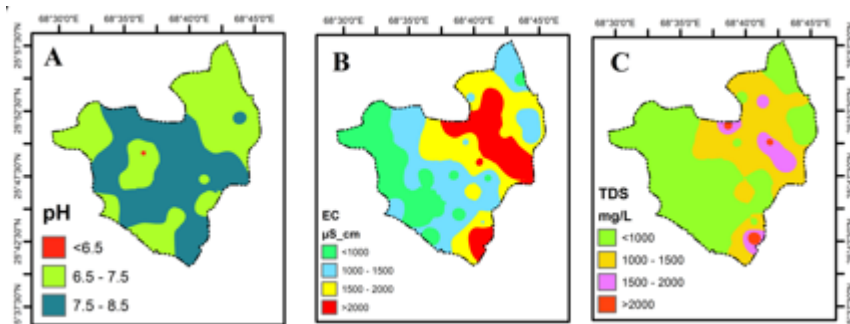


Figure 2 Spatial distribution of pH, EC, TDS

The ion concentration of water is measured via electrical conductivity (EC). The research area's EC value has a mean value of 1482.6 $\mu\text{S}/\text{cm}$ and ranges from 504 $\mu\text{S}/\text{cm}$ to 3800 $\mu\text{S}/\text{cm}$. It is

shown that the maximum allowable levels are present in 64% of the samples. s (that is, 1000 $\mu\text{S}/\text{cm}$) in accordance with WHO guidelines (2011). Within the study area, the EC's spatial distribution is depicted in (Figure 2B). The findings indicated that the greater EC value was found in the western, southern, and northeastern regions of the research area, whereas the lower EC value was found in a few isolated areas in the eastern region. Table 5 .

The distribution of TDS values showed that, with an average value of 948.9 mg/L, the whole research region ranged from 322 to 2432 mg/L. Only 23% of the samples are unfit for human consumption, whereas 77% of the samples contain concentrations over the permissible threshold (1000 mg/L), according to WHO guidelines. According to the TDS spatial variation map, almost 77% of the entire area is below the safe level WHO standard (2011). Table 5 portrays in the northern and eastern parts of the study area (Figure 2C)

The average chloride concentration in this study was 22.1 mg/l, with a range of 8 to 70.09 mg/l. For drinking water, the maximum allowable limit of chloride is 250 mg/l (WHO 2011), and it reveals that all samples do not exceed the maximum permissible limit of the WHO in Table 5. The spatial distribution of chloride in the study area is represented in (Figure 3D). The higher concentration in Cl^- is observed in the western and southern parts of the study area.

	Range	Mean	Standard Deviation	WHO Standard	NDA L	%NDAL
pH	6.4 - 8.4	7.5	0.6	6.5- 8.5	0	0
EC ($\mu\text{S}/\text{cm}$)	504 - 3800	1482.6	830.1	1000	23	64
TDS (mg/l)	322 - 2432	948.9	531.3	1000	8	22
Cl (mg/l)	8 - 70.09	22.1	13.6	250	-	-
F(mg/l)	0.24 - 1.8	0.9	0.4	2	6	17
SO ₄ (mg/l)	18.72 - 542	12.1	112.7	500	1	27
NO ₃ (mg/l)	9.50 - 123	57.4	24.6	50	21	59
Na (mg/l)	300 - 2001	908.0	499.7	200	33	91
Ca(mg/l)	17.10 - 223.37	78.2	57.4	75	19	53
K(mg/l)	5.90 - 154	12.3	10.4	12	9	25
Mg(mg/l)	5.90 - 154	61.8	34.8	50	23	63.00

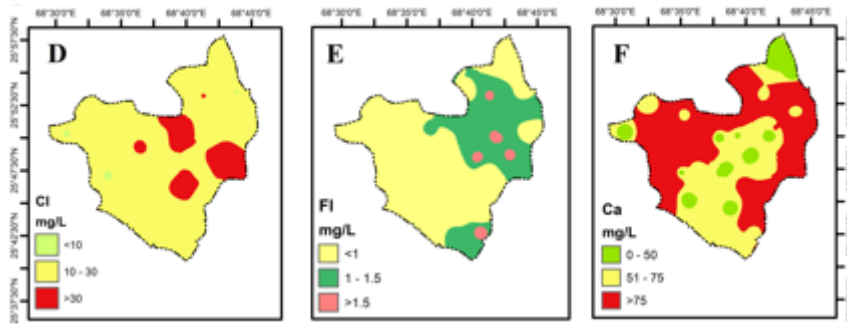


Figure 3 Spatial Distribution of Cl, Fl, Ca

One of the most prevalent elements in natural water is sodium (Na^+), which is present in larger concentrations in rocks. The research area's average sodium concentration was 908 mg/L, with a range of 300 to 2001 mg/l. The suggested limit for sodium concentration in drinking water is 200 mg/l (WHO 2011) in Table 5. Thirty-three samples have a Na^+ content higher than the recommended level for groundwater samples. The research area's spatial distribution of sodium is depicted in (Figure 4H)

With a standard deviation of 57.3, the average calcium ion concentration in the research region is determined to be 78.2 mg/l. According to recommendations made by, the highest acceptable level of calcium concentration in drinking water is 200 mg/l WHO (2011) in Table 5. The western part of the study area is illustrated as having medium to high concentration of Ca^{2+} , and the east-central and northern part is represented as low concentration (Figure 3F)

In the study region, potassium concentrations range from 5.90 to 154 mg/l, with a mean of 12.3 mg/l. In drinking water, the maximum allowable amount of K^+ is 12 mg/l. It was discovered that 75% of the samples are below this limit WHO Table 5. Fertilizer and other nearby industrial operations are the cause of the elevated K^+ content. The K^+ 's spatial distribution map is depicted in (Figure 4I) The potassium concentration decreased toward the eastern and northern regions of the research area, according to the results.

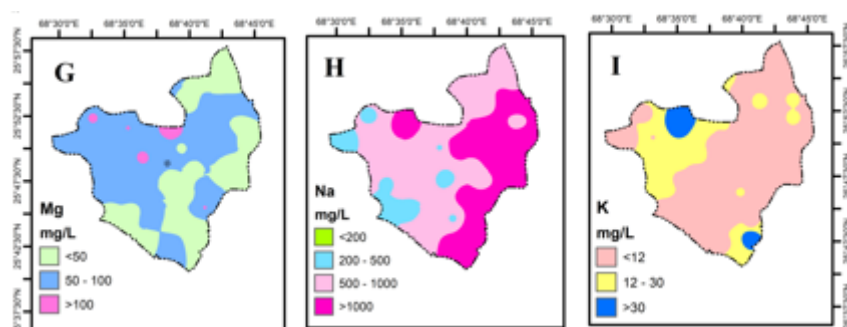


Figure 4 Spatial Distribution of Mg, Na, K

With an average of 61.8 mg/l, the magnesium ion concentration ranges from 5.90 to 154 mg/l. The Mg^{2+} ion's geographic distribution map is depicted in (Figure 4G). According to WHO recommendations, the maximum allowable level for magnesium concentration in drinking water is 50 mg/L (2011). According to the current findings, 63% of the water samples had levels over the allowable limit Table 5.

The range of sulfate content was 18.72 to 542 mg/l. With a standard deviation of 112.7 and an average sulfate content of 12.1, all samples are within the desired range, with only one sample over the WHO limit in Table 5. (Figure 5 J) shows the groundwater's sulfate ion concentration's regional distribution. The findings demonstrated that the western portion of the research region had the highest sulfate concentration, while the eastern portion had the lowest concentration.

The content of nitrate (NO₃) ranged from 9.5 to 123 mg/l. With a standard deviation of 24.6 and an average NO₃ concentration of 57.4, only 41% of samples fall within the WHO's recommended level and 59% exceed it. Table 5. The following figure shows the groundwater's NO₃ ion concentration's spatial distribution: (Figure 5K). The findings demonstrated that the western portion of the research region had the highest concentration of NO₃, while the eastern portion had the lowest concentration.

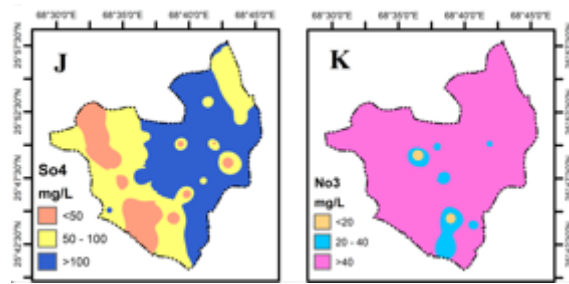


Figure 5 Spatial Distribution of So₄, No₃

3.2 Assessment of Groundwater for Irrigation

Table 7 shows the descriptive statistics of the irrigation indices. Most of the samples are under the permissible limit for irrigation, except for the magnesium hardness (MH), which has 64% of the samples above the limit. Spatially, the high values of the indices are in the west part of Tando Adam. EC and TDS for samples are represented by the United States Department of Agriculture (USDA). Irrigation water can be classified into four distinct categories, namely C1, C2, C3, and C4, based on its Electrical Conductivity (EC) and Total Dissolved Solids (TDS). The distribution of these categories in the samples is illustrated with 0% in C1, 25% in C2, 65% in C3, and 100% in C4 in Table 6. The spatial distribution of irrigation indices shown (Figure 6 A,B) of EC classes (Excellent < 1000, Good 1000-1500, Permissible 1500-2000, Unsuitable >2000) and (b) Spatial distribution of SAR classes (Excellent <6, Good 6.1-8, Permissible 8.1-15, Unsuitable >15) Spatial distribution of SSP classes (Excellent < 20, Good 20-40, Permissible 40-60, Unsuitable > 60) and (d) Spatial distribution of MH classes (Suitable <50, Unsuitable >50) shown in (Figure 6 C,D)

Table 6 USDA classification on salinity gradient based on EC and TDS range

Category	EC ($\mu\text{s}/\text{cm}^{-1}$)	TDS (mg. L ⁻¹)	Hazards & Limitations	Suitable Sample (%)
C1	1000	640	Low hazards no detrimental effects on the plants and no accumulation in soil are expected	35.1
C2	1500	1000	Stress can be shown by sensitive plants, and salt accumulation in the soil	8.00

According to Disli, 2017; Ismail et al. 2023; Adnan et al. 2023; Tadesse et al. 2023

			can be prevented due to moderate leaching	
C3	2500	1600	For most plants affected by salinity (salt-tolerant plants are needed), careful irrigation, good drainage, and leaching are required	22.21
C4	>2501	>1601	Unsuitable for irrigation except for some highly salt-resistant plants, excellent drainage, frequent leaching, and intensive management required	34.69

Table 7 Irrigation water quality indices

Parameter	Mean	STD	Range	Classification	No of Sample	Percent distribution
EC ($\mu\text{S}/\text{cm}$)	1482	830.1	<1000	Excellent	13	37%
			1001 - 1500	Good	10	28%
			1500 - 2000	Permissible	7	20%
			>2000	Unsuitable	6	15%
SAR (me/l)	7	4.41	<6	Excellent	18	50%
			6.1 - 8	Good	4	11.11%
			8.1 - 15	Permissible	12	33.33%
			>15	Unsuitable	2	16.60%
SSP (me/l)	21.67	18.57	<20	Excellent	7	20%
			20 - 40	Good	17	47.5%
			40 - 60	Permissible	5	13.6%
			>60	Unsuitable	7	19.4%
MH (me/l)	40.18	54.68	<50	Suitable	14	36%
			>50	Unsuitable	22	64%

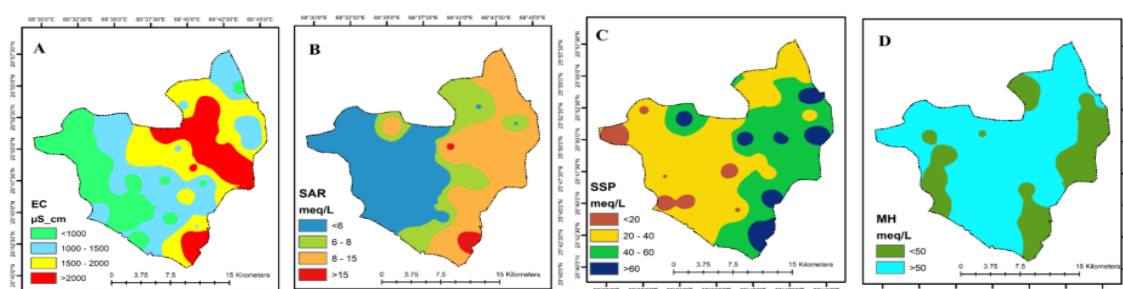


Figure 6 Spatial distribution of EC, SAR, SSP, and MH

Conclusion

Based on the assessment of the study area the following conclusions can be made:

- ❖ Comparison of values with WHO limit shows that 52%, 3%, 97%, 98%, and 48% of samples exceed WHO limits for drinking water for EC, Na⁺, NO₃⁻, SO₄²⁻, and Mg⁺ respectively.

- ❖ Most of the samples are under the permissible limit for irrigation, except for the magnesium hardness (MH), which has 64% of the samples above the limit. Spatially, the high values of the indices are in the southeast part of the Shahdadpur taluka.
- ❖ About 71% of the samples lied in high salinity and low sodium hazard (C3), whereas 13.2 % of the samples lie in very high salinity and medium sodium hazard (C4) zone.
- ❖ Out of the total area of Taluka Tando Adam, 60% was supposed to be suitable, 30% was marginal, and 10% was unsuitable for irrigation purposes.
- ❖ There unsuitable water for irrigation is in the northeast, taluka Tando Adam in. This area is along the Nara canal, and one reason for this can be high water levels due to canal and distributaries leakage, which transports salts to the surface.
- ❖ It has been discovered that the study's application of water quality is helpful in determining the overall quality of the water. Additionally, it is beneficial for the general public to be aware of the various ways in which water quality can be utilized as a tool for water quality management.
- ❖ The findings of this evaluation will contribute to informed decision-making regarding water resource management and sustainable development initiatives in the region.

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Removal of Atrazine Herbicide by Modified TiO₂ embedded nanofibers membrane and their rapid detection in water

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Abstract:

Atrazine is a synthetic herbicide that is used to control and regulate the broad leaves and weeds in sugarcane, corn and sorghum. Due to its toxic nature, the degradation and removal of atrazine is very hard from water. This present work describes the removal of atrazine herbicide from synthetic aqueous solution with the synthesis of titanium dioxide-TiO₂ nanoparticles by the sol-gel method and the fabrication of modified Polyamide-6/TiO₂ nanofiber membrane by electrospinning and its application in the adsorption process. The TiO₂-embedded PA6-NFM can be clearly detected by transmission electron microscopy (TEM), X-ray diffraction, and Fourier transform infrared spectroscopy (FTIR) identified and demonstrated effective in-situ polymerization of the nanofiber membrane. SEM was used to analyze the micro-structure and surface morphology of nanofibers and nanoparticles. The results suggest that the nanofibers are uniform, have a rougher surface and have an average range of diameter around 110 nm and nanoparticles are spherical in shape, smooth and homogeneous structure with an average diameter 120-140nm. The electrospun nanofibers possessed have excellent removal efficiency after contact for only 30 min at room temperature and normal working pH. The removal efficiency of atrazine before and after experiment were assessed using the UV-Vis spectrophotometer method at 470nm wavelength. The results show the removal efficiency of 80% at 1ppm concentration with 2mg nanofiber mass.

Keywords: Water treatment, Nanofibers membrane, Electrospinning, PA6/TiO₂ Embedded Nanofibers, Atrazine removal, Adsorption.

1. Introduction

Due to rapid urbanization and industrialization, water pollution is a major concern worldwide. For instance, the intensive use of pesticides has harmed water resources in developing countries (Saleh et al., 2020). The excessive use of pesticides is responsible for water contamination and its destructive impact on human health and the environment. As an agricultural country, Organochlorine pesticides and herbicides are widely used in Pakistan. However, the extensive use of these chemicals has led to severe environmental pollution and subsequent exposure to humans and other living organisms (Samisdar et al., 2018). This has resulted in a significant number of poisoning cases, with over half of a million people in Pakistan suffering from pesticide-related poisoning each year. However, current data on the use, contamination, and exposure of pesticides in Pakistan are largely unavailable. Only 0.1% of pesticides control the pest, and the remaining become part of our ecosystem (Sanoja-López et al., 2022; Rani et al., 2021).

According to the World Health Organization (WHO), one million humans are suffering from acute pesticide poisoning, with a mortality ratio of 0.5-2% each year. Humans are affected while handling pesticides by ingesting residual pesticides from dust, aerosol, and skin exposure (Donley et al., 2022). Pakistan is an agriculture-based country, as almost 45% of its GDP comes from

agriculture. According to one estimate, 2.5 million tons of pesticides worldwide are used (Poudel et al., 2020). During spraying pesticides on crops, their chemical compounds remain in the soil, which passes into water bodies through rainfall and irrigation. Unfortunately, these pesticides become part of water resources (Pradhan et al., 2022). More than 500 pesticides are present, and there are 54,000 different formulations. The residual pesticides in small concentrations are discharged into surface water and groundwater. Some of these pesticides are persistent in surface water and groundwater for an extended period. This persistence prevents biological decomposition and degradation of these pesticides (Pico et al., 2020). Overuse of pesticides can harm individuals as well as other inhabitants due to the toxicity of pesticides. With the advancement of today's agronomic expertise, pesticides are the most dynamic ingredients for adapting and inhibiting diseases, weeds, and pests to limit crop damage (M. Khan et al., 2015). About 2.5 million tons of pesticides have been used, and their use is increasing (Tariq et al., 2007). Large amounts of pesticides used in agriculture and public welfare actions cause infectious diseases, unwanted vegetation, and plants used for decorative uses (Gilden et al., 2010). They can also prevent the spread of pests, algae, bacteria, fungi, and insects in power tools containing food packaging materials, plastics, refrigerators, paints, paper, and carpets (Steliarova-Foucher et al., 2017). Pesticide application in current farming has enhanced the productivity of agriculture farming globally, but some persistent pesticides continue to harm the ecosystem. In the last 40 years, over 47 technical and scientific studies have been published on pesticides in Pakistan's crops, soil, and water. As an agricultural country, there is no state database showing how pests and herbicides are perceived (Teklu et al., 2015). Long-time exposure to the environment at low concentrations of highly toxic pesticides has caused carcinogenic health hazards to living organisms. Pesticides in groundwater and surface water are causing worldwide distress due to their effects on marine life and contamination of drinking water. The focused pesticide is atrazine, simazine, cyanazine, and propazine which is part of the s-triazine pesticide. Atrazine is a structurally very noxious compound (2-chloro-4-ethylamino-6-isopropyl amino-s-tri-azine) that avoids aquatic ecosystems but also has the potential to contaminate drinking water (F. S. Khan et al., 2008). S-triazine can induce reproductive syndromes in the human body, and some studies have shown the impact of the environmental experience of s-triazine and fertility disorders in both men and women (Kuchenbaecker et al., 2017).

S-triazine is a man-made pesticide used to regulate and control the problematic broadleaf and weeds in different crops such as wheat and sugarcane. Due to its poisonous nature, s-triazine must be flushed in water, and the degradation of s-triazine is very hard. Therefore, this problem should be addressed sustainably to combat such hazardous organic compounds in water.

The extensive use of pesticides and herbicides, especially those from the S-triazine family, such as atrazine (1-chloro-3-ethylamino-5-isopropylamino-s-triazine; ATZ), poses significant health risks to humans and the environment as soil. These chemicals are cytotoxic and carcinogenic, leading to various health issues, including respiratory problems, infertility, and neurological disorders. Furthermore, the movement of pesticides through air, water, and soil can contaminate larger areas beyond where they are applied. Therefore, it is crucial to prioritize the shift towards more sustainable and organic pest control methods in the agriculture sector to mitigate these risks and protect human health and the environment. These pesticides result in the contamination of water bodies (Bayoumi, 2022). In Pakistan, many pesticides are used annually to control plant diseases, increasing secondary water pollution. The degradation time of atrazine varies in water and soil, as its degradation time in water is 10- 105 days and 4-385 days in the soil (Rostami et al., 2021). There

is a dire need for the degradation of such complex compounds and the removal of pesticides from the water before they become part of our environment. Various types of advanced treatment technologies have been used in past years: reverse osmosis (RO), coagulation-flocculation, and distillation. However, these techniques produce hazardous products, has high operating costs (maintenance), need electricity power, and rejection of high molecular weight compounds in the membrane during filtration (Biswas and Goel, 2022; Wanet al., 2022). Nanofiltration is an excellent technology that removes micropollutants such as natural organic matter (NOM) and persistent organic matter (POPs). Nanotechnology is widely used in various disciplines, including agriculture, food industries, biotechnology, and medicine. It is an area of applied science and technology focused on regulating matter on the atomic and molecular scale in the 1-100 nm region and fabricating devices with crucial dimensions within this range. Different kinds of water purification technology embed nanoparticles to clean the water and its quality. In water engineering, the degradation of atrazine herbicides through membrane technology is of significant interest. Nanocomposites are small-sized nanoparticles that adsorb a wide range of organic chemicals through adsorption. Their adsorption capacity and physio-chemical properties make it a more sustainable and effective solution for pesticide removal.

This approach avoids the need for toxic reagents and coproducts, making it a more environmentally friendly method (Parra et al., 2004). Many water purification technologies are on the market, including uses such as boiling, filtration, distillation, chlorination, sedimentation, oxidation, and advanced oxidation processes. Nanotechnology plays a significant role in water purification technology (Tlili & Alkanhal, 2019). Nanotechnology is a technique of manipulating atoms at the nanoscale. In nanotechnology, Nano-sized particles or films are used to soften water and remove various chemical, physical, and biological contaminants (N. A. Khan et al., 2019). Nanomaterials can potentially revolutionize pollution reduction, water treatment, and renewable energy (Patil et al., 2019). Moreover, nanomaterials can enhance the efficiency and effectiveness of environmental sensing, remediation techniques, and water engineering applications (Pathakoti et al., 2018). Nanomaterials with photo-catalytic activities and titanium dioxide have been used as a water and air treatment procedure with band gap energies of 3-3.5eV (Taranto et al., 2009). The photo-catalytic activity arises from the absorption of photons and the appropriate energy to overcome the band gap threshold. Photo-catalysis for the degradation of pollutants has become a leading area of research in recent years, and it is considered a possible way to eliminate water and soil pollution (Jeon et al., 2020). Contamination, which includes herbicides, pesticides, and pharmaceuticals, tends to persist in groundwater and soil in regions where chemical and physical remedies are needed. Photocatalysis could be a promising approach to degrade herbicides and pesticide compounds from water. This current work is focused on fabricating a nanofiltration membrane and its application in developing a point-of-use device to remove pesticides from water. Gaining attention on account of the stable and high quality of water they can achieve, although their cost efficiency needs improvement (Yang et al., 2020). However, the water reuse market needs to be developed with long-term efforts because less than 4% of the total wastewater worldwide has been treated for water reuse. In addition, membrane-based water reuse and treatment technologies face several challenges that require further research and development. (Plakas & Karabelas, 2012). Nanofiltration membranes include some major aspects that are considered for selecting an appropriate membrane: molecular weight, membrane porosity, membrane material (polymer composition and host material), and the surface charge of the membrane sheet in addition to the strength of contaminant rejection. The significance of each

parameter on the removal of the herbicide is the importance of each parameter on pesticide removal is openly interrelated to the characteristics of a particular solute (molecular size, molecular weight, hydrophilicity/ hydrophobicity, and tensile strength) of the membrane. Nanofiltration (NF) offers a substitute benefit for pesticide/herbicide removal. Nanofiltration (NF) works as charged strainers that retain the molecules of pollutants with a size greater than the membrane's pore size. NF removes the delicate particulate matter, organic matter, and dissolved salts (Van der Bruggen et al., 1999).

2. Materials and methods

2.1. Materials

2.1.1 Chemicals and reagents

High-purity atrazine standard (99.7%) was purchased from Merck. Atrazine salt standard 1 gram has 215.68 molecular weight. Titanium Tetra Isopropoxide ($C_{12}H_{28}O_4Ti$), Methanol (CH_3OH), Nitric Acid (HNO_3), Polymers: Nylon-6 ($CO-NH$), Dimethyl form amide (C_3H_7NO), Meta-Cresol, Formic acid (CH_2O_2). All these chemicals, reagents, beakers, test tubes, stirrer magnets, and other glassware of analytical grade were purchased from (Sigma Aldrich and Merck).

2.2. Methods

2.2.1- Synthesis of Titanium dioxide nanoparticles by Sol-gel method

First, titanium tetraisopropoxide (TTIP) was added to methanol at a TTIP: MeOH molar ratio of 1:15, and the solution was stirred for 45 minutes using a magnetic stir bar. Then, hydrolysis of Titanium dioxide was done by adding de-ionized water with a TTIP: DI water molar ratio of 1:4. The pH of the solution was then adjusted by slowly adding 65 wt% concentrated nitric acid dropwise to obtain a pH of 1.5. Sol-gel formation was observed as a white colloid of TiO_2 after 24 hours of stirring. Second, the sol-gel mixture of titanium dioxide was washed with De-ionized water, which was centrifuged at 10,000 rpm for 15 minutes. A white jelly-like gel was formed and dried in the oven for 24 hours at $110^\circ C$ to remove moisture. The dried xerogel was ground using an agate mortar at a speed of 500 rpm for 1 hour. Then, the dry TiO_2 nanoparticles were calcined at 400, 500, 600, and $700^\circ C$ for 4 hours and labeled TiO_2 -400, TiO_2 -500, TiO_2 -600, and TiO_2 - 700, respectively.

2.2.2- Fabrication of Nylon-6 / TiO_2 nanofiber membranes

The Nylon-6 polymer in different concentrations ranging from 15 to 25 wt% was prepared by dissolving the nylon polymer into formic acid and stirring for two hours at 40rpm to get a homogeneous mixture. A 22% w/v solution of nylon was prepared in a formic acid solution in which the formic acid/meta-cresol ratio was maintained at 80:20. The Nylon-6 and Nylon-6/ TiO_2 solutions were stirred for 12 hours at room temperature before electrospinning to ensure that a homogeneous mixture was obtained and complete dissolution take place. The Nano care electrospinning apparatus was used to fabricate the Nanofibrous membrane, with a 22% Nylon-6/ TiO_2 polymer solution filled into a 20 mL syringe with a metal needle tip. The

syringe was then placed on the pump, and a connector from the voltage source was attached to the needle.

The remaining terminal was attached to the receiver, and production was carried out under optimized conditions. The optimal conditions used to fabricate Nylon-6 and Nylon-6/TiO₂ membranes were as follows: voltage = 16 kV, distance between needle and collector = 16 cm, flow rate = 0.100 ml/min, drum rotation speed = 2.25 m/min. During production, conditions were optimized by varying one parameter at a time while keeping the others constant.

2.2.2 Characterization

The fabricated nanofibers membrane morphological images were obtained using Scanning Electron Microscopy (SEM) for surface morphology nanofibers size and structure. Fourier transform infrared spectroscopy (FTIR) was carried out to confirm functional groups. XRD was carried out to study the lattice structure and confirm the incorporation of titanium dioxide nanoparticles.

2.2.3- Batch adsorption study

To study the adsorption and removal mechanism of atrazine and the effects of different pH concentrations of the solution were experimented with. Additionally, optimized parameters were studied. Initially, pH was neutral, and pollutant concentrations (10-50ppm), adsorbent dosage (2mg-10mg), and contact time (30-60min) at room temperature and stirred at 120 rpm to adsorb atrazine. Atrazine solution (50mL) was prepared at the desired pH and concentration. The desired amount of adsorbent was added, followed by orbital shaking at 120rpm for a certain period. Samples were then collected into vials and analyzed using a Perkin Elmer Lambda - UV-Vis spectrophotometer equipped with a deuterium-tungsten lamp with a 200-800nm coherence range. The nanofiber membrane removal rate was calculated using Eq:(2.1). The atrazine removal efficiency, η (%), was calculated using the following equation:

$$\eta = (C_i - C_t) / C_i \times 100 \dots\dots\dots (2.1)$$

Where, C_i and C_t are the initial and final atrazine concentrations of samples (Muqet. M et al., 2018).

3. Results and Discussions

3.1 Nanoparticles and Nanofibers Membrane Characterization

3.1.1 UV-Visible Spectroscopy of Titanium Dioxide Nanoparticles (TiO₂NPs)

UV-Visible Spectroscopy was the first initial characterization study to confirm the formation of Titanium Dioxide Nanoparticles. The UV-Vis spectra of TiO₂NPs were used to compute their band gap, as shown in Figure 1. The wavelength measurement yielded a value of 320 nm, while the determined band gap was 3.87 eV. The UV absorbance spectra demonstrate the ability of TiO₂ to swiftly act as a photocatalyst upon exposure to intense UV light, effectively disrupting robust covalent bonds through its hydroxyl radical. The optical characteristics of the nanoparticles were investigated utilizing a UV-visible spectrophotometer, focusing on the range between 200 and 700 nm.

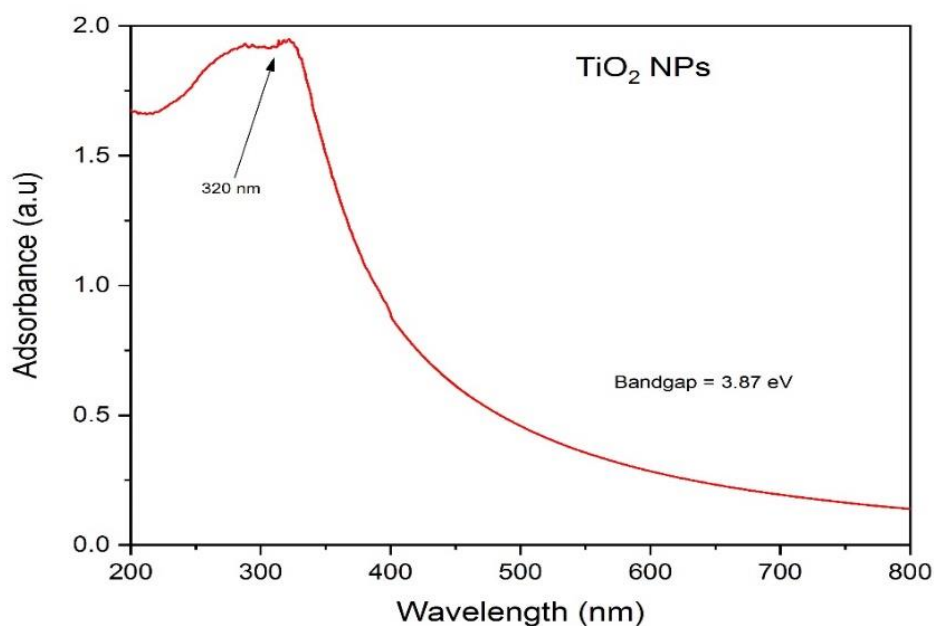


Figure 1. UV-Visible Spectra for the synthesis of titanium dioxide nanoparticles (TiO₂NPs)

3.1.2 SEM analysis of Titanium dioxide nanoparticles (TiO₂NPs)

The SEM technique was used to examine the nano-size dimensions and regular spherical shape of the TiO₂NPs as mentioned in figure 2 (a) and (b). Titanium oxide nanoparticles were found to have sizes ranging from 100 to 300 nm and an average particle size of 120- 140 nm, as mentioned in the histogram (figure 2 c). Detailed examination using high-resolution imaging revealed that most synthesized TiO₂ nanoparticles exhibited regular shapes and were arranged in an orderly manner. However, the SEM image in Figure 2 (a and b) also shows that some particles had clustered together due to the magnetic properties of the titanium oxide nanoparticles. Image J software was used to determine particle size. The small particle size provides a large surface area for hydroxyl ions (OH⁻), with the TiO₂ surface forming hydroxyl radical (OH[•]), which is a strong oxidizing agent and oxidizes large amounts of adsorbed pesticide molecules on TiO₂ surface. It was also observed through the images that the particles were spherical, smooth, uniformly distributed and, the shape of the catalyst was a heterogeneous structure, and no strange structures were detected on the surface.

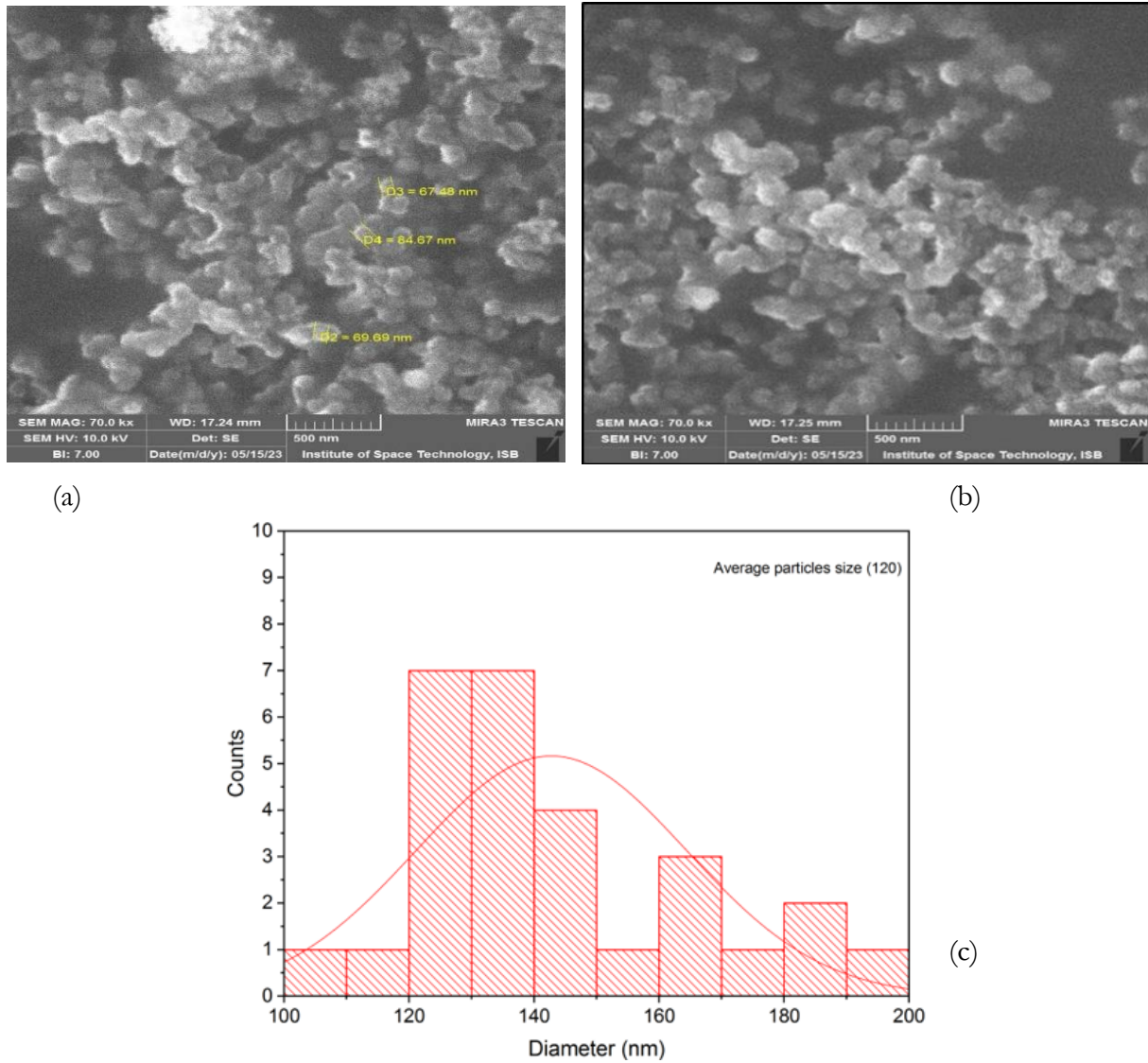


Figure 2. (a) and (b) SEM Images of Titanium dioxide nanoparticles (TiO₂NPs) (c) Histogram Showing the Average Particle Size of Titanium dioxide nanoparticles (120-140 nm).

3.1.3 SEM of Titanium dioxide nanoparticles (TiO₂NPs) embedded nanofiber

Membrane

The SEM images of fabricated Titanium dioxide nanoparticles (TiO₂NPs) embedded in PA-6 polymer nanofiber membrane were used to examine the morphology and analyze the dispersion and distribution of titanium dioxide nanoparticles (TiO₂NPs) particles within the polymer matrix. Figure 3 (a and b) shows SEM images of embedded-composite fibers containing both micro and nano-sized morphology of titanium dioxide nanoparticles, revealing a rougher surface compared to the nanoparticle's multi-filament yarns depicted. Furthermore, the nanoparticles within the fibers exhibit a spherical, irregular shape in contrast to the microparticles. The figure also highlights that the nanoparticle multifilament yarns possess compact agglomeration structures compared to the micro-composite ones. Most of the Nano-sized TiO₂ NPs in the polymer matrix have an average diameter of approximately 110 nm (figure 3c). At the surface of the fibers, there was

significant clustering of the micro-particles due to attractive interaction forces between them. The characteristics of composites are typically governed by the size and distribution of fillers within the polymer matrix, which significantly impact the composites' mechanical properties and overall performance. The size of the particles plays a crucial role in determining their ability to mix evenly and establish a strong interface with the polymer matrix.

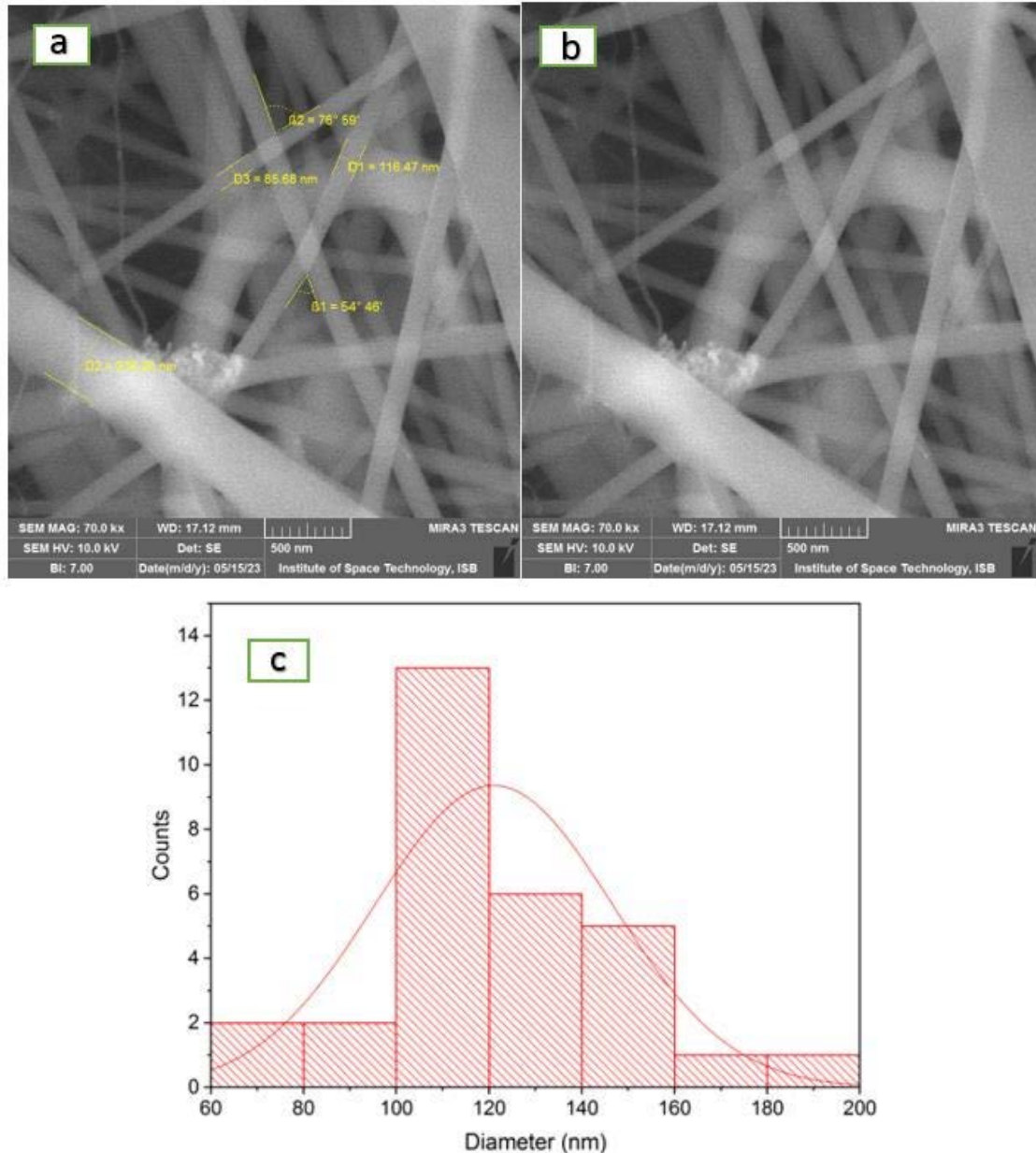


Figure 3.(a) and (b) SEM Images of Titanium dioxide nanoparticles (TiO₂NPs) embedded Nanofiber membrane prepared with the combination of PA -6 polymer (c) Histogram of Average nanofiber membrane.

3.1.4 FTIR Spectroscopy studies of Titanium dioxide nanoparticles (TiO₂NPs):

FTIR spectra was observed in the region 500-4000cm⁻¹. TiO₂NPs were synthesized using sol-gel technique. This technique confirmed the strong binding of functional group interaction of reducing agent with Ti salts (TIP). The FTIR spectra of Titanium dioxide nanoparticles

(TiO₂NPs) are shown in Figure 4. A peak appearing above 665cm⁻¹ was due to the broad stretching vibration of Ti-O. The 1025 cm⁻¹ and 1430 cm⁻¹ peaks correspond to C-F and hydroxyl (O-H) ions, respectively. The absorption range was around 3450 cm⁻¹, indicating the broad stretching of hydroxyl (O-H) ions due to bending 22 vibrations of H₂O or moisture. Peaks at 1645 cm⁻¹ show the presence of C-H groups. The peaks 2515cm⁻¹ and 2924cm⁻¹ correspond to O-H and N-H groups. Another absorption peak at 3450cm⁻¹ was attributed to the broad stretching of O-H group, and its corresponding O-H vibrations occurred at 1430cm⁻¹ due to chemically absorbed water molecules. The intense broad band below 1200 cm⁻¹ was due to Ti-O-Ti vibrations. In addition, the surface hydroxyl groups confirmed the intensity of corresponding peaks. All the peak positions were well-matched with reported peaks of TiO₂ in the previous study (Anin, K et al., 2022).

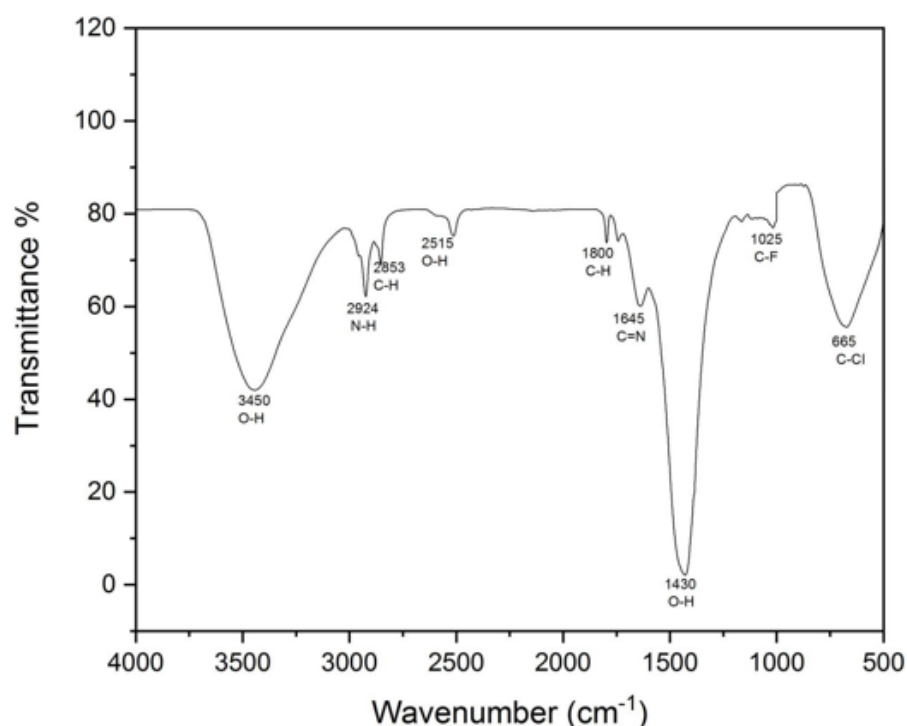


Figure 4. FTIR spectrum of Titanium dioxide nanoparticles (TiO₂NPs)

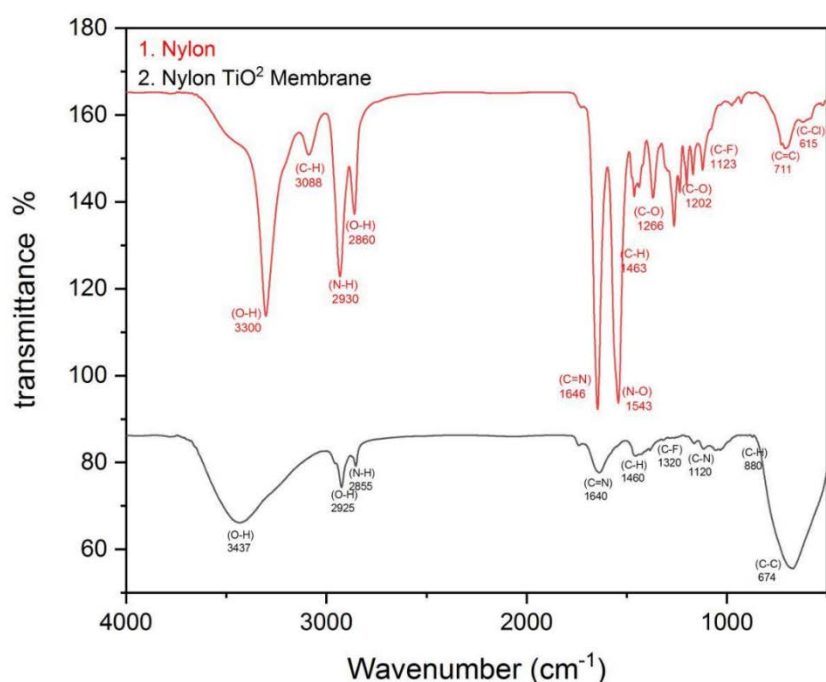


Figure 5. FTIR spectrum of Titanium dioxide embedded nanofiber membrane prepared with the combination of PA-6 polymer and only PA-6 polymer.

3.1.5 XRD spectroscopy analysis

The crystalline behaviors of the membrane with nanoparticles were recorded at the 2θ range. The XRD patterns of the (a) Prepared TiO₂ nanoparticles, (b) only PA-6 nanofiber, and (c) TiO₂ embedded with nanofiber membrane prepared by PA-6 polymer are shown in figure 6. The XRD results of TiO₂ NPs are shown in Figure 6 (a) the diffraction pattern indicating the anatase phase was dominant at 2θ , which shows the existence of a strong diffraction peak of 25.25°, 37.80°, 48.05° and so on. The structural formation of TiO₂ NPs shifted the anatase phase to the small amount of rutile phase with increasing calcination temperatures of 500°C to 800°C. The formation of an extra peak was observed at a high calcination temperature i.e. above 700°C. The XRD results of TiO₂ NPs show that the anatase peaks are sharp with high intensity at 2θ peak range, which complied with the Joint Committee on Powder Diffraction Standard Reference (JCPDS No. 21-1272) with trace rutile phase was observed (Shayestehfar and Yazdanshenas., 2014). In the previous literature, the XRD patterns of TiO₂ NPs have also been reported in the strong diffraction peaks dominating the anatase phase (Nirmala et al., 2011). Figure 6. (b) shows the diffraction pattern of the TiO₂-embedded PA-6 nanofiber membrane. The sharp anatase peak was observed at 2θ range, and the XRD patterns result of the embedded nanofiber membrane proved that the nanoparticles were homogenously embedded with polymer PA-6 to form a stable nanofibers membrane. The third diffraction pattern of PA-6 neat nanofiber is shown in Figure 6 (c) the two sharp peaks at an angle of 2θ range without broad hollow patterns show the semi-crystalline patterns of PA-6 nanofiber. This occurred due to the electrospinning process and the low % weight of the solution less than 20%, 25%, and 30% (Sriyanti et al., 2020). However, in our case, the PA-6 neat nanofiber membrane of 13 % (w/w) diffraction patterns becomes semi-crystal.

Hence it can be concluded that our three XRD patterns of (a) TiO₂ NPs, (b) TiO₂ NPs embedded PA-6 nanofiber membrane, and (c) only PA-6 neat polymer membrane without titanium dioxide were matching with the previous studies.

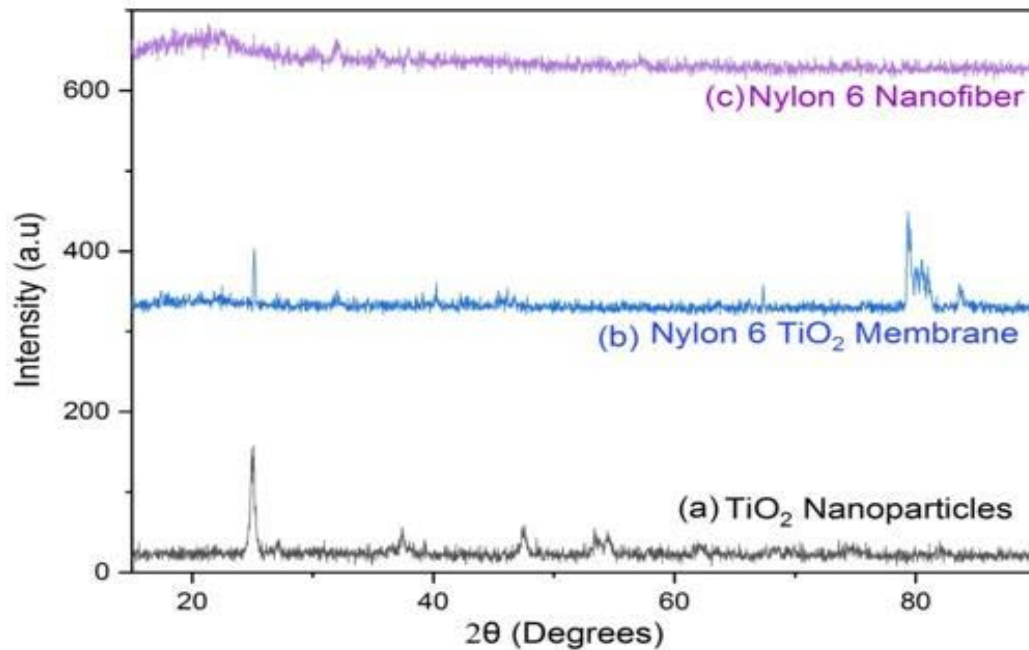


Figure 6. XRD Patterns of (a) titanium dioxide nanoparticles (TiO₂NPs), (b) TiO₂NPs embedded Nylon-6 nanofiber membrane, (c) Nylon-6 neat membrane.

3.2 Adsorption studies

The adsorption capacity of atrazine from aqueous solution was tested by batch adsorption experiments. A 2.0- 10mg (weight of NFM) Nylon-6, Nylon-6/TiO₂, NFM was immersed into 5 pre-concentrations of 10ppm, 20ppm, 30ppm, 40ppm, and 50ppm atrazine solution were put in conical flasks with covered with aluminum foil were put in a mechanical shaker for 30 mins for maximum adsorption (Qureshi. U et al., 2017). The effect of different concentrations on the adsorption of atrazine using Nylon-6, Nylon-6/TiO₂ NFM has been tested by varying concentration samples analyzed by UV-visible spectroscopy. Meanwhile, a series of experiments were carried out at pH 7. The removal efficiency of Nylon-6 NFM, Nylon-6/TiO₂, and NFM was tested for comparison under the same experimental conditions using the removal equation.

$$\eta = (C_i - C_t) / C_i \times 100 \dots\dots\dots (3.1)$$

Where, C_i and C_t are the initial and final atrazine concentrations of collected samples (Muqet. M et al., 2018).

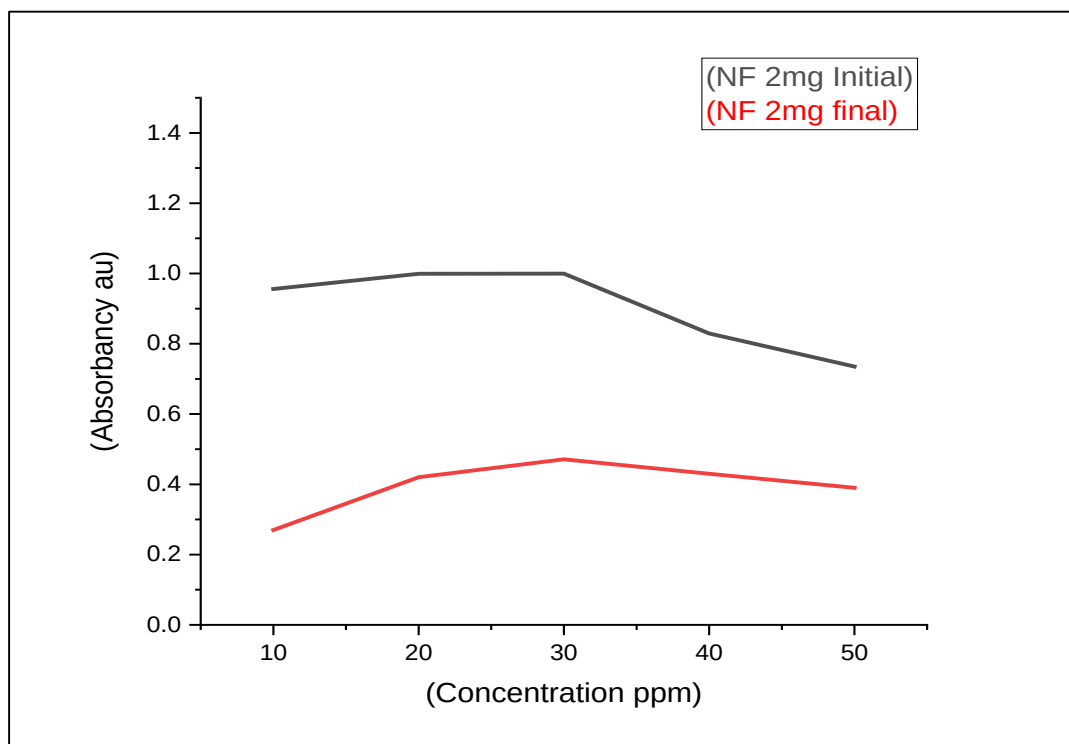


Figure 7. (a) – UV-visible results of initial and final atrazine adsorption experiment.

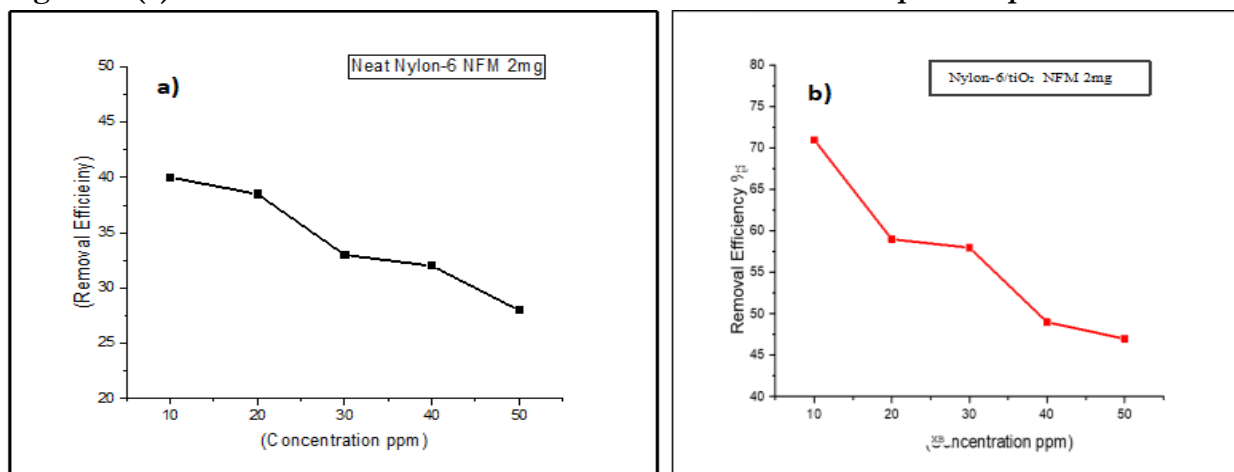


Figure 8 (a) removal efficiency at a concentration of 10 ppm. -50ppm at Neat Nylon-6 NFM and (b) Nylon-6/tiO₂ weight was 2mg, shaker speed was 120 rpm at room temperature for 30 min contact time.

Figure 8 (a) shows the removal efficiency of neat nylon-6 at different concentrations 10ppm, 20ppm, 30ppm, 40ppm, and 50ppm. The graph line represents the removal efficiency increases as concentration decreases. Removal efficiency is reciprocal to concentration. The minimum removal efficiency achieved at 50 ppm i.e 27%. The maximum removal efficiency was achieved at 10ppm i.e 42%. With the increase in solution concentration, removal efficiency decreases. Figure 8 (b) demonstrates the removal efficiency of Nylon/TiO₂ nanofibers membrane at 5 different concentrations (10-50 ppm). This experiment was done at a neutral pH 7 and constant time of 30 minutes, at 120rpm. This graph line represents the decrease in removal efficiency with an increase

in concentration. The minimum removal efficiency achieved at 50 ppm was 43 % and the maximum removal efficiency achieved at 10 ppm was 70%. The results show the removal efficiency of nylon-6/TiO₂ was better than the neat nylon-6. Titanium dioxide nanoparticles enhance the removal efficiency % of nanofibers membrane.

4. Conclusions

This study used Nylon-6 and Nylon-6/TiO₂ NFM as adsorbents to remove atrazine from aqueous solution. Experiments were performed to clarify the specific adsorption properties, potential mechanisms, and feasibility of the Nanofibrous membranes. Our results indicate that Nylon-6/TiO₂ NFM has much higher removal efficiency than most existing atrazine removal sorbents published in the literature, suggesting that it has potential as a new atrazine adsorbent for wastewater treatment. Additional research is underway to confirm the effectiveness of Nylon-6/TiO₂ NFM in removing atrazine from contaminated water.

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Solid Waste Management through Circular Economy Framework: A case study of Hyderabad city in Pakistan

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Abstract:

Solid waste management is a serious concern in all mega cities in Pakistan. The main reason of this challenge stems from managing solid waste through the conventional linear economy approach (i.e. collection, transportation, and disposal at unsanitary landfill site) while ignoring the circularity potential of the waste. Consequently, this approach is contributing towards resource depletion and eventually to the environmental deterioration. As the circular economy has been highly prioritized recently, aiming to move away from old-fashioned of waste disposal practices towards a sustainable waste management and resource use efficiency. Considering the importance of circular economy in context of Pakistan, this study aims to investigate the resources recovery potential from the municipal waste coming at landfill sites in Hyderabad, Sindh. The effective waste transportation, material recovery, and waste treatment process have been explored and assessed based on resources requirements versus resource recovery. The waste composition of waste quantifies at landfill area in this study through collecting on site samples, and then try to merge that waste into circularity model that minimizes transportation distance by around 80% through material segregation and recovery facilities located within the city. Approximately 15.6% of recyclable material can be recovered from waste. The estimated rates assessed from the waste treatment process are as follows: the anaerobic digestion model assessed 360 m³ CH₄/ton of the organic fraction within municipal solid waste (OFMSW), 330 kg/ton compost assessed from OFMSW through the composting process model, 2420 MJ/ton energy accessed from inorganic fraction of MSW using mass burn combustion, and 200 Nm³/ton biogas assessed from MSW using Engineering landfill with gas recovery, excluding the resources required by the process. Therefore, this study helps to assess the potential of solid waste circularity with maximum economic gain, while reducing the environmental damages and ultimately leading towards a sustainable framework for efficient solid waste management.

Introduction:

Pakistan is facing various environmental as well as socio-economic challenges, solid waste management one of them that is became challenging tasks for Pakistan (Safar et al., 2021), due to increase in population, rapid and unplanned urbanization, industrialization, changes in consumption patterns, diversification of solid waste generation and lack of framework to managed the solid waste (Hoang et al., 2022). Regular 30 million metric tons of waste is being generated in Pakistan with per capita waste generation of 0.283 to 0.612 kg that is increasing at the rate of 2.4% (Bank, 2021; PBS, 2023; View of Population and Causes of Agricultural Land Conversation in Hyderabad, Sindh, Pakistan.Pdf, n.d.), and that has been managed through the conventional Linear economy method, Through this approach resources are collected, converted into products, and

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then eventually discarded after getting the required utility, that causes waste accumulation, deteriorates the environment and recourse deficiency due to the over-extraction (Iqbal et al., 2023).

The linear economy has been played an important role in economic growth during the last few decades. The linear model was dominant to waste management, but it generated unprecedented pressure on natural resources and improper waste disposal of waste, due to inadequate waste management that increases the pressure on landfills, (Ghisellini et al., 2016). In the context of waste management the circular economy approach is sustainable and resource management strategy, with the goal of circulate the life cycle chain of the product, that promotes the longevity of materials, processes, and products by embracing circularity, which means that resources are constantly reused, recycled, and regenerated (Tomić & Schneider, 2020).

Hyderabad is the 2nd most populated city in Sindh and 8th in Pakistan which has population of 2.43 million people according to 2023 census, and Hyderabad generates around 1368 tons of solid waste every day with a per capita generation rate of 0.563 kg/day and the major sources of solid waste generation in Hyderabad are the residential, commercial, and institution, the composition of the waste in the city varies with different sectors, (i.e. income variation, lifestyles of the residential and culture) (PBS, 2023; Safar Korai et al., 2014; View of Population and Causes of Agricultural Land Conversation in Hyderabad, Sindh, Pakistan.Pdf, n.d.). However, coordination and implementation frequently fall short, resulting in problems such as overflowing landfills, illegal dumping, economic burden on waste management sector and contamination of aquatic bodies, that is why the aim of this study to provide an improvement assessment for waste management practices, promoting circular economy and provide a framework that shift the waste management of Hyderabad from Linear to circular economy approach.

Methodology:

To investigate the inter-relationship and trends of the municipal solid waste management covered in this study, the methodology was split into two part, the first one is systematic review to gather the data for development of circularity model and second is primary data that was collected through the defined methodology to support the circularity framework.

Waste Generation Analysis:

To assess the waste generation analysis of Hyderabad at the final dumping site interviews from Altas Pak management and Sindh Solid waste management board Hyderabad (SSWMB) management were conducted regarding the waste collection vehicles capacity and there frequency and travelling distance for the final dumping site of the waste.

Waste composition analysis:

To quantify the municipal solid waste composition analysis the 2 transfer station were selected that are located within the periphery of the city where the waste is being temporary dumped, collected and transfer thru dumper final dumping of waste. Overall, 48 samples were collected from both landfill sites on different days of the week. For waste composition analysis the “ASTM-D-5231 procedure test method” used for measuring the composition of unprocessed municipal solid waste of Hyderabad by employing manual sorting.

Development of Circular economy framework

The secondary data were acquired from published literature, comprising research articles and technical reports. Online databases were utilized, such as Google Scholar, Science Direct, & Scopus, Specific keywords were used to search the relevant data, like Circular Economy, Solid waste management, Bio-economy & Resource recovery potential. The purpose of this review was to analyze the overall resource consumption for the treatment purposes and what possible resources can be recovered from the suggested solid waste management system that will promote the circular economy framework.

Results and Discussion:

Waste composition Analysis:

Municipal waste generation rate in Hyderabad was based on output results at final dumping site obtained from the Sindh solid waste management board of Hyderabad. The below defined formula was used to determine the total waste generation rate at the final dumping site.

Waste generation at final dumping site = Collection frequency of vehicles $\times$ vehicles carrying capacity

Waste generation at final dumping site = 80 dumpers per day $\times$ 10 tons/vehicle

Waste generation at final dumping site = 800 tons per day.

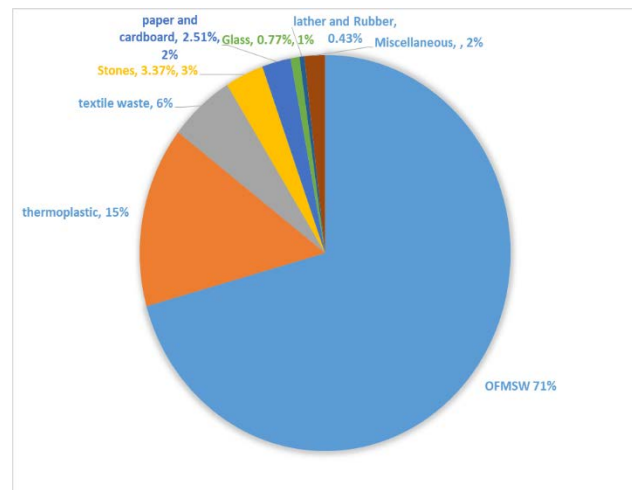
Waste composition analysis:

The average composition of the total analyzed waste during the sample collection at transfer stations in Hyderabad is shown in Pie-chart.

Organic waste (food and yard waste) constitutes 70.75% of the total waste generated in Hyderabad District the second most constitutes is thermoplastic plastic 14.79%, Textile constitutes 5.71%, Paper and cardboard waste constitutes 2.51%, and remaining are Rubber, metal, glass and stones.

Fig 1: Waste composition analysis

Circular economy Model



To shift the waste management of Hyderabad from a linear economy approach to a circular economy approach, the circularity model is shown in Fig. 2, through which the different treatment options were assessed through the literature and found to be the most economical and feasible options for the waste management of Hyderabad.

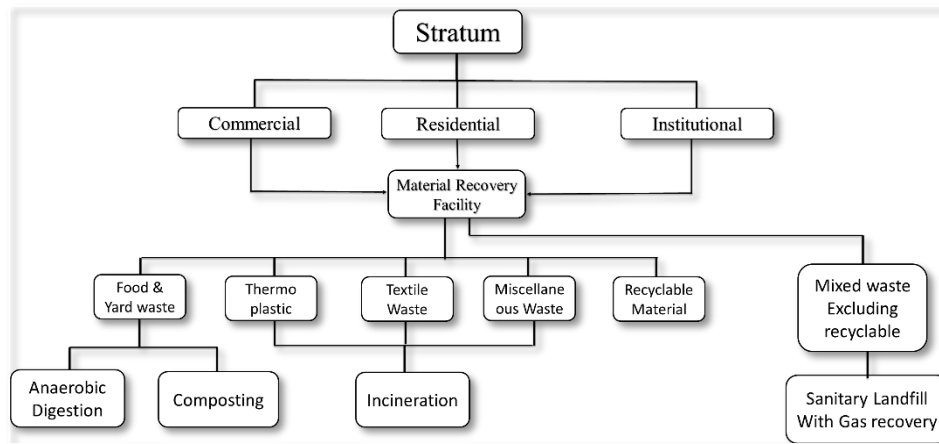


Fig 2: Circularity model for Municipal solid waste management of Hyderabad

Transportation of MSW:

The waste has been collected from the city and initially transferred to the transfer stations Mehar Ali Shah and Goth Achar Mallah, which are 8.5 KM away (average distance) from the city, and then that waste was transferred towards Lonikot for final dumping away from the city, having a 42.5 average distance from both landfill sides. As per the circularity model, If that waste is segregated and treated at the transfer stations (Mehar Ali Shah and Goth Achar Mallah), then we can reduce the traveling distance by 80% and the oil consumption by 60%.

Material Recovery facility:

As per the suggested circularity model, if the waste is collected directly from the source and brought to the material recovery facility, there is a possibility that around 15.6% of recyclable material can be recovered. If we adopt the current practice of waste collection as per the landfill sample composition, then we can recover 4.2% of recyclable material.

Treatment of organic fraction of Municipal Solid Waste through Anaerobic Digestion

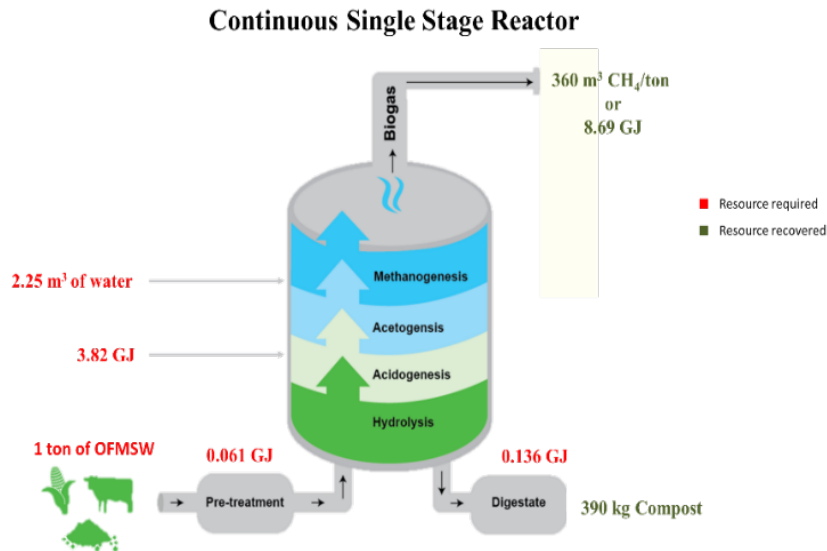
Anaerobic digestion (AD) is a well-established and widely used treatment process for organic fraction of municipal solid waste, it is capable of treating and stabilizing organic materials in the absence of oxygen by the use of a consortia of microorganisms during the hydrolysis, acidogenesis, acetogenesis, and methanogens phases (Babu et al., 2021). In this study a continuous single stage reactor was selected having the design parameters are, Mesophilic conditions, at a temperature of 35 °C (Kothari et al., 2014), with high solid subtract 15% of TS is considered, the hydraulic retention time for this reactor about 35 days (Evangelisti et al., 2014) The expected resource required for treatment of one tone waste in this digester are 0.061GJ of energy required for pretreatment, 0.3m³ of water for dilution, to maintain the 15% TS ratio (Tian et al., 2021). Anaerobic Digestion required some energy for operating the reactor including “pumping of feedstock and water for dilution, mixing of yield, and heating to maintain 35°C temperature” the energy requirement for all these process are 2.1 GJ (Evangelisti et al., 2014). The resource recovered from the digester is of 600 Nm³ of biogas per ton of waste with a methane content of 60% corresponding to a net calorific value of 23 MJ/N m³ from biogas is considered, So the total

energy gain from the biogas production is 8.28 GJ (Kocak, 2022). And 390 kg of Nutrient rich left over material after anaerobic digestion process can be used as a compost (Francini et al., 2019).

Fig 3: Anaerobic Digestion Resource recovery potential (Pacific Gas and Electric Company, 2018)

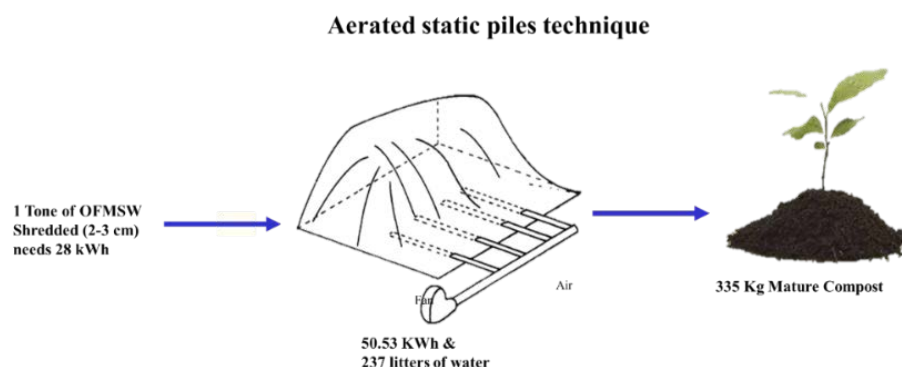
Treatment of organic fraction of Municipal Solid Waste through Composting:

Composting is the natural process of decomposing organic materials into compost, which is dark



in color, and nutrient-dense in nature. This process is carried out by a varied variety of microorganisms, including bacteria, fungi, and worms, which break down the organic materials into simpler substances that plants can absorb as nutrition (Ayilara et al., 2020; Sánchez et al., 2017), For the management of OFMSW of Hyderabad through composting a aerated static pile technique were assess to quantify the resource recovery potential through it.

Aerated static pile composting process requires energy in different pretreatment, pilling and air supply, initially the OFMSW required mechanical treatment that enhance the efficiency of



treatment, the tube grinder is used for shredding purpose that consumes 28 KWh of energy for per ton of organic solid waste for size reduction (Saer et al., 2013). After that the waste was piled on the pipe frames to supply the proper oxygen to maintain aerobic conditions that requires 50.53KWh of energy, For biological decomposition and micro-organism nutrition the 237 Litters/ton of water were also required including rainfall water (Martínez-Blanco et al., 2010). After completion of whole process 33-35% of compost can be recovered from the 1 ton of organic fraction (Cadena et al., 2009; Martínez-Blanco et al., 2010).

Fig 4: Composting resource recovery potential (Íñiguez-Covarrubias et al., 2018)

Treatment of In-organic fraction of Municipal Solid Waste through Incineration:

Incineration is the thermal treatment technique that involves the mass burning of fuel under controlled conditions with the primary objective of volume reduction and energy recovery from the waste stream (Moharir et al., 2019). In this study a mass burn incineration technique with a combination of air pollution control APC technologies was considered for assessing the resource recovery potential (Merrild et al., 2008, 2012). The resource required for incineration process are 1 ton of mixed waste containing inorganic fraction combustion process of municipal waste 36 MJ of energy is required in the form of natural gas (Merrild et al., 2012), and except that to treat the flue gases coming from the stack the air pollution control system also required some material to treat the contaminated air, the resources used in pollution control system are 0.158 m³ of water, 2.5 Kg of activated carbon, 2.5kg of Lime powder and 3.2 Kg of calcium hydroxide Ca(OH)² to treat the 5,600 Nm³ of flue gasses generating from the one ton of MSW during mass burning (Arena et al., 2003).

The resource that can be recovered from the 1 ton of waste through incineration process are 180 kg of bottom ash and 90kg of fly ash can be recovered, it may vary with the waste composition (Arena et al., 2003; Pan et al., 2008). And total 2420 MJ of electrical energy also recovered from the mass burn incinerator (Arena et al., 2003).

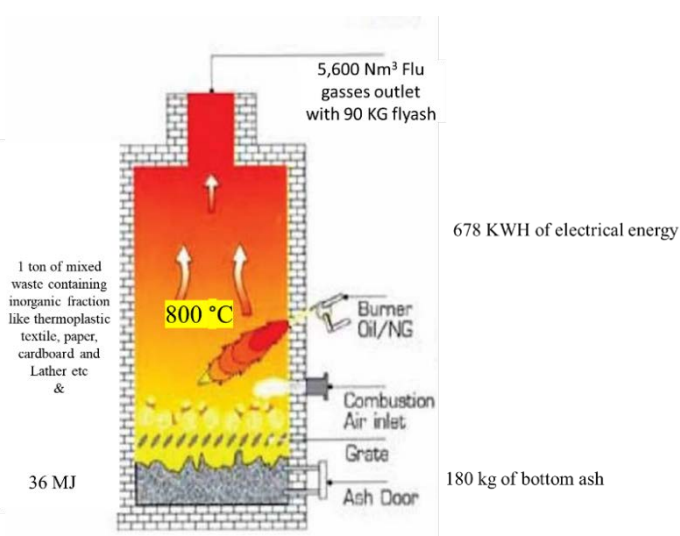
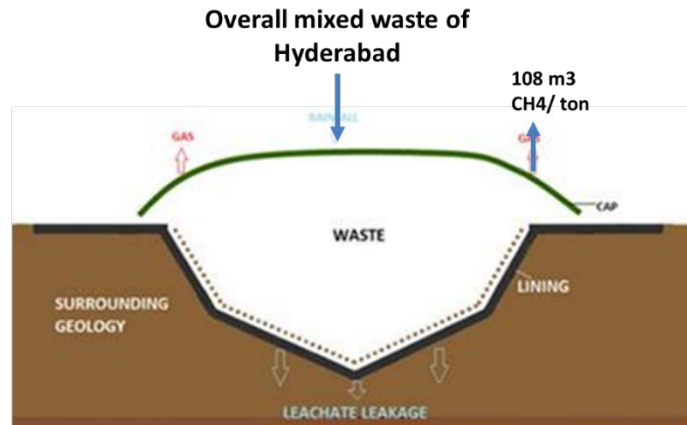


Fig 5: Incineration resource recovery potential

(Karim & Corazzini, 2019)

Engineering landfill with gas recovery:

Landfills are design to dump the waste including hazardous and non-hazardous for safe disposal of that waste. MSW landfills typically contain Organic waste, plastics, paper, glass, and metals which are abundantly found in waste stream (Abdel-Shafy & Mansour, 2018). It is estimated that if the landfill contain mixed waste stream, then biogas is produced at a rate of 200 m³/ton waste including 47% methane, 37% carbon dioxide, and 13% nitrogen, with 47% discharged directly into the atmosphere and 53% is stored and combusted. (Themelis & Ulloa, 2005; Yip & Chua, 08). The landfill model also includes the energy and diesel consumption for landfill operation in process of waste compacting, landfill gas collection system, final cover installation, and land use for the waste dumping. The total estimated energy consumption for the 1 ton of waste dumping was required 55 MJ of energy for compaction, and other operational purposes and 0.239 m area is required for 1 tone of solid waste dumping.



0.239 m area is required for 1 tone of solid waste dumping into the.

Fig 6: Engineering landfill Resource recovery potential (Meegoda et al., 2016)

Conclusion:

This study evaluates multiple waste resource recovery options that include the transportation framework, material recovery facility, Anaerobic Digestion, composting, incineration, and landfill with gas recovery. If the waste Material recovery facility is installed at the transfer station then 80% of distance and 60% of oil leverages can be deducted from the current waste transportation route. As well as material recovery facility will recover around 15.6 % of recyclable material that also have some marginal value. After the material recovery facility if the waste goes through some treatment process then they will also provide some resource.

Through anaerobic digestion, have potential to recover 8.47 GJ of energy and 390 tons of digestive (which can be utilized as fertilizer), and from composting, we can extract 335 kg of compost by investing 78.53 KWh of electricity and the required amount of water. So for resource recovery potential, anaerobic digestion has more than composting, but it needs a complex system and continuous operation to run the system. On the other hand, compost is easier to prepare.

To manage the inorganic constituent of waste incineration resource recovery potential has been assessed it recover 678 KWh of electrical energy from the incineration process by combining 1 ton of an inorganic fraction of municipal waste included with some amount of water, limestone, and activated carbon for emission control measures to limit the flue gases.

If overall waste is dumped into the sanitary landfill, the resource recovery will be 108 m³ CH₄/ton of overall mixed waste.

Anaerobic digestion and incineration waste treatment techniques, along with material recovery facilities at transfer stations, have a higher potential for resource recovery according to the circularity model but it require a more capital cost as compare to composting and landfill sites to operate these treatment option within the Hyderabad city.

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Inactivation efficiency of chlorine and biosynthesized nanoparticles assisted activated carbon against water borne pathogens.

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Abstract

Drinking water contamination and clean water scarcity is a major environmental issue of Kotli district in particular and Azad Jammu and Kashmir (AJK) in general. Anthropogenic activities lead to drinking water contamination, resulting in various water borne diseases outbreak. So, the study was designed to monitor drinking water quality status and optimization of the different water treatment processes for water borne bacteria, isolated from the community water supply of Kotli AJK. Collected water samples from different points in the distribution network were analyzed. Samples were found positive for *coliform* and *fecal coliforms* while more than 100 MPN index was found in fourteen percent of the tested samples. *Bacillus cereus* MBT028, *Bacillus cereus* MBT029, *Bacillus tropicus* MBT031, *Bacillus paramycoides* MBT032, *Pseudomonas aeruginosa* MBT034, identified by 16S rRNA analysis were isolated from tested drinking water samples and used for inactivation studies using chlorine and silver nanoparticles with activated carbon (Ag-NPs/AC) composite. *P. aeruginosa* MBT034 showed complete reduction at 3 ppm free chlorine applied concentration showed low resistance to chlorine while *B. cereus* MBT028 showed resistance even at 7 ppm, and only 2 log removal was observed even at contact time of 45 min. The present study results demonstrated that low dose of chlorine alone was not effective against the isolated strains even at 7 ppm concentration. Among all experiments Ag-NPs/AC composite showed maximum log reduction of all isolated strains at contact time of 30 min. Finally, the finding of this study recommended that Ag-NPs/AC is effective for use in water treatment process.

INTRODUCTION

Ground water aquifers are 70% drinking water sources in Pakistan and contaminated water is a major issue of public health. Overall country faces both water quantity and quality challenges which is documented in many studies (Butt & Khair, 2021). Globally water borne diseases are critical health problem. Many water borne diseases occur due to insufficiency of clean drinking water and poor sanitation (Deshmukh *et al.*, 2016). Drinking water analysis of 29 different cities in Pakistan has showed 11 main water quality problems in collected samples (Haydar *et al.*, 2016.) A study documented that 84% drinking water samples contain microbial contamination in the study area which is used in this research study (Ajk EPA 2018). During chlorination treatment, low dose of chlorine was not effective in eradicating selective isolates and the existence of isolates showed elevated level of isolate's tolerance to chlorine. Greater chlorine concentrations was more efficient in inactivating isolates (Owoseni *et al.*, 2017)

Activated carbon (AC) is carbonaceous material which contains pores and large internal surface area. It is efficiently used as adsorbent in water treatment (Yousef *et al.*, 2019). Agriculture waste is a main source of biological activated carbon (BAC) it provide environmental protection and it also help to sustain ecosystem (Wong *et al.*, 2018). AC coated with silver nanoparticles (AgNPs) possesses high efficiency for water disinfection against microorganisms such as *Escherichia coli* (*E. coli*) in 5 minute (min) of time. Nanoparticles bounded with activated carbon shows 100% bacterial reduction. Silver nanoparticles along with activated carbon has finest catalytic activity as compared to other nanoparticles due to scattering of AgNPs with Activated carbon (Taha *et al.*, 2020). The antimicrobial efficiency of AgNPs was resolved by comparison of the number of

microbes before and after treatment. The maximum concentration of AgNPs showed maximum bactericidal efficacy in total bacteria count (TBC) (Rus et al., 2017).

Therefore, the work reported here is designed to assess the drinking water quality of district kotli and analyzed the efficiency of activated carbon assisted chlorination coupled with biosynthesized nanoparticles against borne pathogens to provide safe drinking water to the local community.

2. MATERIALS AND METHODS

2.1 STUDY AREA

In this study physicochemical and bacteriological analysis of drinking water was conducted from water supply system of Kotli AJK region. Kotli is a district of Azad Jammu and Kashmir - Pakistan. The landscape is mainly hilly with the little flat area available. Groundwater wells, Tube well, bores, and springs are the major sources of drinking water in this region.

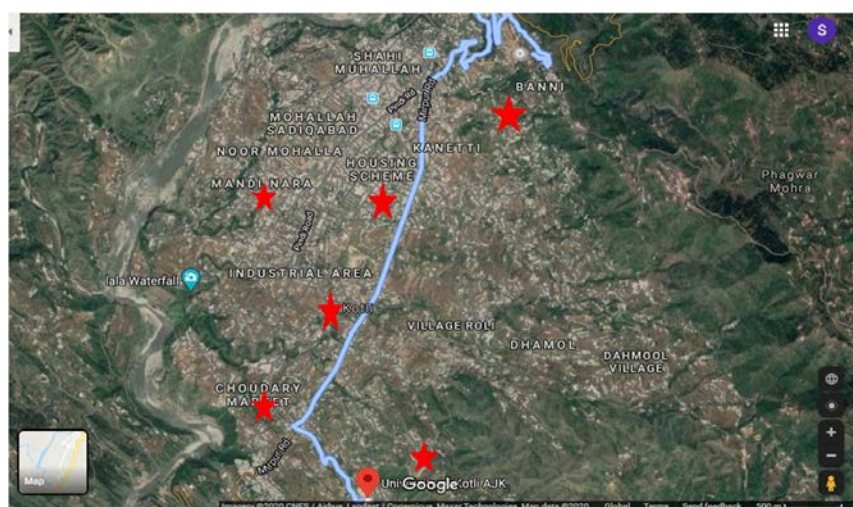


Figure-1: Area map of district Kotli

2.2 Sample Collection

Drinking water sample were collected from different water sources such as tube well, bore, river, tap water, spring and tube well at different locations of district Kotli. Before sample collection bottles were washed, autoclaved, and finally dried in oven at 85°C. The tap water was run for 5min before water collection. Water samples were collected in clean sterilized glass bottles, with added Sodium Thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$; 0.1N) solution to capture residual chlorine if found (Fig 3). After the sample collection, bottles were capped and marked with a specific identification number according to the sampling site. Collected samples were transported immediately to the laboratory for physiochemical and bacteriological examinations.



Figure-2: Drinking water contamination at different sites of study area

Water samples were collected in clean sterilized glass bottles, with added Sodium Thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$; 0.1N) solution to capture residual chlorine if found (Fig 3). After the sample collection, bottles were capped and marked with a specific identification number according to the sampling site. Collected samples were transported immediately to the laboratory for physiochemical and bacteriological examinations.

Figure-3: Water quality sampling from ground water sources

2.3 Physicochemical Parameters

The parameters such as pH, Temperature, Electrical conductivity (EC) and Total dissolved solids (TDS) were determined. Multimeter was used to find the physicochemical parameters of the samples.

2.4 Most Probable Number Method (MPN)

The MPN method is used for water sample examination for coliforms in accordance with the method described by Harley and Prescott (2002). Lauryl Tryptose Broth (LTB), Brilliant Green Bile Lactose Broth (BGLB) and Escherichia coli (E. coli) broth were prepared in the required amount of distilled water and the beakers were shaken slowly. All media were dispensed into the test tubes. Each test tube contains a durham's tube in it. Test tubes were autoclaved at 121°C for 15min. Autoclaved tubes were incubated for 24hour (h) for a sterility test. Gas production and

bubble formation occurred in Durham's tube that specifies the coliform bacteria in a given water sample.

2.5 Isolation and Identification of Bacterial Strains

Serial dilution was performed and 1ml of the sample was spread on nutrient agar plate and incubated at 37°C for 24h. The most prominent colonies were picked on next day and streaked on agar plate again. The most prominent colonies were isolated and maintained at 4°C for further study. The identification of microbes was performed using microscope.

2.6 Biochemical Test

Different biochemical tests were performed to identify different strains. Gram staining, catalase, oxidase, cimmom citrate, indole and MacConkey agar were performed respectively.

2.7 Molecular Identification of Isolated Strains

Molecular identification was performed by using 16S rRNA analysis through Seoul South Korea. The evolutionary history was inferred by maximum likelihood method and Tamura-Nei model (Tamura k and Nei M. 1993). Tamura-Nei model was used to obtain original tree for heuristic search. The trees were obtained by using Neighbor joining algoirhtms to a matrix of pair wise. The confusing positions were deleted from the sequences. Evolutionary comparison was done with the help of MEGA 10 (Kumar *et al.*, 2018).

2.8 Preparation of Activated Carbon

Activated carbon was prepared from corn cob using a method described by Christica *et al.*, (2018). Fig 4 represents the steps of preparation of activated carbon.

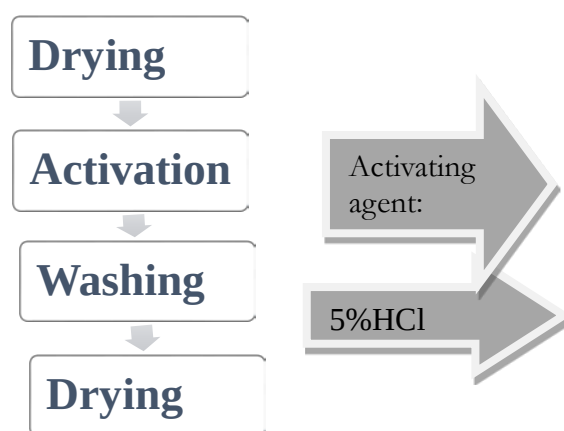


Figure- 4: Flow sheet diagram for the preparation of activated carbon

2.9 Preparation of Biosynthesized Nanoparticles from Mint

MINT (*Mentha piperita*) leaves are used for preparation of silver nanoparticles. The detail of method is shown in (Fig 5).

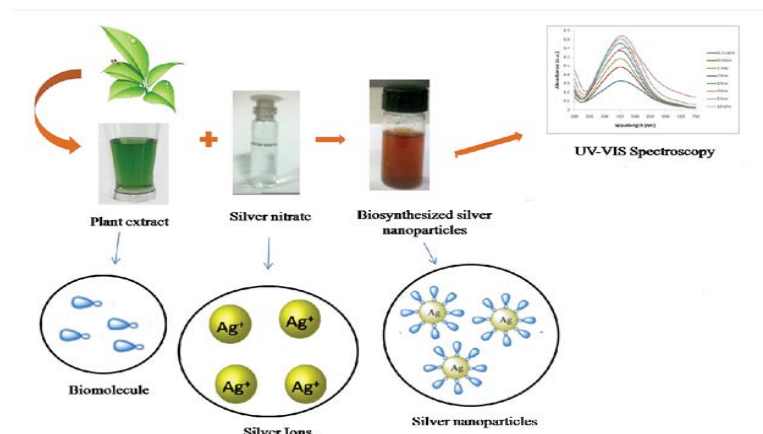


Figure-5: Diagrammatic representation for preparation of silver nanoparticles.

2.10 MICROBIAL INACTIVATION STUDIES

2.10.1 Microbial Inactivation with Chlorine

The selective bacterial suspension was added to 500ml of distilled autoclaved water in a conical flask. For one strain, four different chlorine concentrations 1ppm, 3ppm, 5ppm, 7ppm were used at different contact times of 0, 15 and 30 min. Free chlorine was also measured at every time interval. After the desired contact time, appropriate serial dilutions were performed, and the treated sample was spread on nutrient agar. The number of colonies on plates was counted and the colony forming unit (CFU) was calculated by using the formula: No of colonies x Dilution factor/sample volume (ml).

2.10.2 Microbial Inactivation

- With Ag-Nps/AC Composite Experiment
- With AC
- With Ag-Nps/AC composite and chlorine

Distilled water (250ml) was autoclaved in a flask. After autoclave, the given bacterial suspension was added to the flask. Serial dilution was performed. A 1ml sample was spread on nutrient agar before treatment. Then the composite was added to the given flask. Put it on a magnetic stirrer for two different time intervals. After 5min, a 1ml sample was picked and serially diluted and spread on nutrient agar. After 30min, the same process was repeated. Plates were placed in incubator. After 24h, growth was checked. The same process was repeated for other strains.

2.10.3 Microbial Inactivation with AC Column

The especially constructed glass columns were filled with different concentrations of Ag-NPs/AC composite. Firstly, the column was filled with various depths of Ag-NPs/AC composite and then 250ml of water containing selective bacterial suspension was poured into the column. For each filtrate, serial dilution was performed and spread on nutrient agar. The CFU were counted according using colony counter.



Figure-6: Coulumn experiment with Ag-AC nanocomposite

2.10 Statistical Analysis

Analysis of variance (ANOVA) is a statistical tool which is used to detect difference in means of group when one dependent variable and one independent variable are available (Sawyer *et al.*, 2009). Two way ANOVA is a statistical process that help researchers to determine the effect of two or more independent variables on one dependent variable. Inactivation studies data was analyzed by using ANOVA with using software statistics. ANOVA was used to determine the significance of data. Values were taken in triplicate and analyzed in tool. The f value was evaluated using ANOVA with confidence level of 99.95%. The P value for F is 0.001. If P value was less than 0.01 than it showed that results are significant.

RESULTS AND DISCUSSIONS

3.1 Physicochemical Parameters

The existence of bacteria in water depends on physicochemical parameters of water. The pH of samples ranged between 6.2 to 7.7 while temperature of samples ranged between 18 to 29.5°C. TDS values ranged from 143 to 1620ppm. Only one sample showed TDS more than 1000 ppm. The EC of samples ranged from 243 to 1342 μ s/cm (Table 1).

Table -1: Physicochemical parameters of the water samples

Sampling station	Location	Source	Temperature (°C)	pH	Electrical conductivity (μ s/cm)	TDS (ppm)
1	University	Filter Cafeteria	26.2	6.8	733	372
			24.6	7.0	707	353
2	Village Kurti	Bore Spring	25.9	6.2	1032	516
			21.2	7.1	243	486
3	Highway	Tube well Spring	29.5	6.5	921	458
			24	6.8	785	390
4	Housing scheme	Pipe line Tube well	28.9	6.3	1062	526
			20	6.8	788	396
5	Gulhar colony	Bore Spring	21.2	6.7	811	1620
			23	6.5	959	479
6	River	River	21	7.0	850	980

		River	22	8	789	945
7	Nakyal cross	Pipe line Spring	24.0 28.3	7.3 6.3	399 1382	198 683
8	Dhanghroot	Pipe line Bore	21.1 21	6.5 6.5	407 495	816 986
9	Mandi	Spring Well	23.8 25.8	6.4 6.6	753 1146	454 572
10	River poonch	River Filter	24.7 29	7.7 7.1	286 437	143 218
11	Thalair colony	Spring Bore	21.1 20	6.6 6.5	386 495	766 986
12	Rolli cross	Bore Well	27.6 18	6.3 6.5	1100 778	511 388

3.2 Bacteriological Assessment

All of tested water samples were found heavily contaminated with *coliforms*. The formation of gas in Durham tube after 24h indicates results positive. 14 of samples were heavily contaminated with bacteria and have MPN index of more than 100 while 11 samples showed variable MPN index as shown in Table 2.

Table-2: The most probable number (MPN) table for microbial analysis of water

Study samples	Positive tubes in sample	MPN index in 100ml	95% Confidence limit	
			Low	High
1.	5-5-5	<2400	---	---
2.	5-5-5	<2400	---	---
3.	5-5-5	<2400	---	---
4.	0-0-0	<2	---	---
5.	5-5-5	<2400	---	---
6.	5-5-4	1600	600	5300
7.	5-5-4	1600	600	5300
8.	5-4-3	280	120	690
9.	5-3-3	170	80	410
10.	5-3-2	140	60	360
11.	5-2-1	70	30	180
12.	5-3-3	170	80	410
13.	5-2-1	70	30	250
14.	5-3-2	140	60	360
15.	4-3-1	33	15	77
16.	3-2-1	17	7.0	40
17.	3-2-1	17	7.0	40
18.	5-5-4	1600	600	5300
19.	5-5-1	300	100	580
20.	5-2-1	70	30	250
21.	2-1-1	9	3.0	25
22.	0-0-0	<2	---	---
23.	4-4-0	34	16	80
24.	4-3-1	33	15	77
25.	5-4-3	280	120	690

3.3 Isolation and Identification of Microbes

Spread plate method was used to isolate the bacterial strain. Morphology of the strain was determined using visual inspection of all isolates, color under microscope and color on agar, shape, margin, elevation and size were checked respectively (Table 3).

Table- 3: Strains morphology (visual inspection)

Bacterial Isolates	Color under microscope	Shape	Margin	Elevation	Visual texture	Size (mm)	Color on agar
MBT029	Brown black	Round	Smooth	Dome	Mucilage	1.5	Cream
MBT034	Brown	Oval	Irregular	Attached with agar	Powdery	2.2	Cream
MBT031	Brownish black	Round	Round	Attached with agar	Powdery	2	Pale yellow
MBT028	Brown	Round	Round	Raised	Mucilage	2	Skin
MBT032	Brownish black	Irregular	Irregular	Attached with agar	Mucilage	2.5	Skin

Table- 4: Biochemical Analysis

Bacterial Strains	Catalase	Oxidase	Indole	Cimmon Citrate	Gram staining	MacConkey agar
MBT028	+	-	-	+	+	+
MBT029	+	-	-	+	+	+
MBT031	+	+	-	+	+	-
MBT032	+	+	-	-	+	+
MBT034	+	+	-	+	-	+

3.4 Molecular Identification of Isolated Strains

The results of molecular characterization of isolated strains are shown in (Fig 7,8,9,10,11).

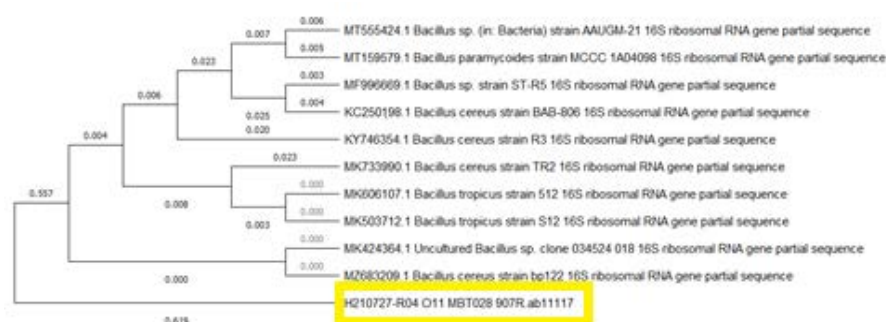


Figure-7: MBT028 Phylogenetic tree

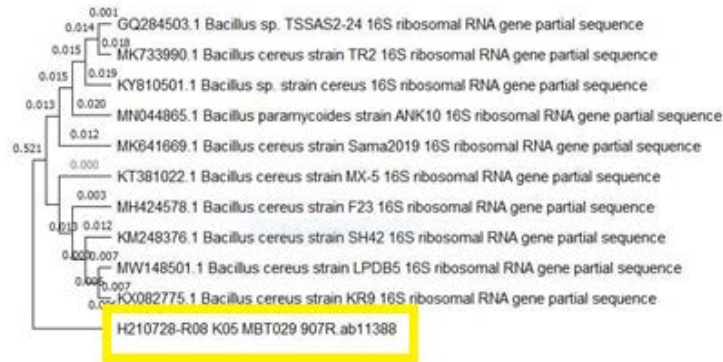


Figure-8: MBT029 Phylogenetic tree

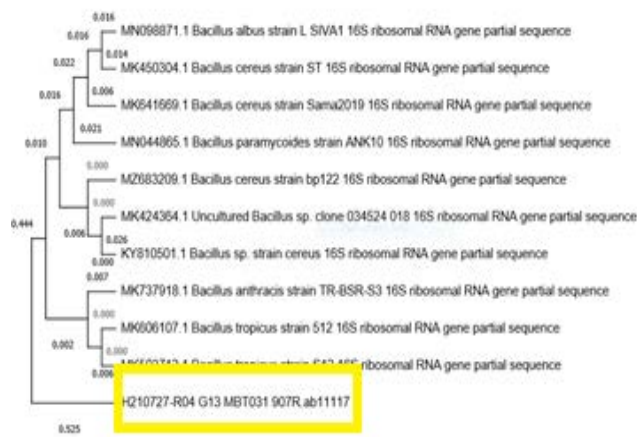


Figure-9: MBT031 Phylogenetic tree

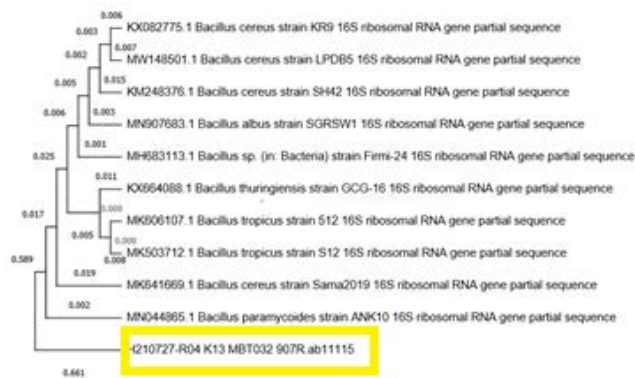


Figure- 10: MBT 032 Phylogenetic tree

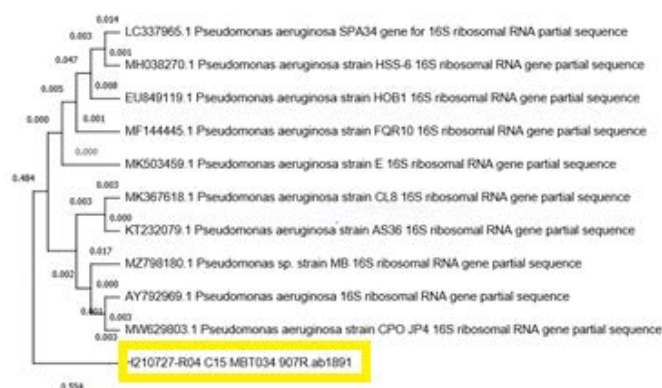


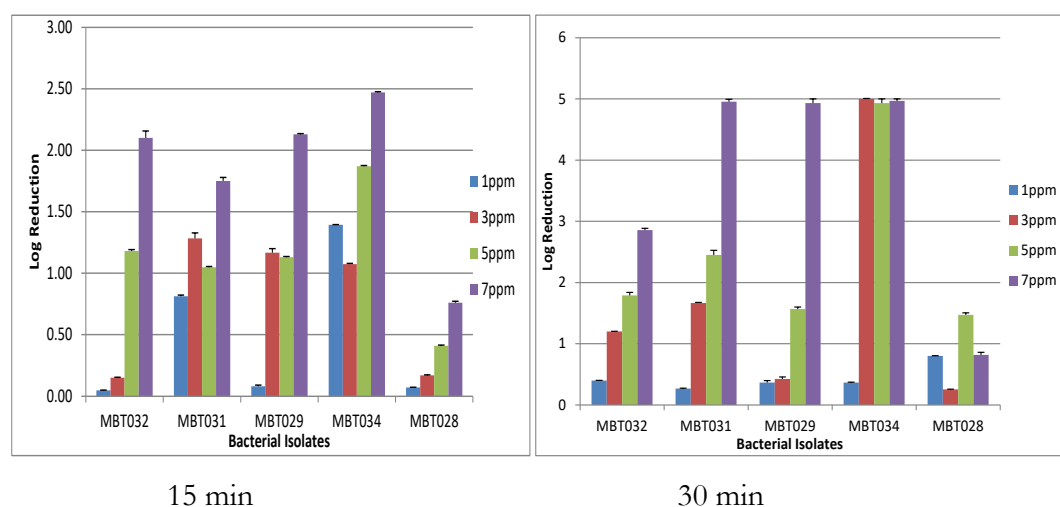
Figure-11: MBT 034 Phylogenetic tree

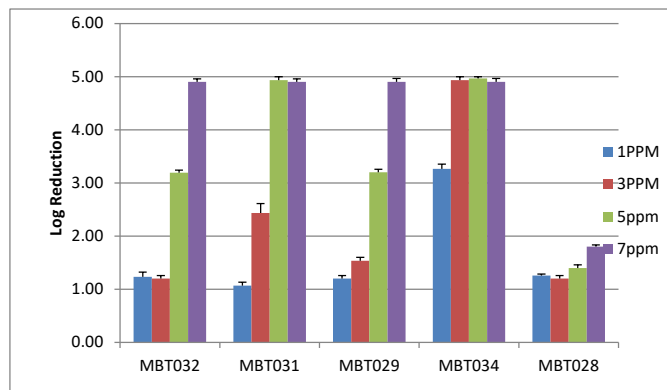
Based on 16S rDNA analysis strain MBT028 and strain MBT029 show maximum homology with M2683209.1 *Bacillus cereus* strain bp122 and KX082775.1 *B. cereus* strain KR9 and identified as *B. cereus* MBT028 and *B. cereus* MBT029 respectively. Based on 16S rDNA analysis strain MBT031 show maximum homology with MK503712.1 *Bacillus tropicus* strain S12 and identified as *B. tropicus* MBT031. Similarly based on 16S rDNA analysis strain MBT032 show maximum homology with MN044865.1 *Bacillus paramycoides* ANK10 and identified as *B. paramycoides* MBT032. Based on 16S rDNA analysis strain MBT034 show maximum homology with MW629803.1 *Pseudomonas aeruginosa* CPOJP4 and identified as *P. aeruginosa* MBT034.

3.5 Microbial Inactivation Experiments

3.5.1 Microbial Inactivation with Chlorination

Microbial inactivation for the isolated strains was performed using chlorine at different concentration. The results of chlorination at different concentration of time for all bacterial isolate are shown in (Fig 12).





45 min

Figure-12: Log reduction at different concentration of chlorine at 30 min and 45 min

3.5.2 Microbial Inactivation with Activated Carbon and Nano Composite

All strain showed less than 1 log removal at contact time of 5 min. Increased in contact time at 30 min MBT029 shows log 5 removal while MBT028 and MBT032 showed 3 log removal. Almost all strains showed maximum reduction at contact time of 30 min. Results are shown in (Fig13).

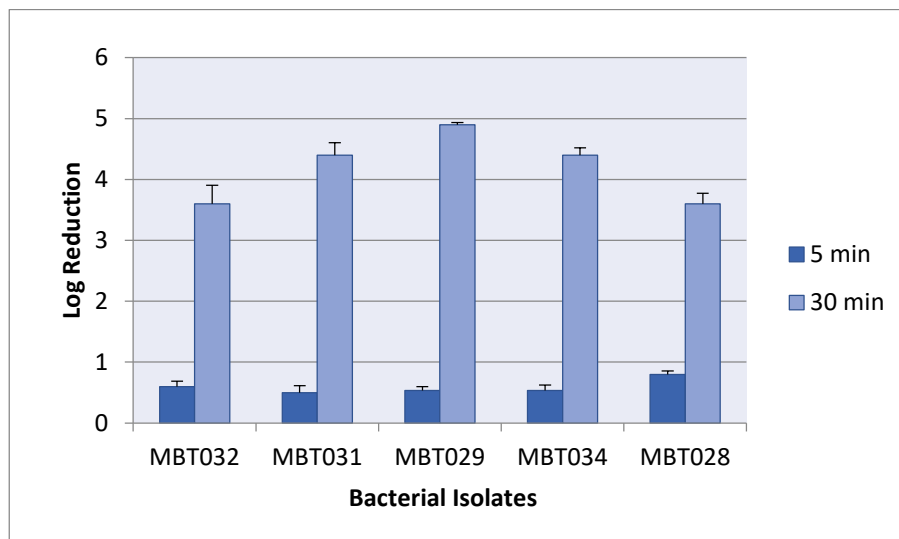


Figure-13: Log reduction with Ag-NPs/AC composite at contact time of 5 and 30 min

3.5.3 Microbial Inactivation with Chlorine and AgNPs/AC Composite

Low dose of chlorine 0.5ppm was used and then treated with AgNPs/AC composite. At contact time of 5min less than 1 log removal was observed while at contact time of 30min maximum log reduction was observed for all strains. Results are shown in (Fig 14).

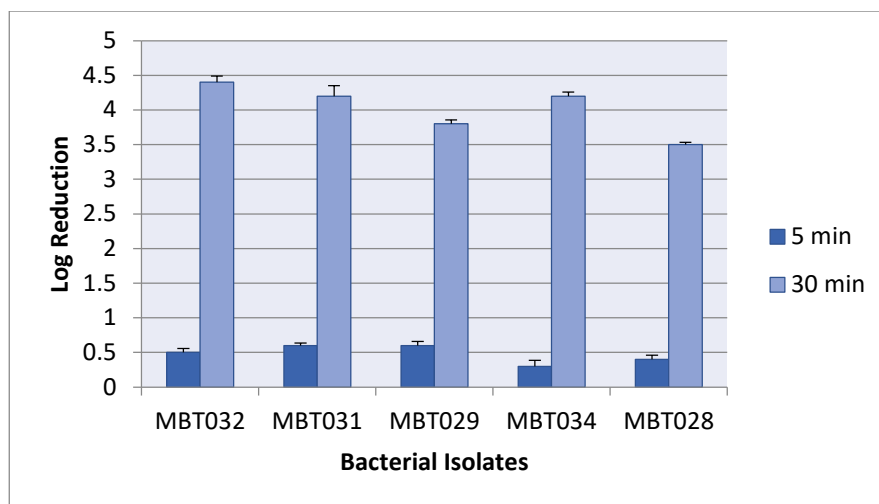


Figure-14: Log reduction with low chlorine concentration and AgNPs/AC composite at contact time of 5 and 30 min

3.5.4 Microbial Inactivation with Activated Carbon

All strains show log reduction but minimum as compared with other treatments. Results are shown in (Fig 15).

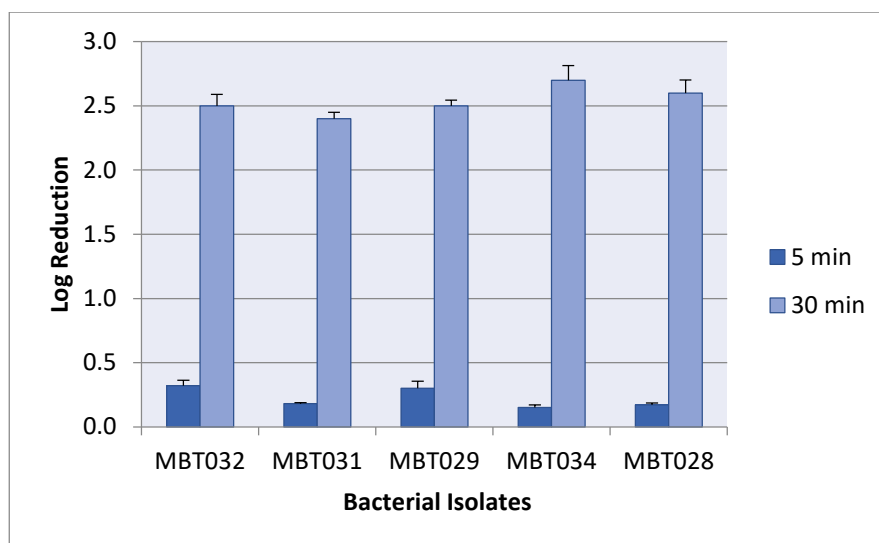


Figure-15: Log reduction with activated carbon at 5 and 30 min

3.5.5 Microbial Inactivation through Column Experiment

All strains show maximum log reduction at contact time of 30min. The column experiment also shows significant results as water pass steadily through column so microbes are adsorbed in column with increase in contact time. Results of column experiments are shown in (Fig 16).

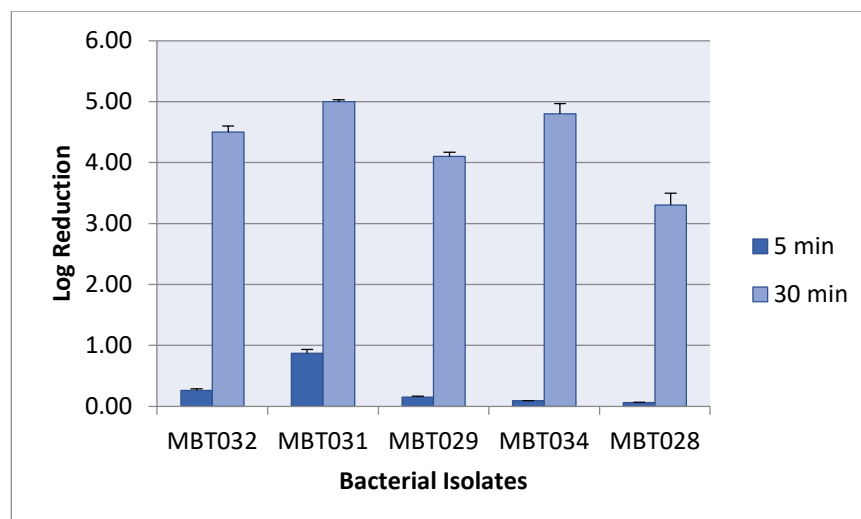


Figure-16: Log reduction in column experiment

3.6 Statistical analysis

Table-5: ANOVA for different microbial inactivation experiments

Model	Mean square (error)	Mean square (time)	Mean square (Strains)	Strains ×time	Grand Mean (GM)	Critical Value (CV)
AgNPs/AC	0.0144	0.8088	84.0013**	1.2955**	2.3267	5.16
Cl ₂ and nanoparticles	0.0075	0.4292**	99.372**	0.2262**	2.3000	3.76
AC only	0.0103	0.0133**	33.4963**	0.0147**	1.3833	7.32
Column Experiment	0.024	1.043**	108.68**	0.411**	2.4033	6.42

The ANOVA results are demonstrated in (Table 5) demonstrated the statistically significant results of all bacterial inactivation experiments.

Table-6: ANOVA at different time and concentration of chlorine

Model	Mean square (Error)	Mean square (time)	Mean square (Strains)	Concentration ×time	Grand Mean (GM)	Critical Value (CV)
MBT032	0.0305	10.1194**	16.0487**	0.5335**	1.5919	10.98
MBT031	0.0097	14.2934**	13.8525**	3.1589**	2.3514	4.19
MBT029	0.0053	8.1654**	17.0814**	1.564**	2.05	3.56
MBT034	0.034	29.933**	9.1238**	2.0756**	3.4397	5.36
MBT028	0.03126	3.80679**	1.44114**	0.24313**	0.8169	21.64

The ANOVA (Table 6) demonstrated the statistically significant results of all bacterial strains. MBT034 and MBT031 showed more significant results as compared to other strains.

4. DISCUSSION

The pH of samples ranged from 6.2 to 7.7. Sampling station 2 showed lowest pH while sampling station 10 showed highest pH. According to WHO guideline pH of water samples ranged 6.5 to 8.5. pH determines either the sample is acidic or basic. Mostly samples pH was found according to WHO but some sample have slight less pH than WHO guidelines. Acidic water is not suitable it causes corrosion of metals pipes in pumping system and alkaline water shows that disinfectant by products are present in water (Rahmanian *et al.*, 2015). The temperature of samples ranged 18 to 29.5 °C. Sampling station 12 showed lowest temperature and station 3 showed highest temperature. The microbes that were pathogenic to animals and humans are mesophilic and this temperature is suitable for bacterial growth. The TDS values ranged to 143 to 1620ppm. Sampling station 10 showed highest TDS while 5 showed highest TDS. Water with TDS value more than 1000 is unsafe for human use and TDS value more than 1200 are unacceptable. Only one sample has TDS more than 1000. Jindal *et al.*, (2011) reported that high level of TDS may be due to waste water discharges and other human activities along the water sources. Water with high TDS causes an unfavorable physiological reaction in the user (APHA, 2017).

The electrical conductivity of samples ranges from 243 to 1342. Sampling station 2 showed lowest EC while sampling station 7 showed highest EC. Dissolved solids present in water such as chloride, calcium helps in carrying current through it. The limit of EC according to WHO is 1000 $\mu\text{S}/\text{cm}$. Sampling stations were found near agricultural and sewage sites due to which huge difference was found in TDS and EC of samples. Similar results were reported by Scatena *et al.*, (2000) many factors affect the electrical conductivity of water such as agricultural and industrial activities affect the mineral content of land but conductivity have overall no bad effect on human health.

The current study showed that drinking water sources of study site were unprotected and highly contaminated with fecal coliform. 14 of samples were heavily contaminated with bacteria and have MPN index of more than 100. While 11 sample were less contaminated. None of water sample met the WHO standard for coliform i.e., 0/100ml coliform/100 ml of water sample (WHO, 2017). Similar results were reported by AJK EPA (2018) in Kotli city in which 86.6% bacterial contamination was found in different samples of drinking water which were collected from different water sources. The occurrences of indicator bacteria specify the possible incidence of fecal contamination in drinking water. Emmanuel *et al.*, (2009) demonstrated that coliform presence in water indicates presence of fecal matter, also indicator of potential pathogenic contamination and cause intestinal illness such as dysentery, cholera, nausea etc.

Based on 16S rDNA studies the bacterial isolates were identified as *B. cereus* MBT028, *B. cereus* MBT029, *B. tropicus* MBT031, *B. paramycoides* MBT032, *P. aeruginosa* MBT032. Two strains *B. cereus* MBT028, *B. cereus* MBT029, were genetically same but their morphology and biochemical identification showed that both were different from each other.

The initial count of *B. paramycoides* MBT032, *B. tropicus* MBT031, *B. cereus* MBT029, *P. aeruginosa* MBT034 and *B. cereus* MBT028 is 7.5×10^6 , 4.5×10^6 , 4.0×10^6 , 6.0×10^6 and 4.5×10^6 respectively. *B. paramycoides* MBT032 and *B. tropicus* MBT031 at 45min contact time and chlorine dose of 1mg/L showed CFU/ml 5.4×10^5 and 4.0×10^4 and at 7ppm chlorine and contact time 45 there was almost complete reduction of microbes. *B. cereus* MBT029 and *B. cereus* MBT028 at showed 1.3 log reduction at 45min contact time and CFU/ml was 1.9×10^5 and 2.4×10^5 chlorine dose 1ppm and at 7ppm chlorine and contact time 45 complete log removals *B. cereus* MBT029 while *B. cereus* MBT028 showed 2 log removal at 7ppm which was least removal observed for any strain. *P. aeruginosa* MBT034 showed 3 log reduction at 1ppm and contact time of 45min at 45min and CFU/ml 3×10^3 . Among all tested strain at *P. aeruginosa* MBT034 showed complete reduction

at 3ppm concentration which demonstrated that strain has low resistance to chlorine while *B. cereus* MBT028 showed 2 log removal at 7ppm which depicts that strain is more resistance to chlorine.

Denisova *et al.*, (2014) observed similar results that at low chlorine concentration number of microbes decrease with 0.63 log while at higher chlorine concentration of 5mg/L number of microbes decreases to 90% after 30s of contact time and researcher also observed that contact time more than one hour do not increase inactivation rate. Lambert *et al.*, (2000) explained that *P. aeruginosa* at 1mg/L dose shows 2 log reduction and with increase of dose to 5mg/L, 5 and 6 log reduction was achieved.

In current study when Ag-NPs/AC composite were used combine against water borne pathogens all strains shows maximum log reduction at contact time of 30min. Ag-NPs/AC composite use is helpful since AC alone was not work effectively for microbial filtration and silver nanoparticles alone cannot be used in a column treatment as it requires a substrate to be efficient. Jawad *et al.*, (2020) also observed the same results and suggested that silver nanoparticles were used as water disinfectant to remove bacteria and they showed strong antibacterial activity against different microbes like *E. coli* and *P. aeruginosa* with different concentration.

In current study activated carbon blank experiment showed less log reduction of microbes as compared with other experiment. Mostly strains showed log reduction of 2 at maximum contact time and no more reduction was observed with increase in contact time. El-aassar *et al.*, (2013) also performed same experiment and described that activated carbon when used as blank minimize the bacterial count but not eradicate at all as compared to other experiment when used with nanoparticles. Siwila *et al.*, (2019) performed experiment with gravity driven wooden filters which are attached with AC for potable water treatment and results indicate that 99% bacteria were removed. Liu *et al.*, (2017) used granular activated carbon and noted that GAC remove different soluble microbial products in 60% water in addition it also minimizes the disinfection by products more than 70%. In this way GAC is an efficient method to remove DBPs byproducts in water.

Result of ANOVA for AgNPs/AC experiment showed significant results ($p \geq 0.01$). The chlorine and nanocomposite showed highly significant results ($p \leq 0.01$). The AC and column experiment results showed significant results. Results of ANOVA in chlorination experiment of for all five strains at different concentration and time showed highly significant results.

5. CONCLUSION

The study was conducted to monitor drinking water quality status of District Kotli, AJ&K and to observe the efficiency of different inactivation methods for isolated strains from drinking water distribution network. Five bacterial strains, isolated and identified by biochemical and molecular characterization were *B. cereus* MBT028, *B. cereus* MBT029, *B. tropicus* MBT031, *B. paramycoides* MBT032, *P. aeruginosa* MBT034. These isolates were mostly opportunistic pathogen. MPN method showed that 56% of the totals samples were heavily contaminated with coliform, fecal coliform and *E. coli* with MPN index greater than 2400. Not a single sample met the WHO standard of 0CFU/100 ml. Disinfection studies using Chlorination, NPs assisted Activated carbon, and low chlorine concentration AgNPs/AC, column experiment and blank AC for selected strains were used in the bench scale studies. Some isolate required high dose of chlorine due to resistance but high dose of chlorine released DBPs. *P. aeruginosa* MBT034 showed complete reduction at 3ppm chlorine concentration while *B. cereus* MBT028 showed least log reduction even at 7ppm chlorine concentration. Activated carbon blank experiment showed less log reduction of microbes mostly strains showed log reduction of 2 at maximum contact time and no more reduction was observed with increase in contact time. Ag-NPs/AC composite experiment and column experiment showed maximum reduction of all strains as compared to chlorination and there was no risk of byproducts.

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A comparative in-situ and ex-situ study for the plastic bio-removal using indigenous soil bacterial strains from Kotli Azad Jammu & Kashmir

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Abstract

The present study was designed to investigate biodegradation potential of indigenous micro fauna against plastics based protective masks, gloves, shopping bags and biodegradable plastic carriers. *Acinetobacter bumanii* MBT024 and MBT027, *Bacillus anthracis* MBT025 and *Bacillus subtilis* MBT026 were isolated, purified and characterized using morphological, biochemical, physiological and 16S rDNA analysis. Shake Flask method was used to conduct biodegradation studies on polypropylene (PP), polyethylene (PE), locally available degradable shopping bags, gloves and masks. Scanning electron microscopy (SEM) for the deteriorated materials' exterior modifications and weight loss analysis was adopted to observe the biodegradation efficiency. A completed biodegradation of biodegradable shopping bags was observed when subjected to *B. anthracis*. Masks and medical gloves showed 39% and 10.21% biodegradation respectively using *A. bumanii* MBT027. In the case of PP, a biodegradation of 19% was observed with *B. anthracis* MBT025, whereas PE demonstrated approximately 29% biodegradation with the same strain of *B. anthracis* MBT025. In this study, when compared to other isolated bacterial strains, *B. anthracis* has played a great role in the biodegradation of plastics, while least biodegradation was observed with *B. subtilis* MBT026 about 4.13 percent. The experimental setup was also performed for the in-situ biodegradation of plastics. In the field method, the highest biodegradation potential was observed for PP, PE and biodegradable shopping about 16.16 percent, 16.80 percent and 16.68 percent respectively. The highest biodegradation potential for masks and gloves was observed at about 23 and 22 percent respectively. The results laid the foundation of the indigenous bacterial strains for bio degradative studies and their potential to mitigate the plastic and well as micro-plastic pollution.

Water Quality Status of Drinking Water Sources Muzaffarabad City and Neelum Valley, AJK

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Abstract

Access to adequate and safe drinking water is a human right and its provision is the responsibility of the state. This responsibility has been conferred through the Constitution of Islamic Republic of Pakistan, Vision 2025, National and Provincial Drinking Water Policies and International Commitments such as Sustainable Development Goals (SDGs). Safe drinking water is basic necessity for human survival and the development of society. Monitoring of drinking water quality is a first step towards its management. Pakistan Council of Research in Water Resources (PCRWR) with the collaboration of AJ&K Water Sector Stakeholders has conducted a water quality assessment survey of drinking water sources, during 2021-2023. The American Public Health Association (APHA) Standard Methods were followed for sampling and testing aesthetic, physico-chemical and bacteriological parameters of 42 filtration plants, 17 water supply and 50 spring water sources in Muzaffarabad City and Neelum Valley, AJ&K. It was found that 12% of water samples of the filtration plants, 88% of the water supply scheme and 92% spring water sources exceeded the safe limit of National Standards of Drinking Water Quality (NSDWQ). Overall analysis identified three major water quality problems in drinking water sources i.e. 43 % Total Coliforms, 31 % E.coli and 37 % turbidity in the current research report. PCRWR with Local Government and PHED regular monitoring has improved the safe water supply of drinking water sources in Muzaffarabad City whereas, due to drinking majority of the public from unsafe spring water sources has increased the load of the water borne diseases i.e. diarrhea, dysentery and typhoid patients in the Government Hospitals that has reported by the Health Department, AJ&K during 2019 to 2023. The present report is based on monitoring outcomes of drinking water sources in Muzaffarabad City and Neelum Valley, AJ&K. It provides an insight to the current situation of drinking water quality, underlying issues and suggests the way forward to tackle the issues. It would also provide a baseline issue for setting realistic targets to be achieved by 2030.

Water, Sanitation and Hygiene (WASH): Emphasizing the Value of Water in Promoting Sustainability

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Abstract

Water, which is the essence of lifestyles, holds an inestimable cost in our international. It has into more and more vital while regarded through the lens of sustainability in terms of water, sanitation, and hygiene (WASH). This paper explores the interplay among these factors and their vital function in fostering a sustainable future. Access to safe water, sanitation, and hygiene are primary human rights, but many human beings do not have these properly. The WASH application ambitions to attempt to accept access to these fundamental services. Water pricing goes beyond determining its monetary importance; It consists of expertise of its vital role in numerous components of lifestyles from agriculture to cultural traditions and its critical position in environment fitness. Improved sanitation can lessen the unfolding of sickness and shield our water from pollutants. Effective hygiene practices, along with ordinary hand washing, can extensively reduce the unfolding of waterborne illnesses. Investing in WASH is not the most effective morally responsible and economically sound decision. For each dollar invested in WASH, there may be a 4-fold benefit in the form of prolonged productivity and reduced healthcare costs. In addition, it contributes to numerous sustainable development goals associated with fitness, education, and gender equality. In summary, spotting the value of water and investing in WASH are essential steps closer to accomplishing sustainable development and equity. This permits us to shield the health and well-being of humanity and the planet and underscores the actual value of water.

Keywords: Water Conservation, Sanitation Infrastructure, Hygiene Practices, Sustainable Development, Water Value Assessment

Water, sanitation, and hygiene issues in Pakistan: Contribution of Engineers in Sustainable Development.

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Abstract

Water, Sanitation, and Hygiene (WASH) are essential components of sustainable development and public health that have an effect on many different areas. Pakistan is facing challenges related to water scarcity, inadequate sanitation facilities, and poor hygiene standards and engineers play important role in addressing these issues. This abstract examines the issues related to WASH facing by Pakistan and highlight the role of engineers in devising and implementing effective solutions. Pakistan faces a challenge in the water scarcity and contamination both pose serious risks to the public' health. The problem is made worse by an increasing population and changes in water supply brought on by climate change. Engineers can contribute by designing and implementing innovative water management systems including rainwater harvesting, efficient irrigation techniques, and the development of sustainable water sources. Sanitation is a major problem in Pakistan, a large section of the population has not access to proper sanitation facilities. Open defecation is common in many areas leading to the spread of waterborne diseases. Engineers may help by designing and executing sanitary infrastructure that is suited to the unique requirements of various communities, such as improved toilet facilities, waste management systems, and sewage treatment plants. In many regions of Pakistan, there is a deficiency of knowledge and education regarding the importance of hygiene habits in mitigating the spread of illnesses. Engineers can work with public health experts in designing and implementing hygiene promotion programs, to incorporate technology that facilitates appropriate handwashing, water purification, and waste disposal. This includes the development of small-scale WASH projects that promote sustainability. In conclusion, engineers must make strategy to address Pakistan's WASH issues. Engineers can contribute to the development and implementation of sustainable solutions that improve access to water, sanitation, and hygiene practices. This abstract highlight the significance of cooperative efforts including engineers, policy makers, public health specialists, and local communities to achieve a better future for Pakistan.

Keywords

Sustainable development, Water, Sanitation, Hygiene, Inadequate sanitation facilities, disease.

Water Quality Assessment of Educational Institutions in Different Districts of The Baltistan Region

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Abstract

Water and life are inherently connected, as water is crucial for supporting all forms of life. The quality of drinking water is of paramount importance for human well-being and environmental preservation. In this research, the focus was on assessing the quality of drinking water in several villages of Baltistan. Various physical and microbiological parameters were examined in tap, filter, and tank water sources. The investigation revealed that drinking water sources in the region were significantly contaminated with waste coliform microbes, posing potential health risks. It is essential to evaluate the factors influencing the quality of drinking water from these sources to mitigate waterborne diseases and associated health hazards. Drinking water samples from different villages in Baltistan were collected and analyzed for physical and microbiological parameters, following the guidelines set by the World Health Organization (WHO). The analysis indicated that nearly all water samples exceeded the recommended values outlined in drinking water standards. Specifically, 20% of the samples showed higher hardness values than the prescribed limits. Microbiological results revealed the presence of fecal coliforms in 80% of the total samples. The assessment of Baltistan's water quality utilized coliforms (total coliform and fecal coliform) as indicators, along with physical parameters such as pH, conductivity, temperature, and total dissolved solids (TDS). The study identified common diseases in the area, including gastroenteritis, diarrhea, typhoid, and skin problems. Addressing the contamination and ensuring the quality of drinking water in Baltistan is crucial for safeguarding the health of the residents and protecting the environment. Implementation of measures to improve water treatment and sanitation practices is imperative to mitigate the risks associated with waterborne diseases.

Keywords: water quality, physical parameters, biological parameter, TDS, PH, Temperature, coliform, Baltistan.

Removal of arsenic by electrocoagulation and filtration

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Abstract

In this current study electrocoagulation (EC) has been assessed as a treatment technology for the removal of arsenic from water. Laboratory scale experiments were carried out using two electrode materials, i.e., aluminum and iron. EC combined with filtration was designed and operated in different conditions (pH, flow rate, arsenic concentration, and current). The arsenic concentration was reduced to less than 10 mg/L by electrocoagulation and filtration using both aluminum and iron electrodes. The comparative analysis of arsenic removal by using EC with ferric electrode and aluminum electrode was conducted and it was investigated that electro-coagulation setup by using aluminum electrodes at optimized condition 10A current, natural pH at 1liter/min flow rate give the best results for arsenic removal within five minutes as arsenic removal was 98% which meet the WHO guidelines.

Keywords: electrocoagulation, arsenic, filtration

Algae-Based Bismuth Nanoparticles and their Antibacterial Activity Against Multi-Drug Resistant *Salmonella Typhi*

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Abstract

Drug-resistant pathogenic bacteria are becoming frequent throughout the world. They have been posing a significant challenge to scientists and researchers. Among many is *Salmonella Typhi* which is an example of a multi-drug-resistant bacteria. In this research, the bismuth nanoparticles were

successfully prepared using the green synthesis method using microalgae *Chlorella vulgaris* biomass. The nanoparticles were characterized by X-ray diffraction (XRD) and Fourier transform infrared (FTIR). The XRD confirms the cubic morphology of nanoparticles, and the results of FTIR show the presence of the Hydroxyl group on the surface of the nanoparticles, which possess high antibacterial activity. The antibacterial activity of bismuth nanoparticles was measured via the inhibition zone on the strain of *Salmonella enterica* serovar which is multi-drug resistant (MDR) *Salmonella Typhi*. The conclusive evidence shows the formation of 20 mm maximum inhibition zone at a concentration of 15mg of bismuth nanoparticle. The synthesized bismuth nanoparticles show antibacterial activity against MDR *S. Typhi*; hence, the study proves bismuth nanoparticles can be used against MDR *S. Typhi*.

Keywords: *Salmonella Typhi*, *Chlorella vulgaris*, bismuth nanoparticles

Assessment of Healthcare Cost in the Urban Cities of Sindh

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Abstract

The evaluation of healthcare expenses in Pakistan's urban areas offers a critical look at the financial consequences of receiving medical care. In the framework of urban cities, Hyderabad, Sukkur, Multan, Faisalabad, and Lahore. It is critical to comprehend the financial implications of healthcare in these areas, where certain populations suffer particular health difficulties. This study explores the complex web of healthcare costs, including direct medical costs, hospitalization costs, lost

wages, and other associated expenses. This study assesses the cost of healthcare in Pakistan's urban cities through analysis using the Cost of Illness (COI) methodology. The data was collected through surveys and interviews among households in the selected cities. Primary data was collected to estimate the Waterborne Disease cost for four diseases (Typhoid, Diarrhea, Dysentery, and Suspected Hepatitis-A) in Hyderabad and Sukkur. The data in Pak Rupees indicates the financial burden associated with each disease in the respective districts. In Hyderabad, Typhoid costs 82,400, Diarrhea costs 171,150, Dysentery costs 48,100, and Suspected Hepatitis costs 10,000. In Sukkur, Typhoid costs 197,900, Diarrhea costs 186,050, Dysentery costs 155,850, and Suspected Hepatitis costs 56,200. This study offers important insights for stakeholders in healthcare and policymakers by looking at the financial burdens caused by healthcare services. The results support well-informed decision-making processes that aim to improve healthcare efficiency, cost, and accessibility in urban environments, aiming to promote socioeconomic well-being and better health outcomes.

Keywords: Healthcare costs; Healthcare expenditure; Socio-economic Well-being, Urban areas, Pakistan.

Introduction

Freshwater bodies are crucial for sustaining life, supporting ecosystems, and meeting various human needs, including drinking water supply. However, these invaluable resources often face contamination from various sources, including wastewater discharge. Discharging untreated or inadequately treated wastewater into freshwater bodies poses significant challenges to public health, environmental sustainability, and socio-economic well-being. There are two types of water sources in the ecosystem: point source and non-point source and point sources are easily identifiable and discharged into water directly to be easily measured at drainage pipes (Mastoi, Channa et al. 2022), and the contaminated water causes waterborne diseases. According to these researchers (Gupta and Misra 2019) the effects of ingesting polluted water on health are widely recognized but often overlooked, particularly in rural regions. Globally, infectious illnesses such as waterborne diseases constitute the leading cause of death among children under the age of 5, and annually, more individuals succumb to unsafe water than to all types of violence combined, including warfare (World Health Organization, 2002). Various waterborne illnesses, including skin allergies, kidney failure, circulatory problems, gastrointestinal distress, cancer, blue baby syndrome, nervous system problems, and bone weakening, are brought on by contaminated water. It's reported that every year, 53,000 children pass away from various watery illnesses, most commonly diarrhea. Due to unfit water quality, around 800 children die from diarrhea every day (Fida, Li et al. 2023).

Various water sources like lakes, groundwater, and rivers are contaminated by physical processes due to anthropogenic activities (Daud, Nafees et al. 2017). The discharge of municipal sewage and industrial wastewater is the primary cause of waterborne disease in Pakistan (Daud, Nafees et al. 2017). In Pakistan, diarrhea is the most common cause of mortality for infants and children, and every fifth person has a disease or illness brought on by contaminated water (Daud, Nafees et al. 2017). The wastewater discharge into the Indus River causes a waterborne disease burden, and this burden impacts the healthcare cost of households.

Serious health problems have been caused by contaminated water; these water reduced human health, higher health care expenses, and higher production losses are all possible consequences of contaminated water (Butt and Khair 2016). Every year, an estimated 250,000 children die due to diarrhea, and the frequency of waterborne illness has increased the medicinal cost among the rural communities (Malik, Yasar et al. 2012). Due to inadequate sewage disposal systems and water supplies in rural regions, surface runoff and infiltration via pastures, as well as leaks in the systems, are the main causes of water contamination (Malik, Yasar et al. 2012). This research aims to

investigate the healthcare costs associated with wastewater discharge into freshwater bodies and their socio-economic impacts. Specifically, the study focuses on assessing the disease burden and economic losses attributed to the compromised quality of drinking water resulting from such contamination. Understanding the magnitude of these impacts is essential for policymakers, public health authorities, and stakeholders to develop effective strategies for mitigating risks, safeguarding public health, and promoting sustainable water management practices.

MATERIALS AND methods

Study Area

The study area for this research comprises two major cities situated along the Indus River in Pakistan: Hyderabad and Sukkur (figure 1). These cities rely on surface water from the Indus River for their drinking water needs. Hyderabad is near the Kotri Barrage, which regulates water flow on the Indus River, while Sukkur is positioned near the Sukkur Barrage, another key infrastructure on the Indus River.

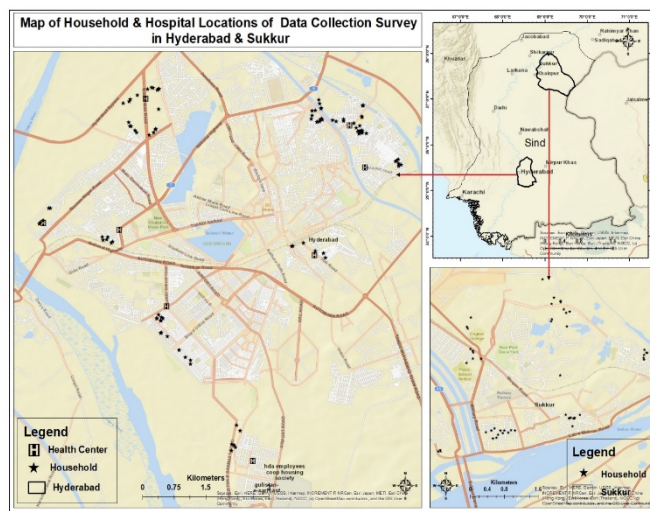


Figure 7: Study area.

Data Collections

To accomplish the study objectives, 200 households were surveyed from two cities using a random sampling method, and secondary data was collected from the District Health Office (DHO). In these two sampling techniques were used (1) Sample Random Sampling Method, in this method random sample were collected by using formula:

Secondary data of aggregated/reported cases of diarrhea from January 2022 to December 2022.

$$\text{Sample Size} = \frac{(Z\text{-Score})^2 \times \text{StdDev} \times (1 - \text{StdDev})}{(M.\text{Error})^2}$$

$$Z\text{-Score} = 1.96$$

$$\text{Std.Dev} = 0.5$$

$$\text{Margin of error} = 10\%$$

Table 7: Aggregated cases, confidence level, margin of error, and sample size for Hyderabad and Sukkur.

	Hyderabad	Sukkur
Aggregated Cases	92,276	33,952
Confidence Level	95%	95%
Margin of Error	10%	10%
Sample Size	96	96

Table 1 shows Hyderabad and Sukkur's aggregated cases, confidence level, margin of error, and sample size. Data was collected within the city using cluster-wise sampling method based on secondary data provided by the District health authority of each district hospital. We divided 100 sample sizes for primary data collection among the top 8 to 10 hospital areas, which are the top reported aggregated diarrheal cases within the city. Tables 2 and 3 show that in Hyderabad, we selected the top 8, and in Sukkur, top 10 areas where diarrheal cases were maximum.

Table 8: Facility wise diarrheal reported cases >5 Hyderabad.

Major City	Facility Code	Facility Type	Facility Name	Aggregated Diarrhea2022	HH Survey
HYDERABAD	213001	THQ	SGH Paretabad	13857	34
	213016	THQ	SGH Qasimabad	8231	20
	213010	HOSP	SGH Shah Bhitai	5903	16
	213005	THQ	SGH Kohisar Latifabad	2666	6
	213018	BHU	BHU Sehrish Nagar	2481	6
	213019	HOSP	Services Hospital Hyd	2383	6
	213009	THQ	SGH Hali Road	2357	6
	213002	THQ	SGH Peads Hospital Tanga Stand	2021	6
				39,899	100

Table 9: Facility wise diarrheal reported cases >5 Sukkur.

Major City	Facility Code	Facility Type	Facility Name	Aggregated Diarrhea2022	HH Survey
SUKKUR	244113	THQ	GH Bagirji	8860	40
	244099	RHC	RHC Bachal Shah Miani	1705	9
	244069	UD	Govt Barrage Dispensary	1403	12
	244108	UHC	UHU Azizabad	1205	6
	244067	CD	ADC Dispensary	1198	6
	244153	MD	MC Female Dispensary	1059	9
	244159	GRD	ED Makka Goth	776	3
	244125	MH	Maternity Home Tamachani	538	3
	244121	MCH	MCH Fatima-tu-Zuhra	469	6
	244131	GD	GD Microwave Colony Sukkur	465	6
				17,678	100

Development of Questionary for primary data collection.

The questionnaire was categorized into four sections (1) Demographic, Family Status and Health Facilities. In this section questions related to the Gender of the Respondent, Age of the Respondent, Highest level of Education in the Household, Source of Income, Monthly Income, Family wealth status, Family Type, Family size (age group wise), Living time period in this area, prefer to visit Healthcare facilities, Satisfaction with diagnosis process, Time travel to reach facilities. (2) Water sources and Services, in this section, questions related to Drinking water sources & storage, Domestic water sources and storage, Agriculture practice and water scarcity, Satisfaction with drinking water quality, home remedies for water treatment, and Mortality rate due to water-borne diseases. (3) Overall Healthcare Cost, In this section, questions about Service Costs (paying for drinking water & domestic water), Social Costs (loss of earnings due to patient's care & self-care), Direct Costs (Doctor fees, medicines, hospital charges and lab charges), Indirect Cost (special food and transportation charges) and (4) Waterborne diseases burden and caring cost, In this section question related with No of Affected Households with waterborne diseases, Positive Cases (age group wise), Awareness, Waterborne diseases cost.

Healthcare Cost

To estimate waterborne diseases, the WBDC was further divided into two categories: Direct Healthcare Cost (DHC) and Indirect Healthcare Cost (IHC). The DHC includes the doctor consultation fee, medicine cost, laboratory cost, and hospital expenditure. The IHC is composed of loss of work and daily wage loss either for the patient's care or for the person who looks after the patient, transportation costs, and special food for the patient.

Formula: $WBDC = DHC + IHC$

RESULTS

Level of Education

Figure 2 shows that the highest level of education attained by respondents in Hyderabad is a bachelor's degree, constituting 25%. Conversely, in Sukkur, Secondary School Education represents the highest level of Education attained by 17% of respondents, as shown in Figure 3.

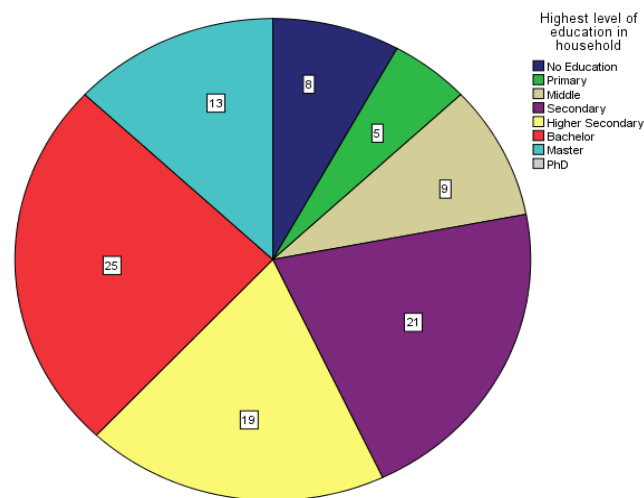


Figure 8: Highest Level of Education per Household in Hyderabad.

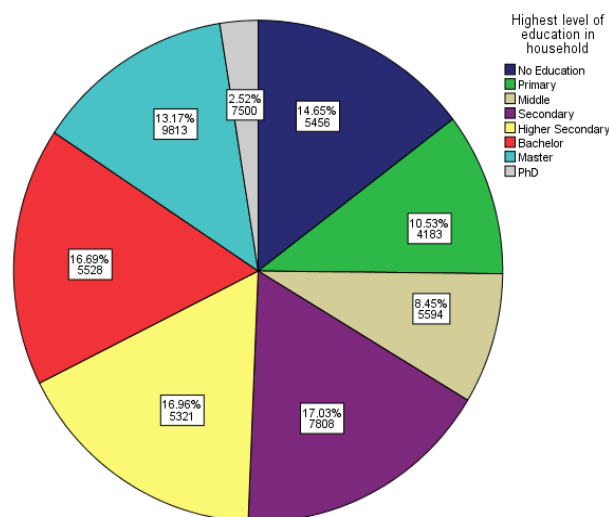


Figure 9: Highest Level of Education per Household in Sukkur.

Family Type

Family type is categorized into two parts joint and Independent. Figure 4 shows that in Hyderabad, 52% of families are categorized as independent, whereas in Sukkur, 49% of families are classified as joint, as shown in Figure 5.

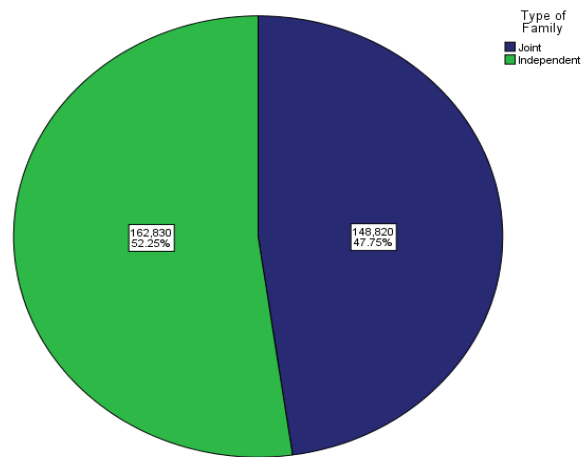


Figure 10: Family Type in Hyderabad.

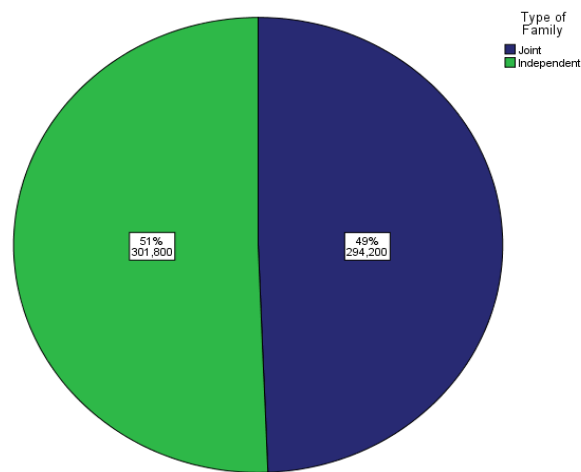


Figure 11: Family Type in Sukkur.

Prefer to Visit Health Facilities

Government Hospitals and Private Hospitals are the two main sources of health treatment in this area; we categorized the Preferred Visit Health Facilities by the community into three categories. 1. government hospitals, 2. Private Hospitals, and 3. Both (Government and Private). Figure 6 shows that in Hyderabad, 59% of respondents prefer Government Hospitals, while in Sukkur, 42% prefer Private Hospitals, as shown in Figure 7.

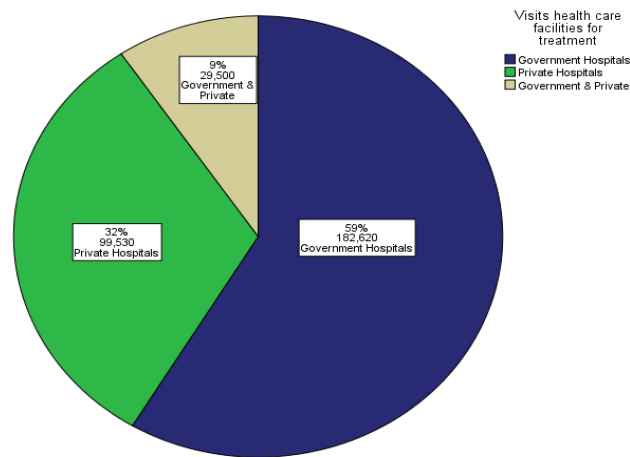


Figure 12: Prefer to Visit Health Facilities in Hyderabad.

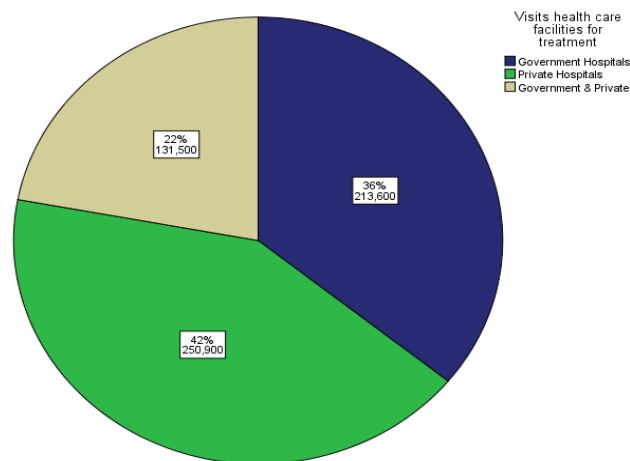


Figure 13: Prefer to Visit Health Facilities in Sukkur.

Sources of Drinking Water

When choosing drinking water sources, availability, easy access, and affordable price. Sources of drinking water are described in 1. Multiple sources of drinking water, 2. Surface water (Tap water), 3. Ground Water (Hand Pump, Dug well, or motor pump), and 4. Filtered Water (Filter plant or Cane water). Figure 8 shows that in Hyderabad, 60% of respondents are using surface water for drinking purposes after applying some types of remedies for water treatment. In Sukkur, 69% of people prefer Ground Water (Hand Pump, Dug well, or motor pump) for drinking purposes, as shown in Figure 9.

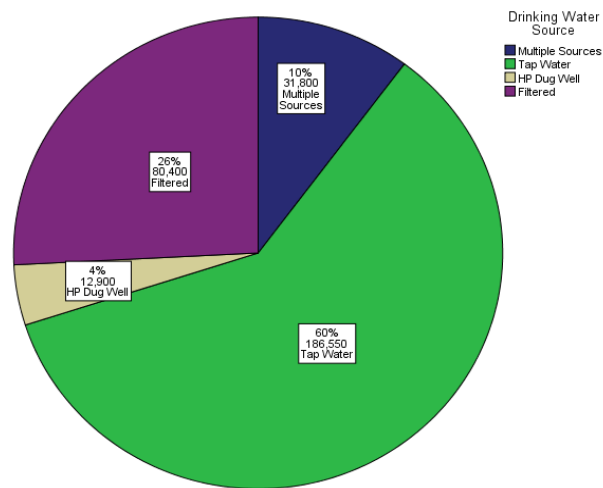


Figure 14: Source of drinking water in Hyderabad.

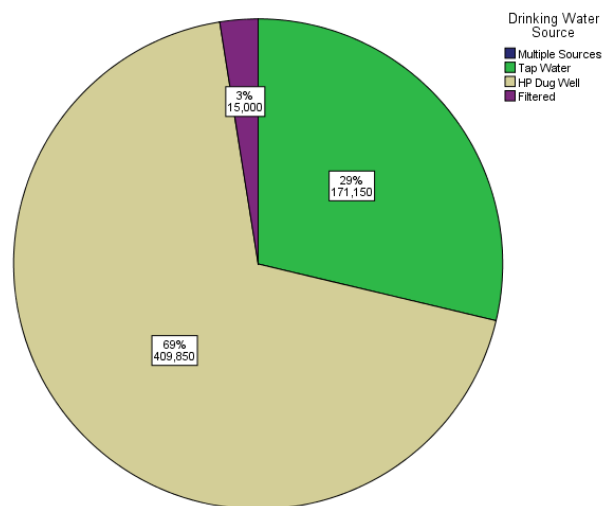


Figure 15: Source of drinking water in Sukkur.

Satisfaction with Drinking Water Quality.

The quality of drinking water matters to the waterborne disease burden in households, and awareness about water quality decreases it. To estimate the awareness of the community, we asked the question, “Is surface water drinkable or not” in this area? Figure 10 shows that in Hyderabad, 73% of people replied that “Yes” surface water is not drinkable, meaning the majority of the Hyderabad community is satisfied with drinking water quality. Meanwhile, 64% of Sukkur’s respondents are not happy with the quality of their drinking water, as shown in Figure 11.

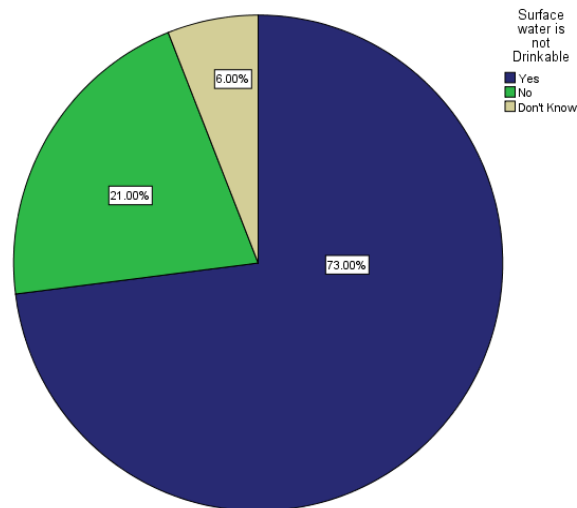


Figure 16: Satisfaction with Drinking Water Quality in Hyderabad.

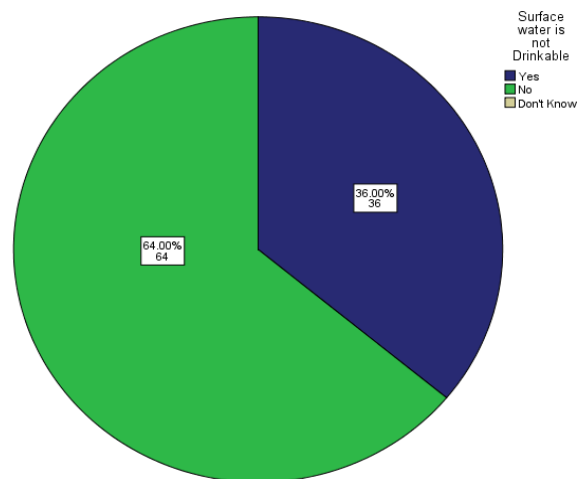


Figure 17: Satisfaction with Drinking Water Quality in Sukkur.

Home remedies for drinking water treatment.

Home remedies the household applies show dissatisfaction with the quality of drinking water provided by government departments or available access in the area. Table 4 shows that in Hyderabad, out of 73% of unsatisfactory respondents, 40% applied some types of home remedies, whereas 33% applied without using any type of filtration process. In Sukkur, out of 64% of unsatisfactory respondents, only 12% of respondents applied some home remedies, whereas 24% used without filtration, a major portion of unsatisfactory respondents, as shown in Table 5.

Table 10: Home remedies for drinking water treatment in Hyderabad.

	Home remedies for drinking water treatment					
	Boil	Filtration	Alum	No remedies	Multiples	Total

	Count	Count	Count	Count	Count	Count
Surface water is not drinkable (yes)	13	3	4	33	20	73

Table 11: Home remedies for drinking water treatment in Sukkur.

	Home remedies for drinking water treatment					
	Boil	Filtration	Alum	No remedies	Multiples	Total
	Count	Count	Count	Count	Count	Count
Surface water is not drinkable (yes)	1	2	5	24	4	36

Source of Income

To reduce the healthcare cost burden, sources of income play a major role in the community. Figure 12 shows that in Hyderabad, 32% of people have a private job, which is better than the sources of income. Of Sukkur's people, 42% are labor, which is higher than other sources of income, as shown in Figure 13. This shows that the cost burden of waterborne disease is higher and more challenging to beat by low-earning communities.

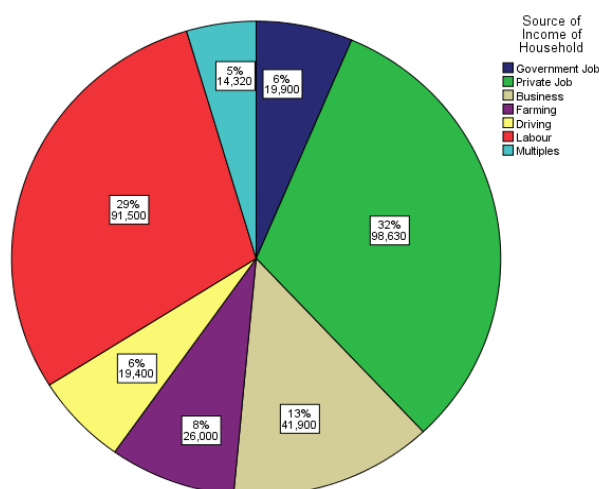


Figure 18: Sources of income in Hyderabad.

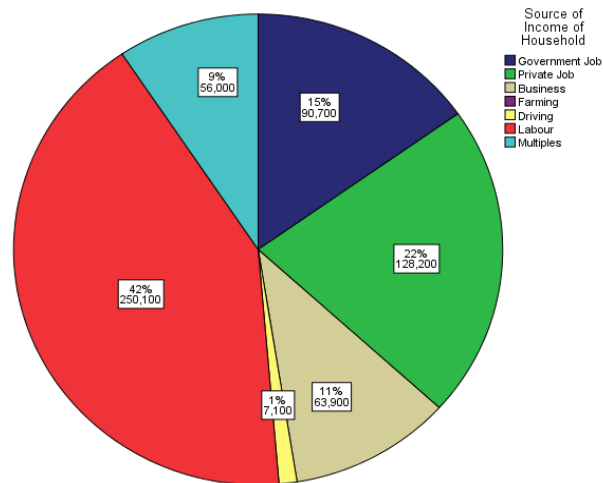


Figure 19: Sources of income in Sukkur.

Total Healthcare Cost

The healthcare cost is counted in Pakistani Rupees (PKR). Figure 14 shows that Hyderabad has a total healthcare cost of 394,420, including Waterborne Disease Costs (WBDC) of 311,650 and Other Diseases Costs (ODC) of 82,770. In another way, the total healthcare cost is the sum of Direct Cost (DC) is 312,700, and Indirect Cost (IDC) is 81,720; similarly, In Sukkur, the total healthcare cost is 666,300, including Waterborne Disease Costs (WBDC), is 596,000, and the Other Disease Costs (ODC) is 70,300. In another way, the total healthcare cost is the sum of Direct Costs (DC) is 58 5850, and Indirect Costs (IDC) is 80,450. As shown in figure 15.

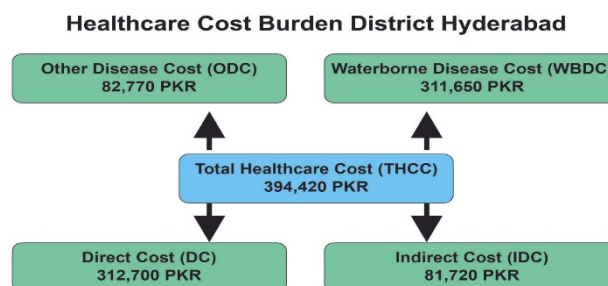


Figure 14: Total Healthcare Cost of Hyderabad.

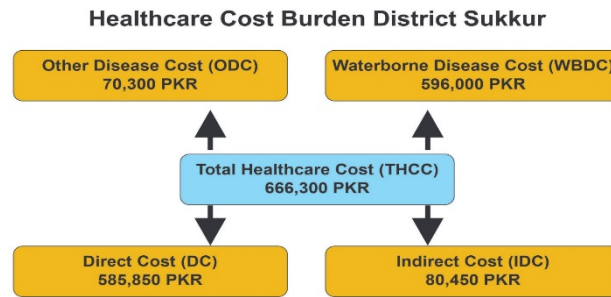


Figure 15: Total healthcare cost of Sukkur.

Water-Borne Disease Burden

Unsafe drinking water causes the burden of waterborne diseases. Typhoid, Diarrhea, Dysentery, and Suspected Hepatitis-A disease are waterborne diseases. Figure 16 shows that in 100 households of Hyderabad, 71 people were affected by Diarrhea. In Sukkur, 81 people were affected by diarrhea in 100 households, the highest among all other waterborne disease cases, as shown in Figure 17.

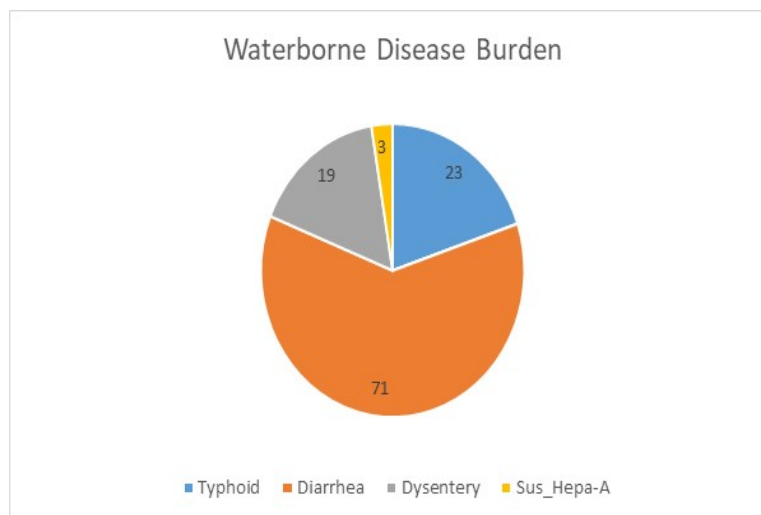


Figure 16: Waterborne diseases burden in Hyderabad.

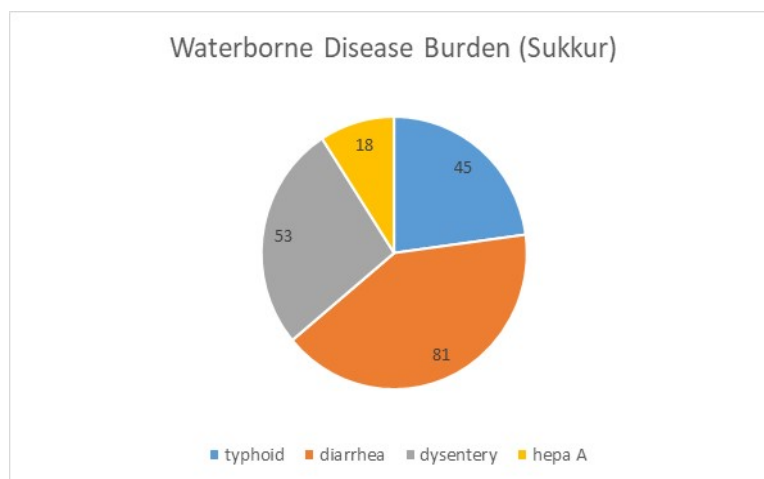


Figure 17: Waterborne disease burden in Sukkur.

Water Borne Disease Cost

Table 8 shows that among four waterborne diseases in Hyderabad, a major portion of the cost burden is due to the treatment of diarrhea, which is 55% of the total healthcare cost, including waterborne diseases and other diseases. In Sukkur, 33% of the total healthcare cost burden is measured due to Typhoid disease, as shown in Table 9.

Dependent Variables	Direct Cost	Indirect Cost	Total Cost	%age
Typhoid	65,328	17,072	3127.00	26%
Diarrhea	135,689	35,461	817.20	55%
Dysentery	38,134	9,966	3944.20	15%
Suspected Hepatitis-A	7,928	9,966	48,100	3%
TOTAL WBDC	247,097	64,571	311,650	79%
TOTAL ODC	65,621	17,149	82,770	21%
TOTAL HCC	312,700	81,700	394,420	100%

Table 12: Waterborne disease cost in Hyderabad.

Dependent Variables	Direct Cost	Indirect Cost	Total Cost	%age
Typhoid	174,005	23,895	197,900	33%
Diarrhea	163,586	22,464	186,050	31%
Dysentery	137,032	18,818	155,850	26%
Suspected Hepatitis-A	49,414	6,786	56,200	9%
TOTAL WBDC	524,038	71,962	596,000	80%
TOTAL ODC	61,812	8,488	70,300	11%
TOTAL HCC	585,850	80,450	666,300	100%

Table 13: Waterborne disease cost in Sukkur.

Comparison of Waterborne disease with drinking water

A comparison of waterborne diseases burden with drinking water sources clarifies the causes and quality of drinking water. In Hyderabad, a major portion of the respondents are affected by diarrhea, and Figure 18 shows that 47% of the diarrheal-affected households use surface water for drinking purposes. In comparison, in Sukkur, a major portion of the respondents is affected by Typhoid disease, and 31% of the community uses Groundwater (Hand pump, Dug well, motor pump) for drinking purposes, as shown in Figure 19.

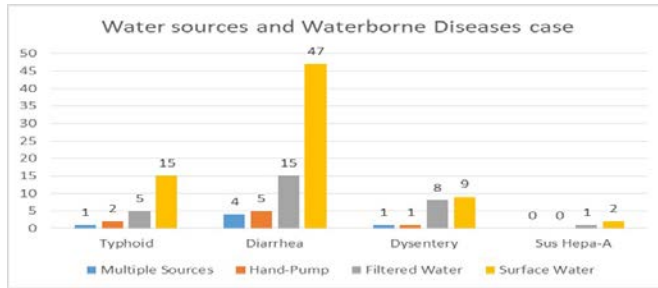


Figure 18: Comparison of Waterborne Disease cases with Drinking water sources Hyderabad.

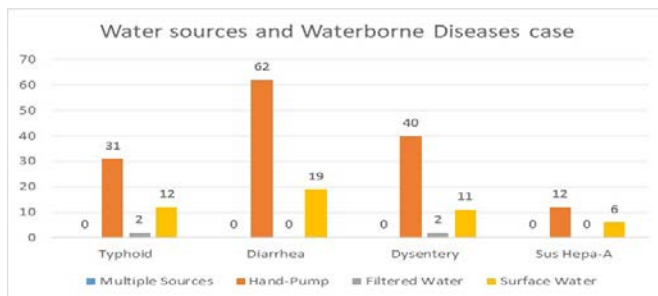


Figure 19: Comparison of Waterborne Disease cases with Drinking water sources Sukkur.

Conclusion

The contamination of freshwater bodies poses a critical challenge to public health, environmental sustainability, and socio-economic well-being on a global scale. The discharge of untreated or inadequately treated wastewater significantly contributes to this issue, leading to the prevalence of waterborne diseases, particularly impacting vulnerable populations such as children under the age of 5. Despite the widespread recognition of the health risks associated with polluted water, particularly in rural areas, the severity of the situation often goes unrecognized. Alarming, waterborne illnesses persist as a leading cause of mortality worldwide, claiming the lives of thousands of children annually. Inadequate sewage disposal systems and water supplies in rural areas exacerbate water contamination issues, resulting in higher healthcare expenses and productivity losses among communities. This study surveyed 200 households in two cities using sampling techniques such as Sample Random Sampling Method and Cluster Sampling Method (within districts). In Hyderabad, respondents' highest level of education was a bachelor's degree (25%), and they spent 53,000 PKR on water. Independent families constituted 52%, spending 162,830 PKR on water. A preference for government health facilities was noted among 59% of respondents, spending 182,620 PKR. In Sukkur, Secondary education was the highest attained level (17%), with a water expenditure of 7,808 PKR. Independent families accounted for 51%, spending 301,800 PKR on water. Forty-two percent of Sukkur's respondents preferred private health facilities, with a spending of 250,900 PKR. Overall, the Total Healthcare Cost in Hyderabad was 394,420 PKR, with 311,650 PKR attributed to waterborne disease costs. In Sukkur, the Total Healthcare Cost was 666,300 PKR, with 596,000 PKR allocated to waterborne disease costs. Sukkur's disproportionately higher contribution to the overall cost (66%) highlights the elevated healthcare expenses incurred due to waterborne diseases compared to Hyderabad. The average waterborne disease burden per household was 4,538, exceeding income levels of 20,000 to 30,000 PKR monthly. This study underscores the urgent need for targeted interventions, public health campaigns, and improvements in water quality to reduce the prevalence of waterborne diseases. The observed discrepancy emphasizes the necessity for enhancements in the conditions and facilities of government hospitals in Sukkur to address the healthcare needs of the population better.

Acknowledgment:

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Impact Of Water Quality on Residences in The Surrounding Areas of The Indus River

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Abstract

Worldwide, waterborne illnesses threaten public health, particularly in Pakistan's urban regions and other developing nations. These disorders can have a significant financial cost, especially for households who are already vulnerable due to socioeconomic factors. This study investigates waterborne diseases and healthcare costs in Hyderabad and Sukkur, Pakistan. It evaluates the level of microbiological contamination, specifically *E. coli* and fecal coliform in water samples. In Hyderabad, Kohisar facility count 10,000 CFU/100ml *E. coli*. Too numerous to Count (TNTC) of fecal coliform in CFU/100ml. In Sukkur, GH Bagirji facility, *E. coli* count was 14000 CFU/100ml, and fecal coliform at Govt Barrage Dispensary was 5800 CFU/100ml. This research provides valuable insights into the waterborne diseases in these districts, aiding in informed policy and intervention strategies. The high concentrations of fecal coliform and *E. coli* bacteria highlight the possibility of waterborne illnesses in these regions. The research highlights the pressing necessity for enhanced water quality management, sanitation infrastructure, and public health initiatives to lessen the impact of waterborne illnesses on households.

Keywords: Waterborne diseases, *E. coli*, fecal coliform, Water quality, Urban areas, Pakistan.

1. Introduction

On Earth, freshwater is an essential resource for a healthy ecosystem and the continuation of life. Freshwater is mainly found in rivers, lakes, glaciers, and aquifers (Solangi, Siyal et al. 2018). The Indus River starts from China's Tibetan Plateau and passes through Tibet before flowing into India. It then travels southward into Pakistan after passing through the Ladakh region of the Union Territory of Jammu and Kashmir. It feeds important towns, including Skardu, Islamabad, and Multan, as it passes through Gilgit-Baltistan, Khyber Pakhtunkhwa, Hyderabad, and Sukkur Sindh. The Indus River finally flows into the Arabian Sea close to Karachi, ending its journey. Pakistan's surface water resources mostly depend on the Indus River's flows. The Indus River is 2900 kilometers long overall (Kahlowan and Majeed 2003). Rivers and streams, important freshwater supplies, are frequently contaminated by three leading causes of water pollution: industries, human habitations, and agriculture. Rapid population expansion, growing urbanization, and the discharge of household, commercial, and municipal wastewater into freshwater sources have all contributed to the worsening of this problem. Every year, 80% of untreated wastewater from industrial and municipal sources ends up in freshwater bodies around the world (Khan, Khan et al. 2018). This wastewater can have a significant financial cost, especially for households who are already vulnerable due to socioeconomic factors. Worldwide, waterborne illnesses threaten public health. Approximately 1.1 billion people worldwide still lack access to safe drinking water, and 400 child (below age 5) fatalities every hour are a result of biological pollution of drinking water (Gadgil 1998).

Microbial contamination of drinking water poses a potential public health risk in terms of acute outbreaks of diseases. Rivers and streams can get contaminated by pathogens, including bacteria, viruses, and parasites, particularly in places with poor access to sanitary conditions and water treatment facilities. According to the World Health Organization, the most frequent and pervasive

health risk connected to drinking water is infectious diseases caused by harmful bacteria, viruses, protozoa, or parasites. According to WHO estimates, contaminated drinking water causes more than 5 million fatalities yearly, of which 4 million are children under the age of five. The magnitudes of the mortality and morbidity from waterborne diarrheal diseases undoubtedly make them the planet's biggest environmental health threat to populations, even though the quality of data on mortality and morbidity from unsafe drinking water is mixed (expert estimates of annual global child deaths vary by almost a factor of 2, from 2 to 4 million) (Gadgil 1998).

In Pakistan, waterborne illnesses include intestinal worms, diarrhea, typhoid, giardiasis, cryptosporidium infections, and gastroenteritis (Daud et al., 2017). An International Union for Conservation of Nature (IUCN) report states that 60 percent of infant mortality in Pakistan is connected to diarrhea caused by water, making it the highest ratio in Asia (Daud, Nafees et al. 2017). Out of 31 Asian countries, Pakistan has the second-highest rate of diarrheal infections. *Salmonella*, *Clostridium*, *E. coli*, and *Enterobacter* are the primary microorganisms contaminating Pakistani water supplies, and all have negative health effects. Water supplies in the Pothwar region have been reported to be contaminated by feces (Noureen, Aziz et al. 2022). The coliforms that digest lactose at 44 °C are included in this group. Fecal coliform counts are commonly recognized for regular water quality monitoring since they are closely connected to *E. coli* levels. Nevertheless, it is advised that isolates be confirmed as *E. coli* through further biochemical testing (WHO, 1993). These days, *E. coli* is widely accepted as a reliable sign of fecal contamination and is advised as the preferred indicator for drinking water monitoring (Schraft and Watterworth 2005). The study's objectives were to determine the fecal contaminations in drinking water samples and assess the water quality in Hyderabad and Sukkur.

2. Material and Methods

2.1 Water Samples

88 water samples were collected from households in Hyderabad and Sukkur Pakistan. The water samples were collected into the 500ml plastic bottles that had been sanitized, chilled and sent the bottles to the laboratory in the ice box.

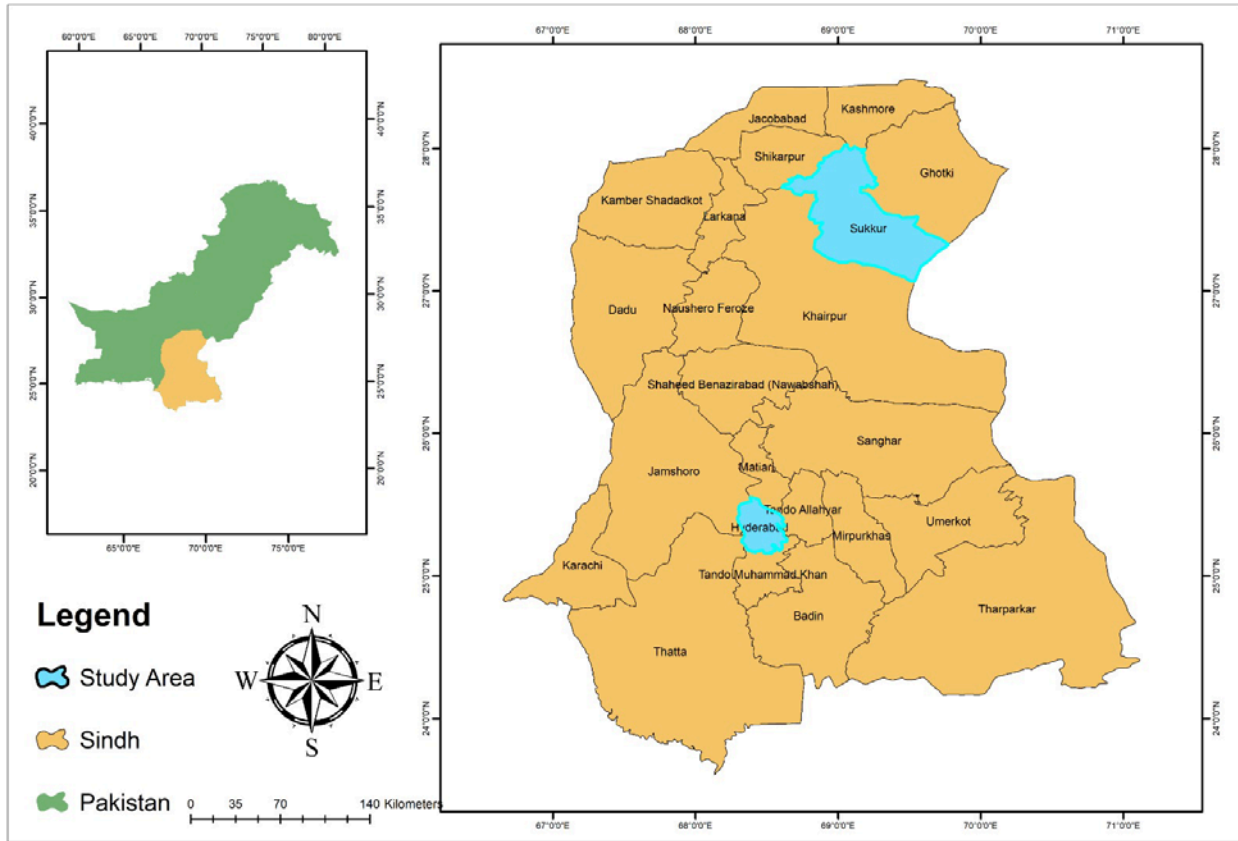


Figure 20: Study Area.

2.2 Microbial analysis

In the laboratory, two methods were performed: firstly, the detection of *E. coli*, and secondly, the determination of fecal coliform levels (Patel et al., 2014).

2.2.1 Pour Plate Method

This technique was used to find *E. coli*. In a sterile Petri plate, 100 microliters of water was poured on Eosin Methylene Blue (EMB) agar and incubated for 24 hours at 37 °C. Next, bacterial colonies were counted in CFU/100ml using a colony counter. The production of a green metallic sheen indicates the presence of *E. coli* (Mkhwanazi et al., 2024).

2.2.2 Membrane Fecal Coliform

Samples were collected, and within 24 hours, they were examined for fecal coliforms using the membrane filtration method recommended by American Public Health Association's Standard Procedures for Water Analysis (APHA) (1995). Membrane filters with a 47 mm diameter and 0.45 mm pore size were used to filter the diluted samples of 0.1 and 1 ml of water. Nitrocellulose filters were used to measure the fecal coliform counts (Millipore). Each filter was aseptically placed on the proper growth medium after filtering (McConn et al., 2024).

2.2.3 Counts for fecal coliform and *E. coli*.

Counting the colonies and identifying features on both Membrane Fecal Coliform (m-FC) and Eosin Methylene Blue (EMB) agar is important. Fecal coliforms are represented by blue colonies

on m-FC agar, which indicate the overall count of fecal coliforms. Green metallic sheen colonies on EMB agar represent *Escherichia coli* (*E. coli*)

3. Results

3.1 Hyderabad

A total of 44 water samples were collected from households in Qasimabad, Hali Road, Peds Hospital, Service Hospital, Shah Bitahi, Sehrish Nagar, Kohisar, and Pretabad, located in Hyderabad. Figure 2 shows the *E. coli* and fecal coliform CFU/100ml in water samples of Hyderabad. In Kohisar, the *E. coli* count was recorded at 10,000 CFU/100ml, representing the highest level observed in Hyderabad, with the fecal coliform count being Too Numerous to Count (TNTC) or above 25000 CFU/100ml. Similarly, in SGH Pretabad *E. coli* count was 1000 CFU/100ml, fecal coliform (TNTC), the second highest among the sampled areas, also SGH Qasimabad count of 160 *E. coli* with (TNTC) fecal coliforms in CFU/100ml. Conversely, the *E. coli* counts on Hali Road, Shah Bhattai, and Sehrish Nagar were 40, 15, and 10 CFU/100ml respectively. In Sehrish Nagar fecal coliform count was 900 in CFU/100ml. Service Hospital Hyderabad and SGH Peda Hospital demonstrated zero counts for *E. coli*, but fecal coliform was TNTC.

Table 14: *E. coli* and fecal coliform in water samples of Hyderabad.

Sampling areas	<i>E. coli</i> CFU/100ml	Fecal Coliform CFU/100ml
Source-01 Paretabad	20	0
Source-02 Paretabad	10	200
HH-01 Paretabad	0	1600
HH-02 Paretabad	0	TNTC
HH-03 Paretabad	0	TNTC
HH-04 Paretabad	0	TNTC
HH-05 Paretabad	0	200
HH-06 Paretabad	0	400
HH-07 Paretabad	0	0
HH-08 Paretabad	1000	0
HH-09 Paretabad	0	0
HH-10 Paretabad	0	400
HH-11 Paretabad	0	0
HH-12 Paretabad	0	2400
Source-01 Qasimabad	0	300
Source-02 Qasimabad	0	0
HH-01 Qasimabad	0	TNTC
HH-02 Qasimabad	160	TNTC
HH-03 Qasimabad	0	TNTC
HH-04 Qasimabad	0	TNTC
HH-05 Qasimabad	0	TNTC
HH-06 Qasimabad	0	TNTC
HH-07 Qasimabad	0	3000
Source-01 Shah Bhittai	0	TNTC
HH-01 Shah Bhittai	0	TNTC
HH-02 Shah Bhittai	0	TNTC
HH-03 Shah Bhittai	0	TNTC
HH-04 Shah Bhittai	15	TNTC
HH-05 Shah Bhittai	0	TNTC
Source-01 Kohisar	0	0
HH-01 Kohisar	0	TNTC
HH-02 Kohisar	10000	TNTC
Source-01 Sehrish Nagar	10	900
HH-01 Sehrish Nagar	0	TNTC
HH-02 Sehrish Nagar	0	TNTC
Source-01 Service Hospital HYD	0	0
HH-01 Servic Hospital HYD	0	TNTC
HH-02 Servic Hospital HYD	0	TNTC
Source-01 Hali Road	40	TNTC

HH-01 Hali Road	0	TNTC
HH-02 hali Road	0	TNTC
Source-01 Peads Hospital	0	0
HH-01 Peads Hospital	0	TNTC
HH-02 Peads Hospital	0	600

In Table 01, the Hyderabad facility demonstrates bacterial growth in drinking water samples, specifically *E. coli* and fecal coliform.

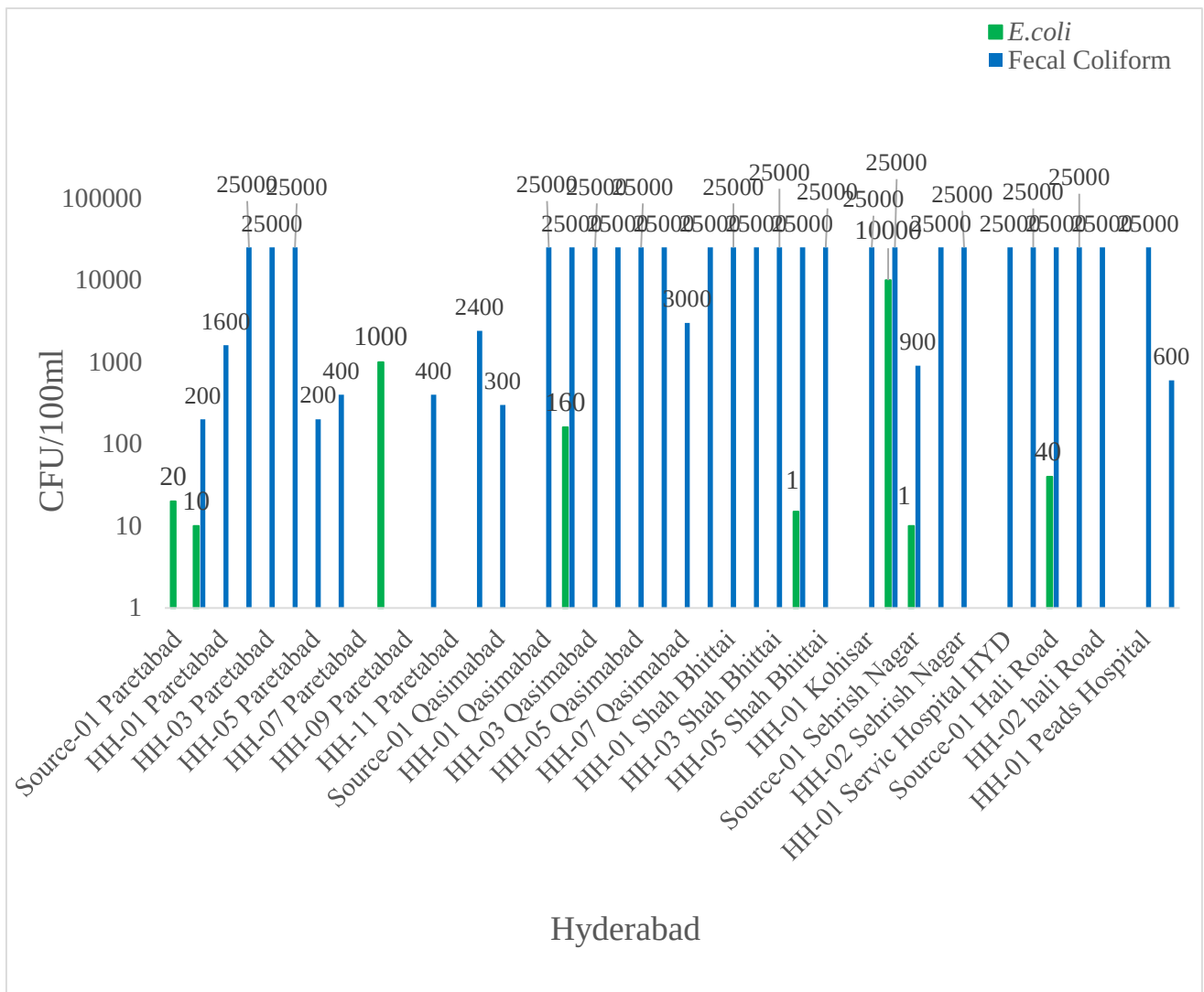


Figure 21: *E. coli* and fecal coliform in water samples of Hyderabad.

Figure 2 *E. coli* and fecal coliform in different areas of Hyderabad. The blue color represents fecal coliform, with levels primarily around 25,000, while the green metallic color indicates the presence of *E. coli* bacteria. The abbreviation TNTC, "Too Numerous to Count," indicates an uncountable amount of bacterial growth.

2.2 SUKKUR

Similarly, In Sukkur, a total of 44 water samples were collected from GH Bagirji, RHC Bachal Shah Miani, Govt Barrage Dispensary, UHU Azizabad, ADC Dispensary, MC Female Dispensary, ED Makka Goth, Maternity Home Tamachani, MCH Fatima-tu-Zuhra, and GD Microwave Colony Sukkur. Figure 3 shows the *E. coli* and fecal coliform count in CFU/100ml. In Barrage, the maximum *E. coli* count was TNTC CFU/100ml. Similarly, In UHU Azizabad and MC Female Dispensary, the maximum fecal coliform count was TNTC CFU/100ml. Table 2 shows *E. coli* and fecal coliform bacteria in selected areas of Sukkur. Most of the samples show zero *E. coli* and fecal coliform.

Table 15: *E. coli* and fecal coliform in water samples of Sukkur.

Sampling areas	<i>E. coli</i> CFU/100ml	Fecal Coliform CFU/100ml
Bagrigi Source-1	0	0
Bagrigi source – 02	0	0
Bagrigi source – 03 (canal)	1000	0
Bagrigi Source 04	0	0
Bagrigi H.H-01	0	0
Bagrigi HH-02	0	0
Bargigi HH-03	2000	0
Bagrigi HH-04	0	0
Bagrigi HH-05	0	0
Bagrigi HH-06	0	0
Bagrigi HH-07	0	0
Bagrigi HH-08	0	0
Bagrigi HH-09	0	700
Bargigi H.H-10	0	0
Bargigi H.H-11	0	0
Bagrigi HH-12	11000	0
BS-Miani - 01 source	0	0
BS-Miani source – 02	0	0
BS-Miani HH-01	0	0
BS-Miani H.H-02	0	0
BS-Miani HH-03	0	0
BS-Miani HH-04	0	0
Barrage source -01	0	0

Barrage source -02	TNTC	0
Barrage HH-01	0	3200
Barrage HH-02	0	2600
Barrage HH-03	0	0
Barrage HH-04	0	0
Azizabad H.H-01	0	TNTC
Azizabad H.H-02	0	TNTC
ADC H.H-01	0	0
ADC H.H-02	0	0
Mc Female H.H-01	0	800
Mc female H.H-02	0	1500
MC Female H.H.-03	0	TNTC
MC Female H.H.-04	0	0
Makkah HH-01	0	0
Maternity Home Source-01	0	0
Maternity Home HH-01	0	0
Fatima source -01	0	0
Fatima source -02	0	0
Fatima H.H-01	0	800
Fatima H.H-02	0	1500
Microwave H.H -01	0	1400
Microwave H.H-02	0	0

In Table 02, the Sukkur facility demonstrates bacterial growth in drinking water samples, specifically *E. coli* and fecal coliform. The abbreviation TNTC, "Too Numerous to Count," indicates an uncountable amount of bacterial growth.

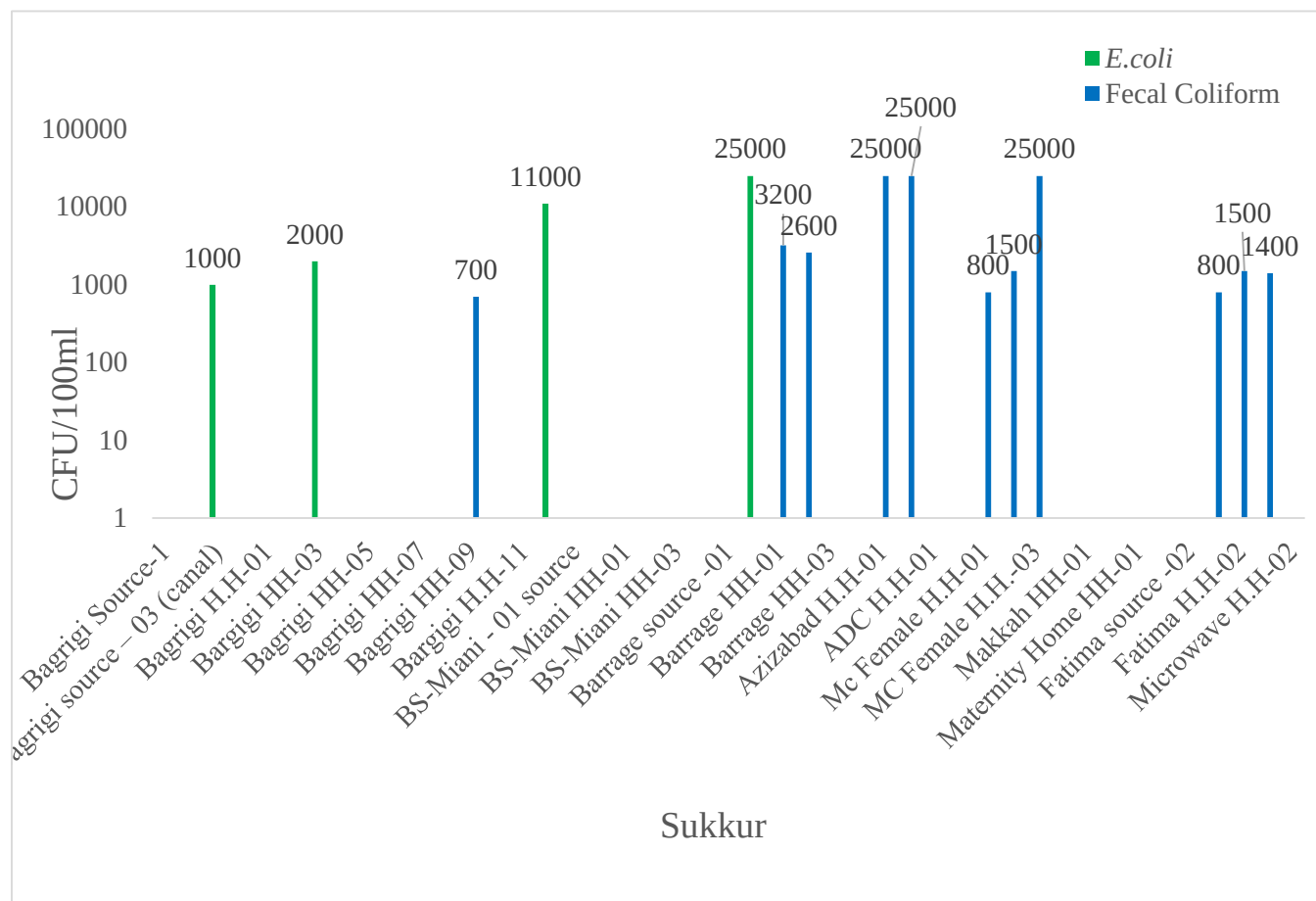


Figure 22: *E. coli* and fecal coliform in water samples of Sukkur.

Figure 3: *E. coli* and fecal coliform in different areas of Sukkur. The blue color represents fecal coliform, while the green metallic color indicates the presence of *E. coli* bacteria.

3 CONCLUSION

This study shows the issue of microbial contamination in freshwater sources, particularly in the Hyderabad and Sukkur districts of Pakistan. The analysis revealed alarming levels of *Escherichia coli* (*E. coli*) and fecal coliforms in various sampled areas, indicating potential health risks associated with consuming contaminated water. In Kohisar, the *E. coli* count was recorded at 10,000 CFU/100ml, representing the highest level observed in Hyderabad, with the fecal coliform count being Too Numerous to Count (TNTC) or above 25000 CFU/100ml. Similarly, in SGH Pretabad *E. coli* count was 1000 CFU/100ml, fecal coliform (TNTC), the second highest among the sampled areas, also SGH Qasimabad count of 160 *E. coli* with (TNTC) fecal coliforms in CFU/100ml. In Sukkur, Barrage, the maximum *E. coli* count was TNTC CFU/100ml. Similarly, In UHU Azizabad and MC Female Dispensary, the maximum fecal coliform count was TNTC CFU/100ml. The presence of these pathogens at such levels highlights the urgent need for improved water management strategies and enhanced sanitation infrastructure to safeguard public health and prevent waterborne diseases. Overall, the results of this research underscore the importance of ongoing monitoring and assessment of water quality, coupled with comprehensive efforts to improve sanitation infrastructure and promote public awareness about safe water practices. Addressing the root causes of microbial contamination requires a multi-faceted approach involving collaboration between government agencies, local communities, and

relevant stakeholders. By prioritizing investments in water sanitation and hygiene infrastructure, Pakistan can take significant strides towards ensuring access to safe and clean drinking water for all its citizens.

Acknowledgment:

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Biodegradation of Single use Plastic by using indigenous Soil bacteria from Kotli Azad Jammu & Kashmir

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Abstract

The present study was designed to analyze the biodegradation potential of indigenous bacteria against plastics based protective masks and gloves. *Acinetobacter humanii* MBT024 and MBT027, *Bacillus anthracis* MBT025 and *Bacillus subtilis* MBT026 were isolated, purified and characterized using morphological and molecular analysis. Shake Flask method and field methods was used for bio degradation. Weight loss degradation analysis was adopted to observe the biodegradation potential. During Shake flask method for masks and medical gloves, 39% and 10.23% highest biodegradation were observed with *A. humanii* MBT027 respectively. The results laid the foundation of the indigenous bacterial strains for bio degradative studies and their potential to mitigate the single use plastic pollution.

Keywords.

Plastic pollution, Covid-19, Gloves, Masks, Indigenous soil bacteria, Biodegradation

1.0 Introduction

Plastic has become a pivotal part of our natural life. Plastic made items are beneficial and convenient in everyday life. But as a persistent contaminant, they could stay in the environment for 100 of years or longer and cause huge environmental issues (Magalhães *et al.*, 2020). From decades plastics cause unpleasant, alarming, highly visible and hazardous environmental pollution (Rochman, 2019). Single use plastic is constantly causing severe environmental pollution and also has adverse effects on the health of humans and animals. The main reasons beyond plastic trash pollution are inappropriate plastic waste management and probably lack of awareness about the damaging effects of plastic bags on the ecosystem (Ramaswamy & Sharma, 2011).

For plastic degradation in the environment, various mechanisms have been reported like photodegradation, thermooxidative degradation, hydrolytic degradation, landfills and incineration but these methods are very slow and unsustainable for mitigation of plastic waste (Andrady, 2011). Biodegradation by microorganism is an effective and more reliable alternate for controlling plastic trash in the environment. It is cost-effective and eco-friendly does not generate harmful pollutants into the environment (Alshehrei, 2017). Microbial enzymes play a significant role in plastic biodegradation. Over 90 genera of bacteria and fungi, including *Bacillus megaterium*, *Pseudomonas sp.*, *Ralstonia eutropha*, *Azotobacter*, *Halomonas sp.*, etc., are reported to be capable of degrading plastic, by producing proteases, lipases, and dehydrogenases enzymes in their systems which play an important role in plastic biodegradation (Ghosh *et al.*, 2013).

The excessive use and mismanagement of medical waste during the coronavirus outbreak led to an increase in plastic pollution. Disposable plastic single use has been considered as the main cause of plastic waste in the environment (Schnurr *et al.*, 2018)

So, the present study was designed to isolate indigenous soil bacteria and to monitor their potential to biodegrade single use plastics like masks and gloves. The study further compared their degradation efficiency in the in-situ field conditions.

2.0 Materials & Methods

2.1 Site selection and sample collection

The study area was located in the region of district Kotli Azad Jammu and Kashmir (AJ & K). Soil samples were collected from the plastic-infested soil from a depth of 3-5 cm and put them in sterile airtight plastic bags. To dry the soil samples, left them at room temperature for one week.

2.1.1 Isolation of bacteria from soil sample

Isolation of bacteria was done by spread plate method and serial dilution methods by using nutrients agar (NA) medium. Single colony streaking was done to obtain the pure culture of bacteria by picking individual colonies from nutrient agar plates with sterilized inoculating loop and streaked it on the nutrient agar plate. Purified culture of bacterial isolates was obtained after several rounds of streaking. The purified strains were maintained at -20°C for further processing (Maroof *et al.*, 2021).

2.1.2 Bacterial Strains colony morphology

Colour, shape and margin of bacterial colony were examined under microscope while elevation, texture and size were examined visually.

Pure culture of bacterial strains was sent to Macrogen Inc., Korea for 16S rDNA gene Sequencing. After sequencing of 16S rDNA gene sequences BLAST search used for the evaluation of obtained sequence (<https://blast.ncbi.nlm.nih.gov/Blast.cgi>) and submitted to NCBI GenBank with the accession numbers OR708538, OR708539, OR7085340, OR7085341. Using the software programme MEGA 7.0, phylogenetic trees were constructed (Adigüzel *et al.*, 2011).

2.1.3 Biochemical Characterization

2.1.3.1 Motility Test

Motility assays were conducted in a semi-solid agar medium comprising 0.2 g agar, 1 mg peptone, and 0.5 g NaCl in 100 ml of distilled water, 5 ml of the medium poured into pre-labelled glass tube. After their plugging, the test tubes were autoclaved. Bacterial isolates were then inoculated using a sterilized straight wire loop in a single stab from top to bottom of the media for inoculating purposes. The tubes were kept at 37 °C for 1 day. After required time, results were noted (Bakht *et al.*, 2020).

2.1.3.2 Growth on Eosin Methylene Blue (EMB) Agar

EMB medium is a differential media aimed to identify bacteria based on their lactose fermentation ability. It also stops Gram-positive bacteria from multiplying. The EMB medium was prepared using distilled water and autoclaved for 15 min at 121 °C. After the autoclaving medium was poured in plates and left for solidification. Streaking was done from one day bacterial fresh growth. In an incubator at 37 °C for 2 days all the plates were placed. The colour of the media and the growth of strain were detected after incubation.

2.1.3.3 Bactericidal Activity of Bacterial Strains Isolated from Soil

From the soil sample, isolated bacterial were used to determine their capability for killing pathogenic bacteria including *Klebsiella pneumoniae*, *Escherichia coli*, *Staphylococcus aureus* and *B. subtilis*. Müller Hinton (MH) agar plates were used for checking of bactericidal activity of bacterial isolates. On MH agar plates test organism was spread then each of the isolated bacterial strain were inoculated as a tiny spot with appropriate marking. For 24 hr plates were kept in an incubator at 37 °C. Isolated strains which can kill pathogenic bacteria developed a clear zone near the inoculated spot. After incubation, the diameter of the zone was measured. Antibacterial effect of azithromycin was also checked (Begum *et al.*, 2017).

2.1.4 Screening of Single use plastic degrading bacteria

Mineral Salt Media (MSM) was prepared by following (Spear et al; 1996) used to check the degradation of face masks and medical gloves Except for the carbon source, which is required for bacterial growth, the media contains all nutrients.

The ability of the bacteria isolates to utilize masks and gloves as a major carbon source for growth was evaluated. MSM was prepared and mixed with agar technical for solidification and autoclaved for 15 mins after that media was cooled and poured in sterilized Petri plates.

Before solidification, sterilized plastic strips weighing around 0.5 g were placed in sterilized MSM in various locations. Plastic strips were heaped with agar media after solidification. The medium was then inoculated with each of the isolated organisms and kept in the incubator for 4-8 weeks at 35-37 °C. Simultaneously the control set was maintained. Zone of clearance producing organisms was selected for further processing (Kannahi & Sudha, 2013; Usha *et al.*, 2011).

2.1.5 Masks and gloves Degradation via Shake Flask Method

Face masks and surgical gloves were used as a source of carbon. Face mask and gloves were acquired from nearby shopping market. Purified bacterial isolates of single use plastic degrading bacteria 1×10^8 CFU (colony forming unit) were added into 100 ml of MSM broth in a conical flask. About 0.3 g face masks and 0.4 g surgical gloves were used as a carbon source washed with absolute ethanol and dried in air for 15 minutes in laminar, added into a flask that contains MSM broth and bacterial isolates. Bacteria used these plastics as a carbon source. Simultaneously control has been maintained with microbe-free media. The flask was maintained on a shaker for 30 days at 120 rpm (Helen *et al.*, 2017).

2.1.6 Weight Loss Measurement

After a pre-defined period, plastics were collected and washed with 70 percent ethanol, air-dried for 15-30 minutes and weighed residue was obtained after 40 days of incubation. The weight of the residue was calculated using the formula as described below:

$$\text{Percentage weight loss} = \frac{\text{Initial film weight} - \text{Final film weight}}{\text{Initial film weight}} \times 100$$

2.1.7 FIELD (IN-SITU) METHOD FOR MPS DEDRADATION

2.1.8 Biodegradation of plastic in Plastic Infested Soil

1 g Masks and 1g gloves were weighed and then buried only for one month in the plastic infested soil for biodegradation. After the required period they were taken out and dried in air for 15-20 min after washing with 70 % ethanol. Weighing of the masks and gloves were carried out to determine the rate of degradation (Waithaka *et al.*, 2017).

2.1.9 Bacterial culture augmentation

Masks and gloves were weighed and added in plastic infested soil for one months. In contrary to augmented land, control land is left alone without the addition of any microbes. All the isolated and purified strains culture was sprayed to speed up the biodegradation process of plastics after one month plastic pieces were sterilized with 70 % ethanol and air-dried for 15-20 min. The rate of deterioration was determined by weighing plastic final weight, which revealed that augmented bacteria played a significant role in MPs breakdown (Mohan and Usha, 2018).

3.0 Results and Discussion

3.1. Isolation and identification of bacteria

Four bacterial isolates were selected, isolated from plastic infested soil. Single colony streaking was done for the purification of selected bacterial isolates. Bacterial isolates were named as MBT024, MBT025, MBT026 and MBT027, where MBT denotes Molecular Biotechnology Laboratory while the digits depict the assigned number. The results of colony morphology of bacterial isolates are shown in (Table 1) & (Fig. 1).

Table-1: Colony Morphology of MPs degrading bacteria

Bacterial isolate	Colour under microscope	Shape	Margin	visual colour	Elevation	Texture	Size (mm)
MBT024	Black	Irregular	Irregular	Off-white	Flat	Creamy	2
MBT025	Brownish Black	Round	Entire	Off-white	Flat	Creamy	1
MBT026	Black	Irregular	Filamentous	Off-white	Raised	Powdery	1.5
MBT027	Brown	Irregular	Irregular	Off-white	Flat	Mucilage	2

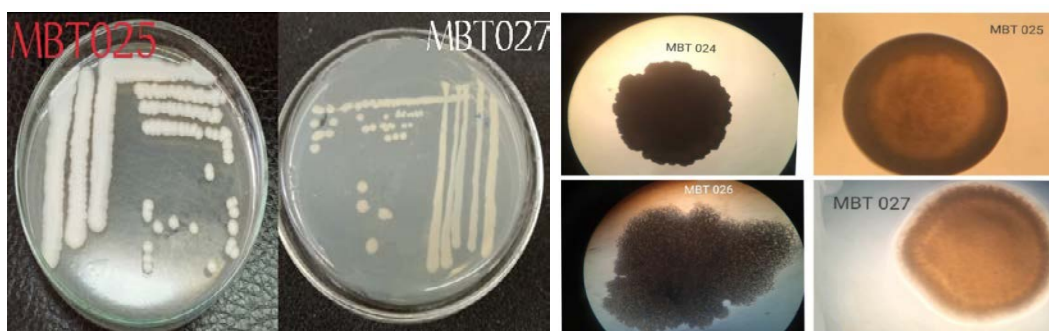


Fig1 Growth of isolated bacterial strains on NA & view of colonies under microscope

3.2 Biochemical characterization

3.2.1 Motility Test

A diffused hazy growth showed motility of bacteria extensively in the medium. Out of four isolates 2 strains MBT024 and MBT027 have shown a positive result for the test. Remaining isolates have showed negative response for test. Results are shown below in (Table- 2).

3.2.2 EMB Agar

Out of 4 selected strains, only two strains MBT024 & MBT027 showed growth on EMB agar. No change in the medium was observed. Results are shown below in (Table- 2).

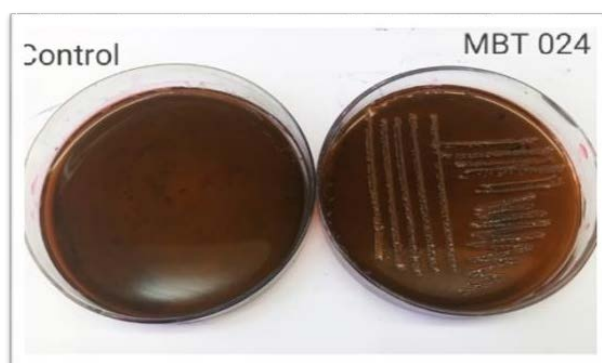


Figure-2: Diagrammatic representation of EMB agar; MBT024 strain shows growth on agar

Table- 2: Biochemical analyses of bacteria by using different biochemical tests

Bacterial isolates	Motility test	Nutrient gelatine test	EMB Agar test
MBT024	+	+	+
MBT025	-	+	-
MBT026	-	+	-
MBT027	+	+	+

3.2.3 Bactericidal Activity of Isolate Bacterial Strains against Pathogenic Strains

This study was done against four pathogenic strains named *K. pneumonia*, *E. coli*, *S. aureus* and *B. Subtilis*. Among all strains, only MBT026 has shown bactericidal activity against all pathogens but MBT024 strain has shown bactericidal activity against *B. subtilis* only. Azithromycin antibiotic also showed an effect against the pathogenic bacteria. Results are shown in (Table- 2).



Figure-3 (A) MBT 026 stain has shown bactericidal activity against *E.coli* (B) has shown effects of Azithromycin antibiotic

Table- 3: Observation of bacterial isolates for bactericidal activity

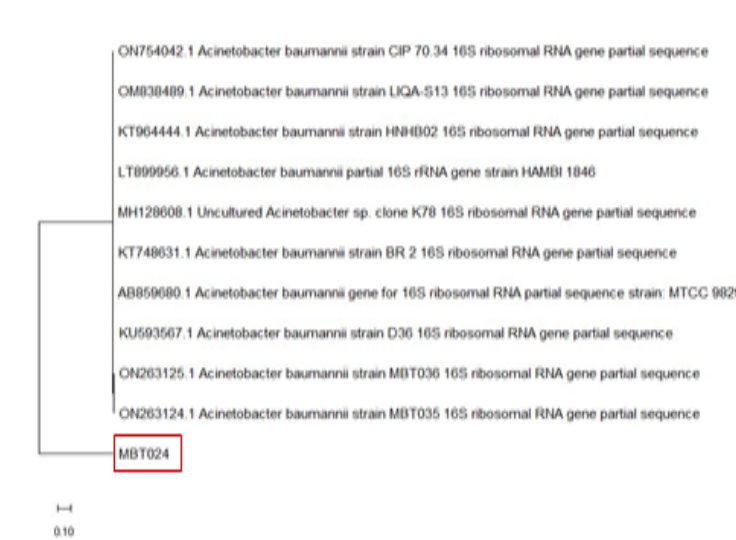
zone of inhibition(mm)					
Bacterial isolates	Pathogens				positive control
	<i>K. pneumonia</i>	<i>E. coli</i>	<i>S. aureus</i>	<i>B. subtilis</i>	Azithromycin (15 mg)
Mean $\pm$ SE					
MBT024	-	-	-	15.05 $\pm$ 0.05	12.5 $\pm$ 0.5
MBT025	-	-	-	-	-
MBT026	14.25 $\pm$ 0.25	22.1 $\pm$ 0.1	10.35 $\pm$ 0.15	11.10 $\pm$ 0.1	44 $\pm$ 2
MBT027	-	-	-	-	-

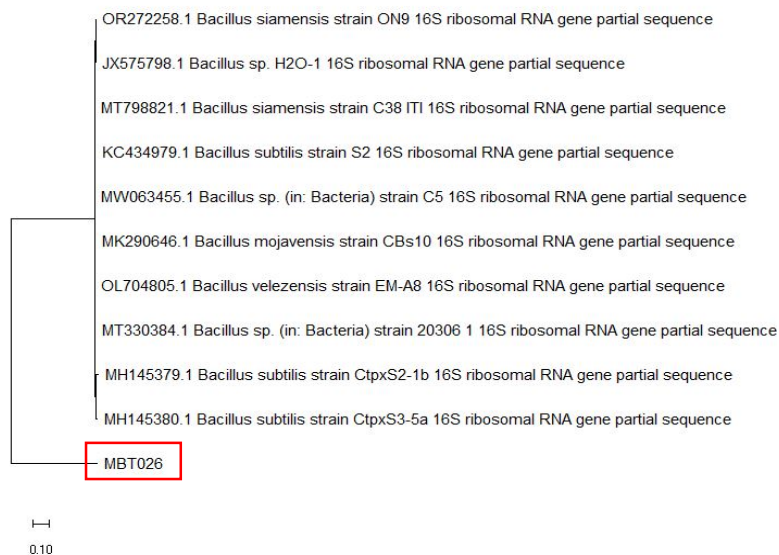
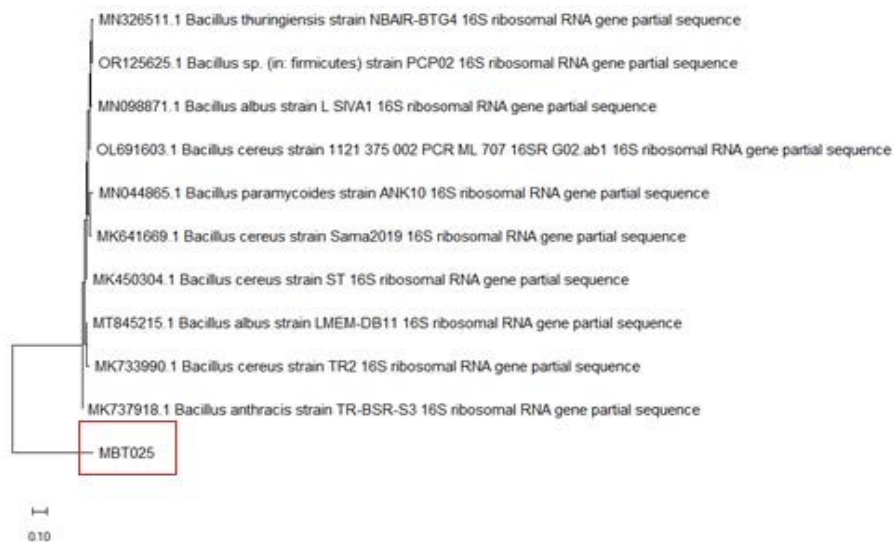
Key - = negative

3.3 Molecular characterization

The selected isolates were identified by using the 16s rDNA sequencing method. The sequences of isolates were compared to the Gene Bank database sequences in ([http:// www.ncbi.nlm.gov/ BLAST](http://www.ncbi.nlm.gov/BLAST)). Using the Mega 7 software application, the closet sequences in the database were aligned, and the phylogenetic analysis was performed to determine the evolutionary relationship with other bacteria in the database.

Based on 16s rDNA analysis strains MBT024 with accession no. OR708540 and MBT027 have accession no. OR708541 showed maximum homology with ON263124.1 and MZ424843.1 and identified as *A. baumannii* MBT024 and *A. baumannii* MBT027 respectively. With accession no. OR708540, MBT025 strain showed maximum homology with MK737918.1 *B. anthracis* strain TR-BSR-S3, so it was identified as *B. anthracis* MBT025. MBT026 strain have accession no. OR708539 showed maximum homology with MH145380.1 *B. subtilis* strain CtpxS3-5a, identified as *B. subtilis* MBT026. Identified bacterial strains phylogenetic trees are shown in (Fig. 2).





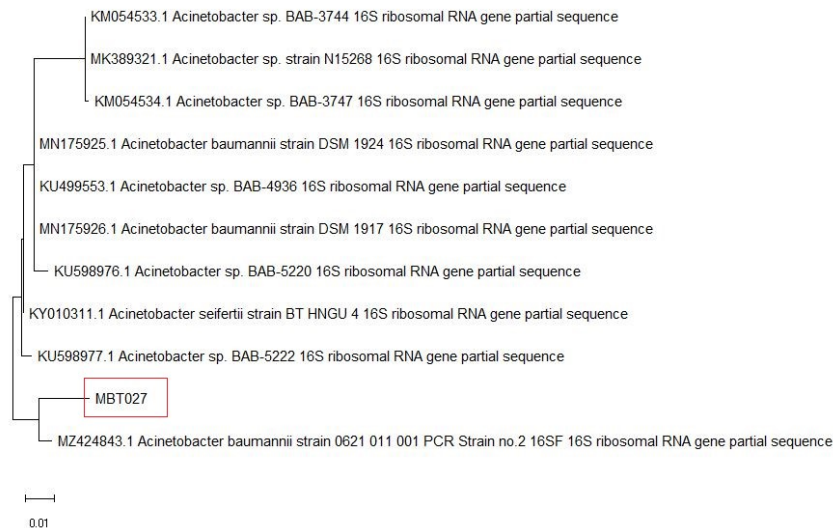


Fig. 4 The phylogenetic tree constructed with Blast and Mega 10 to investigate phylogenetic relationships based on 16s rDNA gene sequences. Bacterial strains studied in this research were highlighted in red.

3.4. Screening of plastic degrading bacteria

Selected bacterial strains were found to have the ability to grow on a carbon-free medium when screened for plastic biodegradation potential. Medium containing plastics it was observed that these strains used the plastics as a source of carbon. The strains showed growth, around the polymer granule within one week after the incubation period. The process of biodegradation involves surface colonization, which leads to the development of biofilm over time. Once attached to the plastic surface, organisms utilized plastic polymer as a carbon source within the biofilm. Control experiments have not shown any growth. The zone of clearance around the bacterial colonies was observed. It showed that extracellular hydrolyzing enzymes (ECPE) involved in the biodegradation process, released into the medium by the target organism. All the strains showed a zone of clearance. This shows the ability of the strain to biodegrade the plastic using their ECPE (Augusta et al., 1993).

3.5 Biodegradation using Shake flask method

After 30 days of incubation period strips were washed with 70% ethanol, dried at 45°C and then weighed for the weight reduction.

3.5.1 Biodegradation of face masks and gloves via shake flask method

For masks, the highest biodegradation potential was observed with *A. baumannii* MBT027 which was approximately 39 % and while least was observed with *B. anthracis* MBT025 at about 1.23 %. For gloves, the highest biodegradation potential was observed with *B. anthracis* MBT025 which was observed as approximately 11.30 % and while least was observed for *B. subtilis* MBT026 about 3.36 % and with *B. subtilis*. This suggests that the bacteria utilized the plastic as a carbon source. These findings align with a related study conducted by (Yao et al., 2022). Results are shown in (Fig. 3)

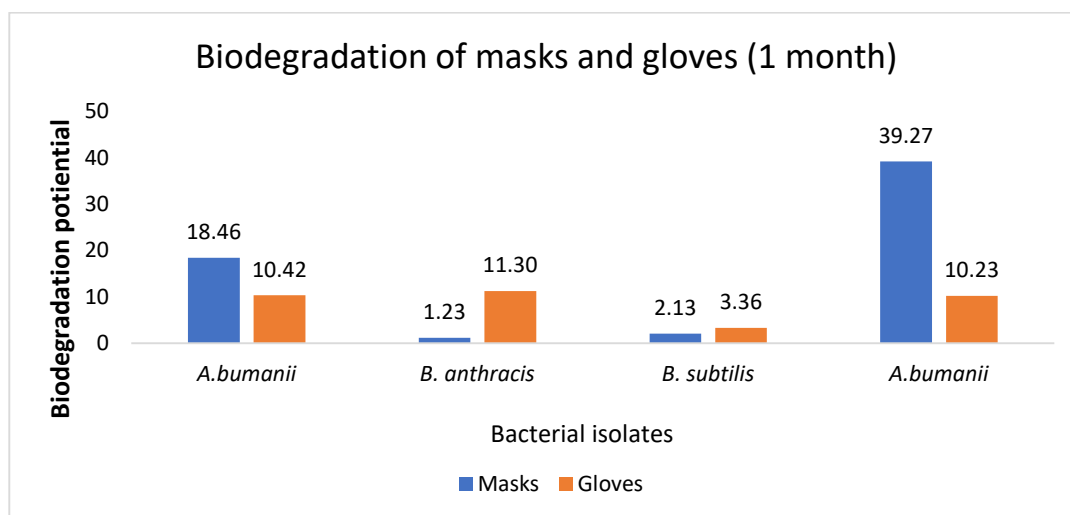


Fig. 5 Biodegradation of face mask and gloves via shake flask method

3.6. Result of In-Situ biodegradation

In plastic-infested soil, masks, gloves, were degraded about 10, 5 percent respectively. In plastic-infested augmented soil, masks, gloves, were degraded at approximately 15, 10 % respectively. It was observed that more biodegradation was observed in the soil augmented with bacterial isolates than in non-augmented soil. The augmentation has helped the existing microfauna to stimulate the biodegradation process.

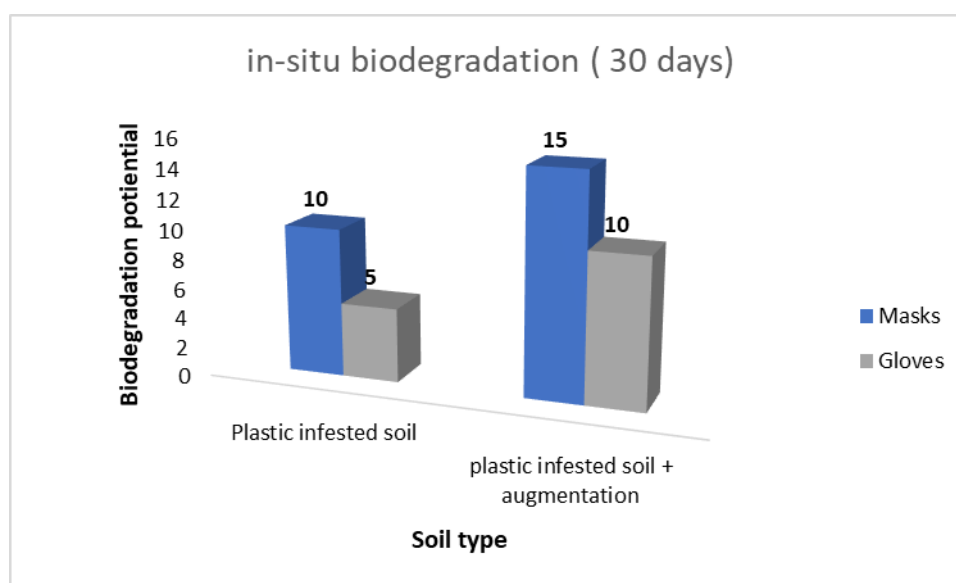


Fig.6 Biodegradation of face mask and gloves via shake flask method

4.0 Conclusion

The conducted research explored the biodegradation potential of indigenous soil bacteria from Kotli AJ & K on masks and gloves. Four bacterial strains were isolated, among which *A. humanii* showed significant degradation potential. The study revealed variations in strain characteristics and degradation of face masks, and medical gloves. This study provides a base line data for the biodegradation of single use plastic and would help in environmental restoration.

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Data availability

Data will be made available on request.

5.0 References

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Theme 2

CLIMATE CHANGE ADAPTABILITY, WATER GOVERNANCE& GLOF

An assessment of economic viability and sustainability of hydroponics using reclaimed water using LCA and LCC

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Abstract

In developed countries, sustainability measures are widely accepted and acknowledged as crucial for addressing environmental concerns. Hydroponics, a soilless cultivation technique, has emerged as a potentially sustainable solution as it can reduce water consumption, land use, and environmental impacts. However, hydroponics may not be economically viable, especially when using reclaimed water, which may entail additional costs and risks. This study aims to address the critical question of whether hydroponics using reclaimed water can achieve a balance between sustainability and economic viability. Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) will be integrated to assess the potential of hydroponics whether it is environmentally sustainable and economically viable. Life cycle assessment or LCA is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service. While Life Cycle Cost (LCC) is an approach that assesses the total cost of an asset over its life cycle including initial capital costs and maintenance costs. The expected benefits of this study include supporting evidence-based decision-making for policymakers, farmers, and stakeholders involved in agriculture. By quantifying environmental impacts and economic costs, this research will facilitate informed choices regarding the adoption of hydroponics with reclaimed water. It is believed that the outcomes of this research work will help to achieve a sustainable approach to agricultural production, aligning with sustainability goals while considering economic factors by adopting hydroponic technique.

Keywords: Hydroponics; Life Cycle Assessment; Life Cycle Cost; Sustainability; Economic viability; GaBi

Climate Change Adaptability, Water Governance & GLOF's: Effects of GLOF's on Climate Change

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Abstract

Global warming, Climate Change and water governance adaptation are crucial matters that influence the development of sustainable communities worldwide. Climate changes affect rising sea levels, precipitation patterns and more extreme weather all have an immediate impact on governance and water resources. Communities' ability to adapt the climate change and its effects on resources of water is essential to their sustainable development and survival. Mitigating the effects of climate change on water resources requires the implementation of tactics and strategies like implementing water conservation measures, improving water infrastructure and developing early warning systems for extreme weather events. We refer to this as the climate change adaptation. It is vital to preserve the health of the public and is regarded as a basic human right to guarantee access to sanitary facilities and clean water. Effective and sustainable management of water resources in the context of climate change depends on water governance. Effective water governance includes guaranteeing that everyone has access to clean water supply and set up rules and laws to protect the quality and quantity of water. It also means promoting community and stakeholder participation in decision-making processes related to water management. Due to the melting of ice caps and glaciers brought on by global warming, there has been a rise in glacial lake outburst floods, or GLOFs. Communities living in hilly regions with a high density of glacial lakes are especially susceptible to these floods. Proactive steps like early warning systems, infrastructure development, and community-based adaptation strategies are needed to address the risks related to GLOFs. In Conclusion, water governance, global warming, and climate change adaptation are interrelated problems with significant effects on community development that is sustainable. To make communities resilient to the consequences of climate change on water resources, these problems need to be addressed with a comprehensive strategy that economic, incorporates social and environmental factors.

Key words: Water governance, Global warming, Sustainable development, Extreme weather events

1. Introduction:

Glacial Lake Outburst Floods (GLOFs) are abrupt outbursts of water from glacial lakes which can be frequently because of avalanches, landslides, and glacier melt. Their connection to climate exchange and its feasible outcomes on human societies and the environment make them substantial. For the reason of comparing the broader results of weather exchange on glacierized areas and creating green model and mitigation plans, it's far imperative to realize the relationship between GLOFs and climate trade. Large quantities of water are launched downstream all through glacial lake outburst floods (GLOFs), which manifest whilst a glacial lake that is blocked by way of a moraine or ice collapses or overtops. The infrastructure, surroundings, and populations downstream may additionally go through greatly because of those occurrences. Although GLOFs have usually happened, there may be growing worry that weather alternate is probably growing their frequency and severity. In order to better apprehend how GLOFs have an effect on weather alternate, this look at will observe both how GLOFs have an effect on the climate gadget and how weather change may additionally affect the frequency of GLOFs.

2. Backgrounds:

Give a quick record of GLOFs, highlighting sizable events and their outcomes on nearby populations and environments. Talk about the evolution of medical knowledge and studies on GLOFs across time, emphasizing giant findings and tendencies within the vicinity.

➤ Objectives:

The Objectives of Effects of GLOFs on Climate Change is as:

1. Examine how Glacial Lake Outburst Floods (GLOFs) affect the weather machine.
2. Examine how weather exchange influences the frequency and depth of GLOF incidents.
3. Draw interest to how GLOFs and weather alternate are related, as well as how this affects mitigation and version plans.

3. Literature Review:

Provide a top-level view of the literature on GLOFs and weather alternate, consisting of facts on reasons, results, and mitigating strategies. Examine ordinary issues, styles, and gaps within the literature to give an intensive summary of the state of understanding as it's far right now. Indicate the areas in which similarly look at is required to enhance our comprehension of GLOFs and their relationship to weather change.

4. GLOFs' Effects on the Climate:

GLOFs may additionally affect the weather device in a number of ways, each without delay and not directly. Large volumes of freshwater being released into rivers and lakes downstream could have rapid effects, changing neighborhood hydrological cycles and influencing regional weather developments. In addition to inflicting erosion and sediment motion, the surprising water inflow may additionally have an detrimental effect on close by ecosystems and landscapes. Furthermore, the buildup of silt and debris in places downstream can exchange the floor's albedo, that may have an effect on nearby temperature traits. Moreover, greenhouse gasoline emissions from GLOFs, together with carbon dioxide and methane, may arise. Gases that have been held for endless years may be launched whilst glacial ice melts or turns into buried. During a GLOF occasion, the abrupt launch of these gases has the capacity to get worse climate trade and increase global warming. GLOFs may have oblique outcomes at the climate system further to those direct ones. For instance, higher carbon emissions from rebuilding efforts and the disappearance of carbon sinks like wetlands and forests would possibly end result from the uprooting of communities and the destruction of infrastructure. Furthermore, the capacity of ecosystems to save carbon and manage the climate can be impacted by using the disturbance of ecosystems and biodiversity loss brought on by GLOFs.

5. Climate Change's Effect on GLOFs:

It is predicted that climate change could have a number of effects at the frequency and length of GLOF incidents. The production of new glacial lakes and the enlargement of the water storage potential of already-present ones would possibly result from the melting of glaciers and ice caps, making it one of the maximum crucial variables. The chance of glacial lake dam collapses and overtopping occurrences is expected to upward push with growing temperatures and retreating glaciers, ensuing in extra frequent and more GLOF occasions. Furthermore, the timing and severity of GLOFs may be impacted by way of changes in precipitation patterns related to climate change. In mountainous areas, extra precipitation or snowmelt can purpose glacial lakes to replenish speedy, elevating the possibility of a dam failing. GLOFs also can be as a result of variations in temperature styles, that can have an effect on the steadiness of moraine dams and the tempo of glacier melt. Furthermore, by means of modifying land use patterns and socioeconomic conditions, climate alternate may additionally indirectly have an effect on a network's sensitivity to GLOFs. For example, by means of upsetting slopes and lowering ecosystems' capability to take in water, urbanization and deforestation in mountainous areas would possibly raise the threat of GLOF occurrences. Similar to this, downstream regions may also see increased exposure to GLOF dangers and worsening effects from those occurrences because of populace enlargement and monetary improvement.

6. Causes and Triggers of GLOFs:

Examine the unique factors including glacier retreat, the growth of glacial lakes, and geological risks that have an effect on the advent and prevalence of GLOFs. Determine whether particular occurrences, which includes seismic hobby or the crumble of moraine dams, would possibly reason GLOFs. Examine how the dynamics of glaciers are converting and how quicker glacier melt is inflicting GLOF dangers to growth.

7. Impact of GLOFs on Glacial Systems:

Explain the outcomes of GLOFs on glacial systems, bringing up alterations within the dynamics, morphology, and rates of ice melt. Talk about the long-term influences of GLOFs on sediment motion, hydrology, and glacial mass balance. Give times of GLOF occurrences and the results they have got on positive glacial systems to focus on the complexity and form of these phenomena.

8. Environmental Consequences of GLOFs:

Assess the outcomes of GLOFs on human settlements, infrastructure, and livelihoods, as well as for downstream ecosystems, habitats, and biodiversity. Talk approximately the extra trendy socioeconomic consequences of GLOFs, such as community relocation, infrastructure destruction, and interruption of commercial enterprise operations.

9. Feedback Mechanisms between GLOFs and Climate Change:

Examine the intricate relationships that exist between weather exchange and GLOFs, along with any remarks tactics that could boom or decrease the consequences of either phenomenon. Examine the approaches wherein GLOFs have an effect on air flow, international weather dynamics, and nearby weather patterns, as well as the approaches wherein these impacts are pondered lower back into the weather gadget.

10. Mitigation and Adaptation Strategies:

Give a precis of the present day and recommended methods to reducing the danger of GLOFs and adjusting to climate trade. These consist of land-use planning, danger mapping, early warning systems, and larger-scale climate exchange mitigation tasks. Assess the viability, financial impact, and viable advantages of numerous version and mitigation strategies for mitigating GLOF dangers and addressing weather exchange.

11. Conclusion:

In the Conclusion, this research has given an intensive analysis of how Glacial Lake Outburst Floods (GLOFs) affect international warming. It is clear from an examination of the origins, outcomes, feedback mechanisms, and mitigation techniques that GLOFs pose an extreme chance to human settlements as well as the environment in glacierized areas. More common and extreme GLOFs will in all likelihood arise because of weather change's acceleration of glacier melt and alteration of nearby climatic patterns, posing a growing risk to ecosystems and inclined populations. Reducing GLOF risks and growing resilience inside the face of endured climate change require powerful edition and mitigation measures which are based totally on scientific research and multidisciplinary collaboration. To save lives, livelihoods, and the planet's delicate ecosystems, coordinated moves at the neighborhood, nearby, and global ranges are had to cope with the interrelated concerns of GLOFs and weather trade.

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An Integrated Framework Fostering Decent Work Opportunities Among Transgender Individuals in Developing Nations: An Interplay of Career Orientation, Social & Family Support, and Career Initiatives

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Abstract

The purpose of this study is to provide insights into the potential associated with fostering decent work for transgender individuals, with a special emphasis on the interconnected aspects of career orientation (CO), social & family support (SFS), and career initiatives (CI). Furthermore, this study contributes to the ongoing discussions regarding equity, diversity, and workplace inclusion by including the unique challenges experienced by transgender people in developing countries like Pakistan. Data collection involved 237 transgender people from 5 district of Khyber Pakhtunkhwa i.e. Charsadda, Mardan, Haripur, Abbottabad and Mansehra. Research findings demonstrate a favorable predictive relationship of CO, CI (mediator), SFS (moderator), and with DW, emphasizing their crucial role in fostering DW amongst transgender individuals. This study emphasizes the crucial roles of CO, CI, and SFS in assuring transgender employees of DW at work. It investigates how these variables lead to improved working conditions and an acceptable work-life balance for transgender individuals. The present investigation highlights the crucial roles of CO, CI, and SFS in assuring DW of transgender individuals at work. It investigates how these factors lead to improved working conditions and an acceptable work-life balance among transgender individuals.

Keywords:

Career Orientation, Social & Family Support, Career Initiatives, Decent Work, Transgender Individuals

1. INTRODUCTION

Nowadays, compared to underdeveloped countries, transgender people in developed countries have substantially less employment-related difficulties such as job instability, gender discrimination, and inclusion in the workplace (Mustafa et. al. 2023). In these developed nations, NGOs, legislators, and the government all contribute to support and promotion of DW for transgender individuals (Köllen & Rumens, 2022). However, acquiring DW conditions for transgender individuals in developing countries are more difficult and challenging (Rani et. al., 2022; Seaborn, Barbareschi & Chandra, 2023). Therefore, this study aims to address these gaps in these countries for economic inclusion and provision of basic rights to this marginalized community (Papadaki & Ntiken, 2023).

DW refers to the belief that employment should not only offer financial benefits, but also provide people with certain fundamental rights, opportunities, and protection (ILO, 1999). However, the effectiveness of ILO in promoting DW ultimately depends upon the willingness of member countries and worldwide organizations to comply with and enact labor standards and rights (Thomas, 2021). Therefore, DW is not merely a moral obligation, but it is also an essential driver of social stability, economic growth, and well-being for humanity, with broad implications for individuals and nations (Kreinin & Aigner, 2022).

Transgender individuals perform essential roles in advocating for equality of opportunity, fostering diversity, and making contributions to the community in numerous ways, from educational institutions to the workforce and beyond (Köllen & Rumens, 2022). However, they confront discrimination in the workplace and an absence of legal protections almost around the world, resulting in an imbalance of DW, because of deeply entrenched prejudices and systemic barriers (Smith & Sinkford, 2022).

Transgender individuals of Nigeria, Mexico, Georgia has particular problems in finding adequate jobs and fair career opportunities (Yousuf et. al., 2022). However, it is critical to address structural barriers and promote inclusion in order to improve their social and economic conditions (Jain & DasGupta, 2021; Mustafa et. al. 2023; Yousuf et. al., 2022). Therefore, it is concluded from the above stated arguments that supporting and encouraging Transgender individuals in the context of decent work is critical for maintaining job equality and providing discrimination-free job opportunities as all other people avail. In this way, they can contribute to economic development, social harmony, and overall progress in society.

SFS is integrated into the framework for research to investigate its moderating effect on the relationships of CO and DW as well as CO and CI. The system of practical and emotional support provided by an individual's family and large social circle is referred to as SFS (Semborski et. al., 2022). SFS gives transgender individuals mental, practical, and emotional resources they need to get over societal barriers, achieve their career goals, and contribute in a more varied and equitable way (Kashyap, Nakra & Arora, 2022). It is critical to understand the captivating strategic importance of both SFS and CO, when it pertains to enabling Transgender individuals to actively participate in meaningful DW related activities (Di Lorito et. al., 2022). However, it is important to remember that, despite these circumstances, the participation of Transgender individuals in DW-related activities does not occur automatically. CO has visible and crucial relevance; however, these characteristics are inadequate on their own to directly trigger Transgender individuals for DW. There is a crucial need to understand the internal mechanisms which could explain this connection. In order to fill this knowledge gap, we proposed CI as a mediating variable in this association. CI are organized activities and programs that assist individuals in developing their careers through the provision of support, opportunities, and resources for progress and development (Liu & Ren, 2022). SFS and CO serve as the dynamic catalysts driving the growth of individual's CI. Considering this mechanism, it becomes evident that CO serve as the primary catalysts for enhancing CI and effecting positive change in DW.

This research was carried out to investigate how CI can affect the association between CO and DW among transgender persons. This study enriches the literature through investigation into the internal dynamics of how CO enable Transgender individuals to engage in DW activities, considering the role of CI and SFS as mediator and moderator respectively. To accomplish study objectives, the study unfolds into various sections. The next section analyzes the pertinent academic work on the emergence of various constructs and assumptions. The subsequent section discusses the research methodology of this study. The last section discusses results, discussions, theoretical and practical implications, and limitations of the study.

2. Literature Review

Theoretical foundation

Over the last two decades, there has been a significant increase in interest in the notion of "Decent Work," driven by an obligation to promote social inclusion and protect underprivileged workers (Green, 2021). DW is crucial which ensures workers well-being and promotes equitable growth in the economy (Drubel, 2021). Hence, encouraging decent labor is not just an ethical obligation, but also an essential component of economically viable and equitable communities (Cooke, Xu & Bian, 2019).

The term 'career orientation' is a wide notion that involves an individual's career preferences, attitudes toward work, and perceived skills and abilities (Cortellazzo et al., 2020). CO facilitates individuals in shifting from a broad knowledge of work and life toward a more focused understanding of feasible and realistic career options available to them (Tschopp, Grote, & Gerber, 2014). However, scholars have pointed out a dearth of study on different aspects of career orientation (Khattab et al., 2022). Therefore, to make careers more feasible and practicable, it is imperative to comprehend and put the concept of career orientation into practice. We underline three dimensions of career orientation in this

study which are career aspirations, career decidedness and, career importance. The intention of an individual to acquire or pursue a particular profession is known as their career aspirations (Dries & Pepermans, 2007). Career decidedness refer to the extent to which people are confident in their job selection decision. Career importance refer to how much individual's work contributes to their sense of self-awareness and provides a sense of meaning and purpose of life (Hall & Chandler, 2005). In conclusion, career orientations are fundamental motivators of people's behavior and job decisions because they represent how people perceive and approach their careers.

Career initiatives refer to a continuous process whereby an individual establishes career aspirations and determines how to accomplish them (Ayentimi et al., 2020). The environment where the majority of career decisions are being made is dynamic: professions are rapidly changing, society is becoming more complex and diversified, and people should always prepare themselves to meet these changes instead of converging career paths (McMahon, Watson & Patton, 2014). According to Biko (2013), individuals frequently experience discouragement, despondency, and hopelessness about their prospects during periods of societal transition and economic uncertainty. Additionally, individual frequently feel frustrated and hopeless regarding their futures during periods of societal shift and economic instability (Kenny, Blustein & Meerkins, 2018). CI provides individuals with knowledge of different career opportunities, his interests, and so on (Bonache & Stirpe, 2016). It assists him in selecting a job that matches his life style, preferences, family setting, and opportunities for self-development (Roe, 2014). The most fundamental and essential aspect of career planning initiatives are self-exploration and evaluation; a person must comprehend his or her own requirements, abilities, skills, strengths, and interests in order to make professional preferences (Coetzee, 2014). Last but not least, career initiatives enable individual to achieve his/her objectives and promote aspirations which can enable to achieve future goals.

Social and family support, which includes the help, care, and connections provided by one's social network (friends, colleagues, family members etc.), is unquestionably important for individual well-being (Semborski et. al., 2022). Furthermore, it is critical to encourage emotional, practical, and occasionally financial assistance, as well as establishing a feeling of security and belonging (Wang, Marsico, & Do, 2020). However, the lack or insufficiency of such assistance may contribute to higher stress, psychological concerns, and a higher risk of being socially isolated (Delerue Matos et. al., 2021). Therefore, Understanding the importance of SFS is essential, not just for improving personal resilience as well as the quality of life, but additionally for developing communities that are stronger and more integrated (Semborski et. al., 2022).

Hypotheses Development

2.1 Career Orientation and Decent Work

The multifaceted connection between career orientation CO and DW needs thoughtful consideration. The relationship is intricately interconnected with an individual's professional objectives, beliefs, and preferences being aligned with the fundamental concepts underlying DW (Graça et al., 2021). Furthermore, it is dependent on an individual's professional objectives and beliefs aligning with the ideals of DW (Xu, Liu & Tang, 2022). Individuals who value equitable treatment, protection, and dignity in the workplace not solely increase their personal fulfillment at work, but, also contribute to promoting ethical environments (Islam et. al., 2021). However, organizations that cast aside these values may have difficulty retaining individuals who value reasonable work standards (Slatten et. al., 2021). Therefore, it is apparent that integrating a person's career orientation with the standards of decent work is a critical aspect in encouraging ethical and rewarding career pathways and supporting a positive work atmosphere (Razavi et al., 2020). Consequently, individuals as well as organizations must acknowledge the crucial importance of ethical work standards for shaping career excellence and workplace dynamics (Batat, 2022). We devised the following hypothesis based on these arguments:

H1: Career Orientation are positively related Decent Work.

2.2 Career Orientation and Career Initiatives

According to Renee Barnett & Bradley (2007), there are numerous factors that influence an individual's consistent approaches which play integral role for pursuing the career planning initiatives that are appropriate for work success. CO are perceived to be among the most key factor in this aspect (Rodrigues, Butler & Guest, 2019). An individual's career orientation may favorably affect their ongoing achievements and future goals, but it may also have a positive impact on their career initiatives (CI), which decides their career ambitions and the way to achieve them (Oh et al., 2013). The current study focuses on the action regulation theory which examines the changing dynamic relationships among career orientation, participation in career activities, and perceived career achievement (Haenggli et al., 2021). A meta-theory on the regulation of behavior and action that is goal-directed is called action regulation theory (Zacher, 2017). However, according to this theory, employees control their behavior through mental abilities like goal selection and development, career orientation, career initiatives, continuous monitoring and feedback of their actions. Therefore, CO assists individuals in realizing their ambitions by establishing realistic objectives, and CI plays an important part in making those aspirations feasible (Jackson & Wilton, 2016). In light of above mentioned arguments, it seems rational to assume that:

H2: Career Orientation is positively associated to Career Planning Initiatives.

2.3 Career Initiatives and Decent Work

According to Chibili (2019), CI involve exploring various job options, taking a personal assessment to determine compatibility for these options, and sorting out the most suitable approaches for establishing career track. CI can reintegrate individual's professional as well as personal objectives in order to accomplish broader goals and develop DW (Rothwell et al., 2014). However, CI is a continuous process which enables individuals to progress through various changes until they accomplish their highest potential DW (de Waal, Habil & Goedegebuure, 2016). CI is a good predictor of DW, because CI demonstrates confidence, high self-esteem and ambition to work which encourages in taking the initiative to establish, complete, and achieve both professional and personal goals (Bakshi & Joshi, 2014). An excellent CI can assist in streamlining DW pathways (Sumalatha & Nirmal Roy, 2020). Established goals allow people to concentrate on what they are creating; the more an individual works towards an established goal, the faster they'll be apt to achieve it (Schor, 2021). In essence, CI encourages individuals to be more productive and efficient in order to reach higher levels of DW. We developed the following hypothesis on the basis of these arguments:

H3: Career initiatives are positively associated to decent work.

2.5 Mediating Effect of Career Initiatives

The International Labour Organization (ILO) has become increasingly concerned to promote the DW for all people. The main purpose of DW is to provide support for and serve community members who have diverse identities (Parmenter, 2021). Individuals can deal with such CO by increasing their CI. CI is unique capabilities that contribute to improved DW of transgender person (D'Cruz et al., 2022). CI serves as a mediator, supporting the dynamic synergy between CO and DW. There are two justifications for the mediating role of CI in the relationship of CO and DW. The first justification is that CO encourages people to get involved in more CI, which is the core components for improved DW (Direenzo, Greenhaus & Weer, 2015). The second justification is that individuals may better comprehend their values, abilities, and objectives with the support of CO, CI helps individuals realize their objectives, which enhances DW (Palma, Hinna & Mangia, 2017). The following hypothesizes has been put forth in light of these justifications:

H4: The association between career orientation and decent work is mediated by career initiatives.

2.6 Moderating Effect of Family and Social Support

SFS networks are essential for ensuring that all individuals have access to DW employment prospects. These considerations demonstrate how SFS, CO, and CI have a complex and important interaction. consequently, these kinds of support systems frequently play a crucial role in assisting people in their quest for and maintenance of DW. When a transgender person is equipped with SFS in their job development, the connection of CO and DW may be enhanced by building a harmonious environment of searching out and seizing possibilities (Delerue Matos et. al., 2021). Transgender people who have access to significant SFS are more equipped to proceed in their careers. Transgender individual who have access to significant SFS are more ready to proceed in their careers (Semborski et. al., 2022). The assistance they receive enables them not just advance professionally but also continuously pick up new skills, which eventually benefits DW (Mustafa et. al. 2023). Given these reasoning, the following hypothesis is presented:

H5. Family and social support favorably moderate the direct impact of career orientation on transgender individuals' ability to find acceptable employment.

2.6 Moderating mediated Effects of Social & Family Support

Understanding the link between CO and SFS is essential (Wang, Marsico, & Do, 2020). Moreover, SFS provides a solid basis for guidance and emotional stability (Mustafa et. al. 2023). Nevertheless, it's important to keep in mind that not everyone has access to this kind of help, which emphasizes the necessity of social activities that create inclusive environments (Schor, 2021). Consequently, recognizing and developing SFS networks may lead to fair chances for career advancement, which would be advantageous to both people and society as a whole. The argument is that SFS has a positive moderating effect on the relationship between CO and CI because of the previously mentioned factors. As mentioned earlier, the interaction between CO and DW is mediated by an individual's CI, and SFS has a conditionally positive influence on both the indirect and direct connections between CO and DW through CI. Given the previously cited reasoning, it would seem reasonable to make the assumption that:

H6. The indirect impact of career orientation on transgender individuals' ability to find decent work through career initiatives is strongly moderated by social and family support; the effect becomes significantly stronger when social and family support is higher.

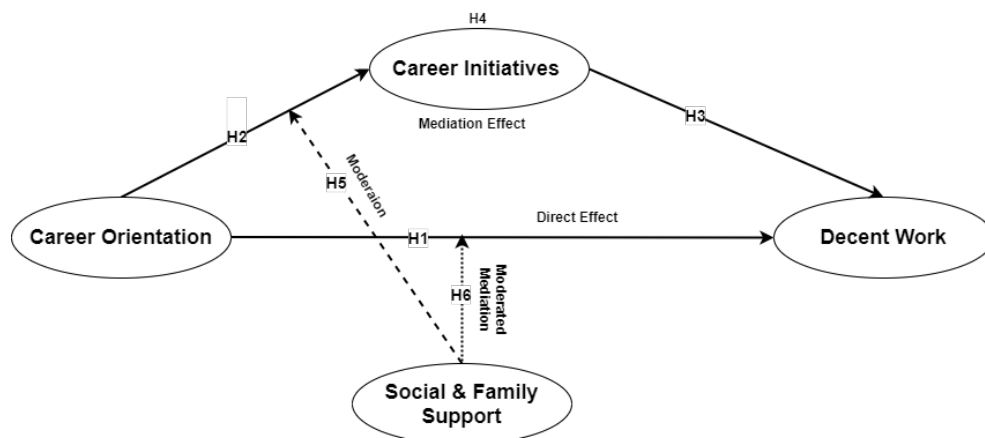


Fig. 1 Theoretical Framework: Decent work

3. METHODOLOGY

3.1 Data collection Research Participants

To investigate a balanced assessment of the issue, data were collected from 237 Transgender individuals residing in Khyber Pakhtunkhwa Pakistan. The information was gathered in order to better understand how SFS and CO affects the DW of transgender persons. Initially, 317 Transgender individuals were approached to get involved in the survey; however, only 273 persons were willing to participate in this survey. A survey approach was used to collect data, and a convenient sampling was utilized for this purpose. To facilitate this process, five male research assistants were given the responsibility to collect data from transgender people in the designated areas. However, understanding the significance of additional assistance, we have involved five transgender facilitators in data collection process. These people were helpful in contacting and collaborating with transgender community to get required information. Therefore, we established a strategy by organizing five teams, each of which included a research assistant and a transgender facilitator. The transgender facilitators were helpful in ensuring that participants were available and willing to provide information. Meanwhile, the research assistants efficiently administered the surveys employing the expertise they had in data collection. Furthermore, it is interesting to note that a significant number of the Transgender individuals we approached had limited literacy, frequently having just basic or primary school education. Therefore, the majority of surveys were filled out by research assistants, who documented the information that was provided by respondents. We have originally administered the questionnaires in Urdu to ensure that transgender individuals understood the research objectives and pertinent concepts. This study included consultations with academic experts as well as human resource specialists. The intention was to determine and resolve any inconsistencies or logistical problems that may have occurred either before or after the data-gathering procedure.

4. MEASUREMENT

Transgender individuals have been asked to share information regarding SFS, CO, and CI that they have employed in response to DW. Finally, they were requested to provide opinions on the DW of their career accomplishment through the application of CI. We evaluated each of these ideas using a five-point Likert scale, where 1 meant strongly disagree and 5 meant strongly agree. To measure the variables involved in our study, we have adopted a collection of 43 questions; 40 questions from the variables included in this study and 3 control variables i.e. skills, education and age.

4.1 Decent Work

An adopted questionnaire from ILO (2008) containing 10 items scale were used to measured DW. The ILO has devised a community of work agenda that focuses on workplace rights, job creation, social dialogue, social protection, and gender equality as a cross-cutting objectives. These items generated an alpha value of 0.863.

4.2 Social & Family Support

An adopted questionnaire containing 13 items were employed for SFS. Six questions of social support are adopted from Sarason et. al., (1987) and seven most relevant questions out of 18 of family support were adopted from Dunst, Jenkins & Trivette (2007). These items produced an alpha value of 0.797.

4.3 Career Orientation

Career orientation is the degree of commitment to a profession or job responsibilities, was used a six-item questionnaire devised by Ellemers et al. (1998). These items generated a Pearson alpha value of 0.853.

4.4 Career Initiatives

The respondents shared their perceptions of the importance of career initiatives, their understanding of career objectives, and the significance of career initiatives in the process of career development. The 11-items scale was employed to evaluate this variable adapted from King (1999) and Gould (1979). An alpha value of the 11-items was 0.895.

5. ANALYSIS AND OUTCOMES

Finding the linear relationships among the variables used in the proposed model was the primary objective of this research. We made use of a covariance approach to analyze the linear relationships. According to Williams and Brown (1994), the simultaneous shift of two random variables is measured using a covariance-based approach. While the covariance-based approach is employed for determining the direction of the connection among the research variables, the variance-based approach reveals how the data set is distributed around its mean value. For data analysis, we used a different of statistical software, including AMOS 7.0, LISREL 8.54, and SPSS version 20.

Table 1

Demographic Profile (n = 237)

Transgender' Skills			Transgender' Age (Years)		
		Percentage			Percentage
Professional skills	47	19.83%	21-30	79	33.33%
Unskilled persons	190	80.17%	31-40	118	49.79%
			41-50	24	10.13%
			51-60	11	4.64%
			More than 60	5	2.11%
Transgender' Education					
		Percentage			
Illiterate	98	41.35%			
Primary	77	32.49%			
Matriculation	51	21.52%			
Intermediate	07	2.95%			
Graduate	03	1.27%			
Master	01	0.42%			
Higher than Master	0	0%			

5.1 Descriptive Statistics

The outcomes of descriptive statistics and relationships between variables are shown in Table 3. As per descriptive data, more respondents overall reported greater SFS scores. The SFS mean for the response group is also higher. CI and DW average levels were, correspondingly, 4.5 and 4.4. PWDs had an average age of 23 years. According to the findings of descriptive data, more respondents with disabilities on average reported better DW scores. Additionally, the SFS respondent sample mean is 4.8. The correlations matrix demonstrated substantial and favorable correlations among the dependent, mediating, and independent variables. Table 3 findings showed the association between CO and DW ($r = 0.23, p < 0.001$), CO and CI ($r = 0.38, p < 0.001$) CO and CI ($r = 0.27, p < 0.001$); CI and DW ($r = 0.42, p < 0.001$); SFS and DW ($r = 0.19, p < 0.001$), Analyses of the indirect effects of these connections are possible.

Table 2

Descriptive statistics and the correlation coefficient

Construct	M	SD	CR	1	2	3	4	5	6	7
Skills	13	.73	-	-						

Age	23	.81	-	-	-					
Education	3.2	.79	-	-	-	-	-			
CO	4.1	.91	.95	.09	.06	.49**	.81			
CI	4.5	.96	.89	.07	.07	.27	.38**	.78		
DW	4.4	.85	.87	.06	.04	.19	.23	.42**	0.89	
SFS	4.8	.82	.83	.06	.08	.07	0.9	.26	0.19	.87

Note(s): n = 273; SFS: Social & Family Support; CO: Career Orientation; CI: Career Initiatives; DW: Decent Work

5.2 Analysis Results

Regression analysis was used to examine the conditional direct influence of CO on DW in addition to the mediation effect of CI with regard to the CO-DW connection. Results are displayed in Table 3. Model 2 demonstrated a strong correlation between CO and DW ($\beta = 0.414^{***}$, CI = 0.050). H1 is suggested in confirming these findings. According to Model 5 in Table-3, CO ($\beta = 0.419^{**}$ CI= 0.032) highly predicts CI. These results confirm that H2 is accurate. Additionally, Model 3 shows that CI ($\beta = 0.346^{**}$ SE = 0.058) highly predicts DW. Consequently, H3 is confirmed.

In addition, Model 3 offers the mediating impact of CI in support of the CO-DW relationship in order to evaluate the CI mediating effects of CO and DW. After adding CI to Model-3, the coefficient of CO is still significant; in the meantime, the beta value has significantly dropped from Model-2 ($\beta = 0.169$, $p < 0.001$). The statistical results indicate that CI acts as mediating factor in the relationship between CO and DW. Thus, the current study's findings statistically supported H4.

Table 3
Regression Results

Variables	DV: Decent Work			MV: Career Initiatives	
	Model-1	Model-2	Model-3	Model-4	Mode-5
Controls					
Income	-.032 (0.055)	0.024 (0.039)	-.015 (0.039)	0.005 (0.047)	0.058 (0.041)
Education	0.044 (0.674)	0.018 (0.049)	0.008 (0.066)	.004 (0.073)	0.068 (0.067)
Age	0.085 (0.210)	0.037 (0.078)	-.017 (0.083)	0.019 (0.072)	-.081 (0.079)
Predictor					
CO		0.414*** (0.050)	0.169*** (0.038)		0.419*** (0.032)
CI			0.346*** (0.058)		
R ²	0.034	0.323	0.412	0.038	0.462
Adjusted R ²	0.041	0.359	0.432	0.029	0.437
F-value	2.724*	69.564**	71.235**	21.009**	78.531***
Durbin – Watson	2.891*	71.734**	78.097**	21.704**	82.562***

Regression Results. Note(s): DV (dependent variable); MV (mediating variable); CO = Career orientation; DW = Decent Work; Standard errors (parentheses); Significance level: ***p < 0.001; **p < 0.01.

The regression results of Hayes' (2013) "PROCESS" are shown in Table 4. According to the results, there was a positive and favorable correlation between DW and CO, SFS, and associated interaction terms ($\beta = 0.424, 0.224, 0.139$; $p < 0.001, 0.001, \& 0.001$ correspondingly). Moreover, there was a significant correlation between DW and CO, SFS, CI, and the associated terms of interaction ($\beta = 0.337, 0.168, 0.311, 0.116$; $p < 0.001$ across all values).

Table 4
Regression Results (Process-related)

Path Analysis	Career Initiatives	Decent Work
Controls		
Income	0.014 (0.064)	0.027 (0.076)
Education	0.019 (0.076)	0.019 (0.078)
Age	0.021 (0.077)	0.014 (0.066)
Predictors		
CO	0.427*** (0.042)	0.337*** (0.047)
SFS	0.224*** (0.038)	0.168*** (0.054)
CO * SFS	0.139*** (0.047)	0.116*** (0.051)
CI		0.311*** (0.036)
R ²	0.409	0.369
F-value	71.083***	65.437***

Note(s): CO = Career Orientation; CI = Career Initiatives; SFS = Social & Family Support; Standard errors (parentheses); Significance level: *** $p < 0.001$

In addition, the simple impacts were evaluated for both high and low SFS levels, according to the regression results displayed in Table 5. A sample of 5,000 was bootstrapped in compliance with Edwards and Lambert's (2007) instructions, and the outcomes of this procedure were applied to produce bias-corrected intervals of confidence for each test of significance in the present study. Higher SFS levels are associated with both a direct effect ($\beta = 0.680$; $p < 0.001$) and an indirect effect ($\beta = 0.339$; 95% bias-corrected CI: [0.177 0.364]) of CO on DW, as illustrated by Tables 5 and 6. In contrast, a direct effect ($\beta = 0.323$; $p < 0.001$; bias-corrected 95%) and an indirect impact (DW through CI; $\beta = 0.157$; $p < 0.001$; bias-corrected 95%) CI: [0.274, 0.479]) 95% bias-corrected were shown with lower levels of SFS and CO. H5 and H6 have been validated because the statistical data show that the direct as well as indirect impacts increase when the extent of SFS increases.

Table 5
The Conditional Direct Effect

Conditional Direct Effect						CI
Conditions	(95%) Effects	SE	T	p	LL	UL
Low (-ISD)	0.323	.059	5.997	0.069	0.274	0.479
Middle	0.440	.043	8.298	0.000	0.429	0.580
High (+ISD)	0.608	.042	9.738	0.000	0.485	0671

Notes: UL (upper limit); LL (lower limit); moderator (Social & Family Support); Bootstrap resample (5,000); SE (standard error).

Table 6
The Conditional Indirect Effect

Mediator	Conditional Indirect (Social & Family Support)				CI (95%)
	Conditions	Effect	SE (Boot)	LL	UL
Social and Family Support	Low (-ISD)	0.157	0.059	0.234	0.352
	Middle (0)	0.282	0.041	0.177	0.364
	High (+ISD)	0.339	0.042	0.207	0.449

Note(s): Social & Family Support (moderator); Bootstrap resample (5,000); standard error(SE); lower limit(LL); upper limit(UL); $\pm$ (standard deviation from mean).

Additionally, the study conducted a comprehensive analysis to determine whether the indicator of moderated mediation's Boot CI excluded zero, indicating the existence of substantial indirect effects by SFS. There is no conflict about the statistical results, which are fully described in Table 7. The moderated-mediation effects are not simply positively, but they are additionally fully backed by a 95% bias-corrected CI ($\beta = 0.053$; [0.013, 0.058]) that excludes zero. These convincing findings show that SFS moderates the direct connection between CO and DW along with the indirect effects of CO on DW by CI in a productive manner at the same time. Consequently, there is substantial empirical support for both H5 and H6.

Table 8
Moderated-Mediation Analysis

Independent Variable	Dependent Variable	Moderating variable	Mediating variable	Index	SE (Boot)	LL	UL
Career Orientation	Decent Work	Career Initiatives	Social & Family Support	0.053	0.008	0.013	0.058

Note(s): standard error(SE); lower limit(LL); upper limit(UL).

5.3 Hypotheses Testing

To evaluate the study hypotheses, structural equation modeling (SEM) had been employed. Table 3 depicts the path analysis findings. The finding shown in Table 3 indicates that SFS and CI are favorably and significantly correlated ($\beta = 0.34$, $t = 6.63$, $p .00$). Hypothesis 1 of the research is therefore confirmed. Moreover, CO and CI are favorably and significantly correlated ($\beta = 0.31$, $t = 5.35$, $p .00$) which verify that hypothesis 2 confirmed. Additionally, the findings demonstrated a significant relationship between CI and DW ($\beta = 0.43$, $t = 6.81$, $p .00$). These results are consistent with research Hypothesis 3. Similarly, it is evident from the findings that SFS and DW are significantly related ($\beta = 0.21$, $t = 3.63$, $p .00$). As a result, research Hypothesis 4 was confirmed. Hypothesis 5 was confirmed through the values of CO and DW showed significance ($\beta = 0.171$, $t = 3.32$, $p .00$).

Table 4 and 5 depict the findings of multiple regression analysis for the validation of indirect effect of SFS and CO. However, the direct effect of SFS was reduced and become insignificant ($\beta = .08$ SE = 0.067, t -value = 2.31). These outcomes indicated that CI mediates between the association of SFS and CO and supported H6. Moreover, the findings also indicated that when CI was included in the model as mediator, the direct effect of SFS was reduced and became insignificant ($\beta = .06$ SE = 0.066, t -value

= 1.23). These values established that CI mediates between the interactions of CO and DW and supported H7.

6. DISCUSSION

Investigating the internal mechanisms underlying the transition of CO into DW is the primary focus of this study. This study validated all six hypotheses that examined the mediating and moderating functions of SFS and CI, respectively, and produced an experimentally moderated mediation framework. The study's H1 overwhelmingly demonstrates that CO and DW have a direct correlation. These results align with the research by Xu, Liu, & Tang (2022), which verified that CO enhances DW in transgender individuals. H2 confirmed that CO and CI have a direct connection. These results validate the considerable correlation between CO and CI and are in line with the research of Rodrigues, Butler, and Guest (2019), who made contributions to the concept of dynamic capacity. Regarding H3, there is evidence of a positive correlation between CI and DW. The outcomes support the research conducted by Chibili (2019), who found that CI could help people develop DW. The connection between CO and DW and the function of CI as a mediator was the focus of research hypothesis H4. H5 validates CI's moderating effect, whereas H6 confirms mediated moderation. All hypothesis has been approved and found to be consistent with earlier research.

6.1 Theoretical Contributions

The current research contributes significantly to the existing literature and provides decent work in a very unique and distinguishing manner. The primary strength of this research is that it is one of the few studies that has employed a thorough analysis of CO to determine DW. There are very few prior studies that have provided a comprehensive description of how to improve DW. It's interesting to note that this is the first study project to ever examine the mechanisms of DW enhancement through CO, CI and SFS, of Transgender individuals in Pakistan. Second, the current research adds to the body of knowledge by providing a DW-Model for Transgender individuals with a focus on emerging nations like Pakistan. The model explains how the interaction of various variables, such as CO, CI and SFS, affects DW. The explanation of the connection across SFS, CO and CI was the third theoretical addition to the current research work. When a transgender are conscious of the value of DW, thinks clearly about it, and understands how transgender actions affect DW positively, he or she will act voluntarily in a career-oriented manner. Therefore, the transgender in question should make an attempt to enhance their DW through SFS and CO. The investigation of SFS and CO in delivering DW through CI is the fourth and fifth contribution of this research study respectively. CIs are significant, concrete actions that a transgender must take in order to improve his or her DW at their job. Evidence supporting CI causes and effects is scarce in the literature currently in publication. The current study thus concentrates on SFS and CO as prospective determinants of CI and DW as an outcome in order to fill the aforementioned research gap in the corpus of extant knowledge. This study examines the mediating roles of CI; it is suggested that CO has a stronger impact on DW through the mediating actions of CI. Finally, the moderating role of SFS indicates that societal support play an important role to promote DW among transgender individuals.

6.2 Practical Implications

The current study has significant implications for the governing body as well as transgender individuals. In accordance with the study, DW can be improved at the individual level through CI and this would contribute to an improvement in the DW of transgender. According to the research, the first important implication is that, CI is a transgender initiative that is carried out voluntarily, thereby, policymakers and other administrative bodies and transgender themselves should emphasis on the growth of CI because doing so will encourage individuals to perform their obligations in a more career-oriented direction. The second significant implication of this research is that, in order to improve the CI, the role of

transgender is crucial because, when the transgender contributes to professional growth, the CI will also improve, they will be inspired by their career development approach and be more motivated to demonstrate CI, which is a prerequisite for DW. The combined impact of CO, CI and SFS on DW is another significant research implication. When transgender are intrinsically motivated to improve DW because of learning, conscious awareness, and concern for career growth, and this drive results in tangible actions like CI, this mindset and behavior simultaneously contribute to having improved DW.

6.3 Conclusion

There are a large number of transgender community of working age worldwide. It seems obvious that a dearth of decent work affects transgender much more severely than other groups. Despite the reality that data on their career prospects are lacking and cross-national comparisons are challenging. Even after completing their education, a lot of transgender encounter difficulties to find decent work, which can lead to frustration and a decreasing level of ambition. However, due to biased impediments and misleading assumptions about their potential for work, a number of Transgender individuals give up actively seeking employment. Instead, they make an income doing low-value jobs in the informal economy with little support from their families and communities. Therefore, in order to motivate Transgender individuals to fulfill their responsibilities in a more career-oriented manner, NGOs, policymakers, other government organizations, and transgender community themselves should place stress on the development of DW. The primary objective of this research was to investigate the impact of SFS, CO on CI and DW. It has also been examined whether CI play a mediating function in the relationship between SFS, CO and DW. Transgender individuals can improve their DW by implementing CIs that result in a noticeable increase in DW. However, the CI serve as a bridge between the SFS, CO and DW. Therefore, the strength of the connection between CO and CI is significantly influenced by the transgender parsons' career perspective.

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Exploring the Role of Social Determinants in Non-Adaptive Behavior among Farmers in Pakistan

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Abstract

This study aimed to investigate the social determinants of non-adaptive behavior among farmers in Pakistan. The study focused on four dimensions of social factors: social comparison, social norms and networks, perceived inequity, and techno-salvation. The sample size was 355 farmers, selected using the Cochran formula for unknown population, from four districts of Punjab, including Rawalpindi, Chakwal, Attock, and Jhelum. Random sampling was used, and qualitative research methods were employed. The questionnaire was adapted from previous studies, and SPSS was used for descriptive, correlation, and regression analysis. The results of the study showed a strong relationship between all dimensions of social determinants and non-adaptive behavior. The findings suggested that social comparison, social norms and networks, perceived inequity, and techno-salvation were significant determinants of non-adaptive behavior among farmers in Pakistan. These findings have important implications for policymakers and practitioners working to improve the agricultural sector in Pakistan. They suggest that interventions aimed at addressing social factors, such as promoting positive social norms and networks, reducing perceived inequity, and improving access to technology, could be effective in promoting adaptive behavior among farmers in Pakistan.

Climate Change Adaptability: Improved Water Governance Strategy: Integrating a Proactive Risk Reduction Approach to Climate Change Challenges for Sustainable Development in Pakistan
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Abstract

This study's objective is to examine climate change adaptability, improved water governance mechanisms, and alternative strategies to counter the potential challenges of climate change, water scarcity, and GLOFs. Climate change and water scarcity pose a significant threat because of its profound impact on all facets of society and necessitate a holistic and proactive approach to mitigate their impacts effectively in Pakistan, which is currently lacking. Pakistan ranks 14 out of 17 “extremely high-water risk” countries in the world, and as per the IMF's recent report, Pakistan is third among the countries facing severe water shortages. Pakistan is also facing GLOF and high floods, which have killed hundreds of people, uprooted thousands more, destroyed livelihoods, and devastated infrastructure. Although Pakistan is a low greenhouse gas emitter, it is considered to have high climate vulnerability. This study will primarily emphasize how to make an efficient water governance system and what alternative strategies are to cater to imminent challenges. Secondary: how to address the potential threats of water scarcity, adopting advanced and operative measures, e.g., a water reservoir to enhance the water storage capability from 11% to at least 20%, modern technologies, drought-resilient crops, advanced irrigation systems, early flood warning and control mechanisms, etc. Tertiary: how alternative policies and water governance techniques play an imperative role, which can lead towards sustainable development economic growth. The research will offer several recommendations for climate change adaptability, water governance, boosting the resilience of vulnerable populations in Pakistan, and integrating a proactive risk reduction approach into the broader framework of sustainable development in the face of climate change challenges to ensure a safer and more resilient future for all.

Keywords: - Water Governance; Climate Change; Resource Scarcity; Sustainable Development; GLOF; Proactive Approach; Adopted capacity.

Physico-Chemical and Biological Analysis of Alpine Lakes Water in Gilgit-Baltistan

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Abstract

Water quality of alpine lakes, reservoirs, and rivers in developing countries gets affected by the contaminated inflows, exacerbated by ever increasing population, urbanization, modernization and increased recreational activities creating the problems of sewage disposal and contamination of surface waters like alpine lakes. There are many lakes in GB where 24 are well known. The alpine lakes in Gilgit Baltistan are contaminated due to weathering of rocks, leaching of soil, mining processing and tourism which has a huge influence on surface water pollution. The present study was designed to assess the contamination level and health risk assessment of heavy metals in two alpine lakes (phander, Satrangi). Overall, 36 water samples in triplicates were collected from two lakes in two seasons (Summer and autumn) from six sites each and analyzed for different physico-chemical parameters, heavy metals, microbial parameters (*E. coli*, Total coliform bacteria) and also determined BOD and COD of water samples. The concentration of Physical parameters EC, pH, TDS. Turbidity, temperature, color, chemical parameters chlorides, sulphates, phosphates, nitrates, iron, fluorides, carbonates, bicarbonates, hardness, calcium, magnesium, sodium, potassium and heavy metals AS, Hg, Cd, Cr, Mn, Pb, Al, Se, Ba, Ni, Zn, Cu in two lakes were compared with NSDWQ standards and WHO, overall, the physical and chemical parameters concentration was found to be with in the NSDWQ limits while the both the lakes were found contaminated microbiologically. Alpine lakes (Phander, Satrangi) water quality evaluation indices, including the water quality index WQI, human health risk assessment HHRA and) and Fuzzy-Topsis for physico-chemical parameters, heavy metals, BOD, COD and biological parameters, were estimated using the analytical results of the target parameters. The WQI was calculated for all physico-chemical and microbial parameters, BOD, COD and heavy metals of Satrangi lake in Autumn seasons is 3.288 and 3.9751 in summers, both the values fall in grade A ($WQI < 25$) The quality of water in Satrangi lake is excellent for Drinking, Irrigation and Industrial use. The WQI calculated value of Phander lake in summer was found 41.908 while in Autumn seasons is 36.5788. Both the values fall in grade B ($WQI < 50$). The quality of water in phander is good for Domestic, Irrigation and Industrial use. The average human exposure through drinking water in Phander lake in two seasons (summer and winter) for the selected heavy metals (Hg, Cd, Cr, Mn, Pb, Al, Se, Ba, Ni, Zn, Cu, As); the CDIs values were found in adults and children in order of $Cd < Mn < Ba < As < Al$ while, the CDI values of $Hg = Cr = Pb = Se = Ni = Zn$ and Cu are equal in concentration. The concentration of Hg, Cr, Pb, Se, Ni, Zn and Cu were found BDL. The CDIs of heavy metals in Satrangi lake were found in order $Mn < Cr < Ba < Al$ while the $Hg = Cd = Pb = Se = Ni = Zn = Cu = As$ were found BDL in (summer and autumn) in both Adults and Children. the HRI order in Satrangi lake were not found in safe limits because the HRI value for barium is ($Ba > 1$) the water in Satrangi lake in two seasons were found not safe for human consumption. Weathering of rocks is the main source of heavy metals contamination in satrangi lake them. The Fuzzy ideal solutions to each alternative we ranked of each alternative A_i to the relative nearest degree. From the tables IN Summer=MID Summer=OUT Summer> IN Autumn=MID Autumn=OUT (Autumn) was found the order ranking for Satrangi Lake and IN Summer>MID Summer>IN (Autumn)>MID (Autumn)>OUT (Summer)>OUT (Autmn) for Phunder Lake. It shown that IN (Summer), MID (Summer) and OUT (Summer) had highest concentration for Satrangi Lake and IN (Summer) for Phunder Lake respectively while, OUT (Autumn) had lowest heavy metal concentrations for both in water of Phunder Lake and Satrangi Lake.

Keywords: Alpine lake, Physico-chemical, biological indicator, Health risk, Gilgit-Baltistan

Looming Water Crisis in Chitral- GLOFs As a Climate-Induced Challenge and Ways for Mitigation

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Abstract:

Chitral, a region renowned for its stunning glaciers, faces a growing threat of water security due to climate-induced challenges. the frequent occurrence of glacial lake outburst floods (GLOFs), a phenomenon resulting from the melting of glaciers due to climate change is taking a devastating form with each coming year. The recurrent burst of glaciers in recent years with devastating floods in the regions of upper Chitral is also adding to the looming threat of water crisis in the region. This study aims to comprehensively examine the interconnected factors contributing to the water crisis in Chitral, exploring the scientific, social, and economic dimensions of glacial lake outburst. By understanding the dynamics of glacier behavior, assessing water availability, and analyzing the socio-economic repercussions, this research aims to contribute valuable insights and recommendations for the policymakers, communities within the region, and researchers engaged in mitigating the impacts of the water crisis in Chitral.

Keywords: Chitral; climate-induced challenge; glacier burst; GLOFs; water crisis; socio-economic repercussions

Adapting to Climate Change by Mitigating GLOFs in Pakistan

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Abstract

Water is a vital resource and foundation for life, but due to climate-induced water scarcity and the looming threat of glacial lake outburst floods (GLOFs), the agricultural sector in Pakistan is facing a critical stage. The theme delves into the crucial interplay between climate change adaptability, water governance, and GLOF mitigation, aiming to cultivate resilience and secure sustainable agricultural production in such a climate shift paradigm. By the adoption of drought-resistant crop varieties, diversification of cropping systems, and implementation of water-saving irrigation technologies as strategies for farmers to adjust to altered rainfall patterns and extreme weather events. Also, effective water management is paramount for agricultural sustainability. The irrigation management models, transparent water allocation policies, and community-based water conservation initiatives as potential avenues to enhance equitable and sustainable water use in the agriculture sector as agriculture is the backbone of the country. Our findings aim to inform the development of robust water governance frameworks that empower farmers and optimize resource utilization. The specter of GLOFs necessitates proactive mitigation measures. We analyze the effectiveness of early warning systems, floodwater control infrastructure, and community-based evacuation plans in minimizing agricultural losses and safeguarding livelihoods in GLOF-prone areas. By proper planning we can contribute to the development of comprehensive GLOF preparedness strategies that prioritize the protection of agricultural lands and food security. Ultimately, the theme highlights the critical need to value water as an indispensable resource for agricultural sustainability. By fostering climate adaptability, strengthening water governance, and enhancing GLOF preparedness, we can cultivate resilient agricultural systems that thrive in the face of a changing climate and ensure food security for a good social and economic future.

Keywords: Climate Adaptability, Water Governance, GLOF Preparedness, Agricultural Resilience, Sustainable Farming, Valuing Water

Evaluation of Precipitation Patterns, Extremes, and Drought Over Pakistan

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Abstract

Satellite-Derived Precipitation Products (SDPPs) have become increasingly important in recent years, providing global coverage and relatively inexpensive production costs. However, their performance in regions with a diverse climate and complex topography is still under evaluation. The purpose of this research is to analyze the Tropical Rainfall Measuring Mission (TRMM) of Multi-satellite Precipitation Analysis (TMPA/3B42), the improved Global Precipitation Measurement (GPM)-based Integrated Multi-Satellite Retrievals (IMERG), and Global Precipitation Climatology (GPCP) SDPPs against Surface Precipitation Gauge (SPG) observations over Pakistan for the period 2000 to 2019. Homogeneity tests (Pettitt, Buishand, and Standard Normal Homogeneity Test) are applied to the SPG data to ensure the quality, comparability, and reliability of the precipitation data. To evaluate the performance and accuracy of SDPPs on a seasonal (December – March, April – June, July – September, and October – November) timescale, the Pearson's Correlation (R), Mean Absolute Error (MAE), Relative Bias (RB), Root Mean Square Error (RMSE), and Nash-Sutcliffe model Efficiency (NSE) coefficient are used. The daily performance of SDPPs in detecting precipitation events is assessed using the Probability of Detection (POD), False Alarm Ratio (FAR), and Critical Success Index (CSI) statistical approaches. To quantify the magnitude of trends and assess their statistical significance, non-parametric approaches (Sen's slope estimator and the Mann-Kendall test) are employed. Additionally, precipitation events are categorized as mild, moderate, severe, and extreme based on the 85th, 90th, 95th, and 99th percentiles, respectively, and are subsequently analyzed. The Standardized Precipitation Index (SPI) is also calculated for the year 2002 (as this year marks the peak of the most prolonged drought episode in the history of Pakistan, lasting from 1999 to 2002, affecting almost 70% of the country's total area) to analyze the efficiency of SDPPs in detecting droughts. Our findings reveal a clear north-south gradient in total annual precipitation across Pakistan, where the upper half, encompassing the core monsoon zone, receives significantly more precipitation than the southern half. The maximum annual precipitation amount (>1000 mm/year) is observed in the higher latitudes of the country, whereas the minimum amount (<150 mm/year) in the lower latitudes of Pakistan (Sindh and Balochistan). While all SDPPs capture the spatiotemporal patterns of precipitation, their accuracy varies across the region. IMERG and TRMM demonstrate better capabilities in detecting precipitation extremes at all the thresholds, followed by GPCP, which tends to overestimate the extremes. TRMM emerges as the most reliable SDPP and performs relatively well in capturing drought patterns with slight underestimation in certain areas such as D.I. Khan. The highest overestimation by TRMM is recorded in Sindh which is up to -1.99 at Chhor, Nawab shah and Padidan while in Karachi a little overestimation is observed. Conversely, both IMERG and GPCP consistently exhibit a bias towards overestimating precipitation, particularly in lower latitudes and during drought years. This study will help to contribute to regional adaptation and policy planning by providing crucial insights and identifying the appropriate satellite product for precipitation measurements.

Rainwater Harvesting Potential Sites at Margalla Hills National Park

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Abstract

Life without water is not possible. Adoption of modern lifestyle and increase in population is leading to a water scarce world. The demand of world population cannot be met, which is resulting in increased groundwater abstraction. The world is facing water crisis and Pakistan is no exception. Urban areas of Pakistan are affected badly where extraction is higher while the construction of pavements has disturbed groundwater infiltration. The Federal Capital of Pakistan, Islamabad, is in Pothohar region of the country and faces severe water shortages, particularly during summers. Extensive ground drilling by public and private users lowers groundwater table. Satellite imagery of LANDSAT 7 ETM+ and ASTER DEM 30m resolution were used to construct the site suitability map for groundwater recharge of Margalla Hills National Park. Factors considered included land cover, drainage density, elevation, and slope. Suitable weightages were assigned to these factors according to their influence on infiltration in the study area. Since streams originating from Margalla hills are the main source of groundwater recharge for the areas lying at foothills and also are a source of surface water for the residents of capital city, as all the streams ultimately drain into Rawal Lake. The water recharge at Margalla Hills will help in raising the water-table level of the surrounding areas through increasing stream water flow, and the resultant increased runoff could be utilized effectively through harnessing the runoff by installing water harvesting structures at areas which are worst hit by climate change. Groundwater recharge potential at Margalla Hills National Park may prove to be effective in dealing with the water crisis in Islamabad as it will raise groundwater table of the adjacent areas.

Keywords: Water scarcity, Groundwater recharge, Margalla hills, Islamabad, Urban sectors

Impact Assessment of Glacier Lake Outburst Flood in Chitral Pakistan

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Abstract

Climate change is causing significant loss of glaciers all over the world. Glaciers in Himalaya are receding faster than in any other part of the world increasing the phenomena of Glacier Lake Outburst Floods (GLOFs) in the region. Himalayan glaciers in northern areas of Pakistan act as a source of life by feeding more than 60% to the water flows from upper Indus Basin. This study presents an analysis of socio-economic damages of Glacier Lake Outburst Flood (GLOF) events in district Chitral. Chitral valley is situated in the north of Khyber Pakhtunkhwa province. Glaciers are the main features of the life in valley with 13% area covered with glaciers. Many glaciers have developed glacier Lakes, and the valley experienced many events of Glacier Lake Outburst floods in past. Three sample villages of Booni, Reshun and Ghohkir were randomly selected for micro-level analysis of flood damages. Analyses of the study showed that the flood has affected more than half population of the study areas. The trend of maximum temperature has increased, and minimum temperature showed a decreasing trend in forty years. Precipitation in form of rainfall has increased. Rising temperature and precipitation in form of rainfall increase the melting of glaciers, reducing snow accumulation during winter season and increased the phenomena of Glacier Lake Outburst Floods (GLOFs) which has affected all the livelihood opportunities for locals.

Keywords: Climate Change, Mountains, GLOF, Glaciers, livelihood.

Introduction

The earth's climate has always been categorized by natural disparities. However, the mean annual air temperatures rose rather intensely in the 20th century (Bolch, 2007). During this period the beginning of industrial revolution has created unparalleled changes in the chemical composition of earth atmosphere. Now evidence show these changes are affecting the global climatic system (Kuma and Rupa, 2006). The impact of climate change on mountainous environment is very important to understand because 20% of earth's surface is covered by the mountains. Climate change and variability is making the life of people in mountainous areas more difficult as the mountains are more sensitive to these changes due to their topography, delicate nature, and steep gradient (Hussain *et al.*, 2005). The changes in glaciers geometry provide strong evidence of climate change so glacier observations have been used for climate monitoring from many years (Luckman and Kavanagh, 2000). Glacier lake outburst flood is the sudden discharge of water under high pressure from a glacier (Richardson and Reynolds. 2000). This sudden release of water has catastrophic effects in downstream areas damaging the property and agricultural lands (Mokrech *et al.*, 2008). Large amount of water can be stored in or under glaciers and cause serious flooding even no lake is visible. Any glacier forms glacier lake outburst flood (GLOF) and glaciers with no visible lakes present serious flood hazards (Carey, 2005).

Pakistan has an area of about 17,000km² covered with glaciers. Climate change causes the melting of these valuable glaciers making Pakistan more prone natural hazards (Khan, 2013). According to Germanwatch Global Climate Risk Index 2017 Pakistan ranked 7th among the most vulnerable countries to climate change. The study area of Chitral experiences frequent Glacier Lake Outburst Floods (GLOFs) in its long history but with the beginning of twenty first century both the intensity and frequency of these flood increase many times. There are about 542 glaciers in Chitral covering an area of 13%. Almost 187 glaciers out of these have form glacier lakes (Rehman *et al.*, 2015). The weather pattern of the area also shows a change affecting the crops and fruit ripping process.

MATERIAL AND METHODS:

Environmental setting of study area

Chitral is the district of Khyber Pakhtunkhwa province in the north of Pakistan. It covers an area of about 15,000 km² in a mountainous territory and located at the height of 1000m - 7700m than sea level (asl). It shares its borders with the Afghan provinces of Badakhsha and Kunar to the west and north. In North the thin strip of the Wakhan Corridor separates Chitral from Tajikistan. The Ghizer district in northern areas of Pakistan located in the east of Chitral and to the southeast are the western regions of Dir, Swat and Kohistan districts. The district has more than 40 peaks above 6000m and valleys located 900m below these mountain peaks (Dichter 1967; Haserodt 1996) (Khan *et al.*, 2013). High mountain ranges are the main feature of Chitral. Most of land is either glaciated or cover with rocks. Glaciers covered approximately 686km² that is 10% of total land area. More than 20 glaciers are about 10km. The climatic condition of Chitral is dry and temperate and bulk of precipitation is received during winter season. Summer months from June to September are usually dry that promote the formation of glaciers in high mountains. These glaciers fed the river system of Pakistan (Ives *et al.*, 2010).

Methodology

To achieve the objectives of the study both primary and secondary sources of data collection were used. Primary data were collected through a standard questionnaire, personal observations, and focused group interviews. In order to carry out micro-level analysis of flood effects three flood-affected villages were considered as a sample of study. The sample villages were Reshun valley, Koragh and Shughram village in which 200 questionnaires were filled used random technique. The questionnaire contains information of main components such as social services, facilities, existence of infrastructure, potentials of natural resources etc. The respondents belong to a variety of professions include farmers labors, businessmen and educationists etc. Secondary data were obtained from District Disaster Management Unit (DDMU) about the flood events and their damages. Climatic data of maximum temperature, minimum temperature, rainfall and precipitation of the region were collected from Pakistan metrological department Lahore station. The data were then statistically analyzed to assess the consequences glacier melting due to climate change on the communities living in areas adjacent to glaciers.

Results and discussion

Analysis of flood effects through questionnaire survey

Socio demography:

All the respondents were male and 82.5% of them were married. In study population about 85.5% lived in joint family system and 14.5% have nuclear family. They were belonged to various occupations e.g., divers (10%), shopkeepers (7.5%), labors (17.5%), government (6%) private (6.5%) employees, retired people (7%) some students (11.5%) and unemployed (11.5%) were also interviewed. Majority of the respondents (18%) were servicing in armed forces either in Pakistan army or in frontier corps. Flood has affected income source of 49% people. Among the respondents 88% were literate and all of them (100%) have access to primary education. Flood has affected schooling of 39% children in the area by damaging of roads and school building.

Infrastructure and other facilities:

Health center in the area is located at the distance of half an hour from the village. 2% respondents experienced health problems after flood. Flood affected the power house in Reshun valley that supplies electricity to upper Chitral Mastuj tehsil. So, it affected electricity supply of 100% respondent. The power house is still not being fixed. Road access to the areas also has not been constructed at all. All the interviewed persons (100%) own property that has been damaged by flood. 16.5% people lost their shops, 27% farm land and 8% other business property. During flood all people of the area have to displace from their home. Flood washed away completely the houses of 17% respondents and 83% of them move to their relatives and 2% to the rented house. The community received flood warning from Metrological Department. The villages depend on spring water for drinking purpose before and after flood but after flood water quality degraded. All the respondents used solar panel for lighting which is not very affective they said as the study area received very little solar light due to its geographic location. Most of the respondents used LPG cylinders (54.5%) for cooking and 45.55% used firewood purchased from market. All the respondents (100%) said that the flood also affected the price of their basic non-edible commodities

Effects of flood on Agricultural land:

Among the respondents 58.5% own land area of 1- 3 acres, 31 % own 4-5 acres, 8.5% have 7-9 acres and only 2% have above 9 acres land area. 80.5% respondent lost 1-3 acres land, 7% lost 4-6 acres of land in flood.

Livestock

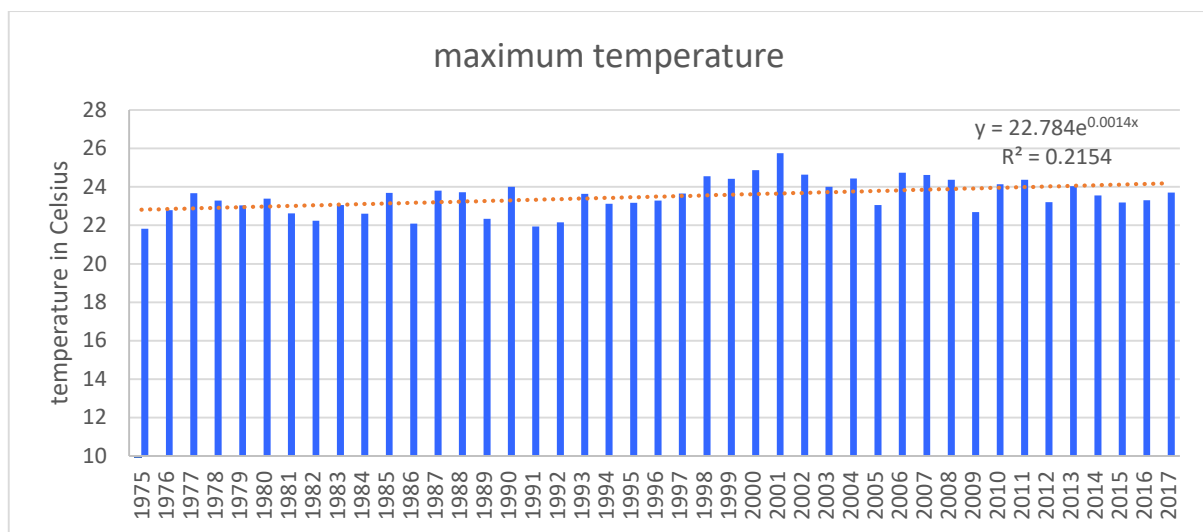
In study area people breed livestock e.g. cows, goat chicken etc. among the respondents 42.5% have one cow, 50 % have two cows and 10 % have 3 cows to meet their own dairy needs.

Relief and compensation:

In the study area 95.5% respondents received compensation from government and NGOs among them 43.5% received food aid, 57% received relief funds and 4.5 % did not received any compensation at all, none of the respondent was satisfied from the relief and compensation provided.

Interpretation of climatic data as a major cause of flood

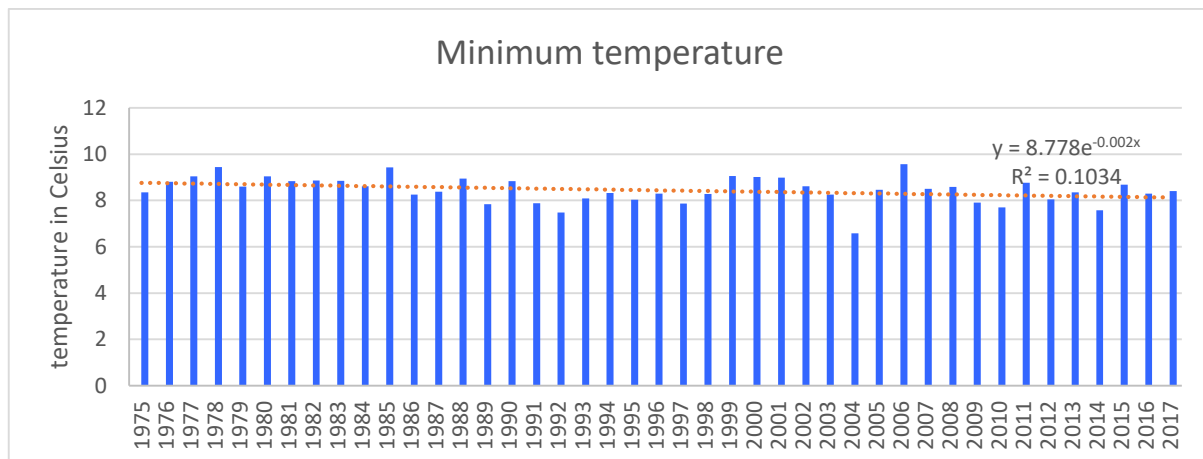
In Chitral valley mean maximum temperature increases in forty-two years. The trend line in graph of annual mean maximum temperature shows that the mean annual maximum temperature gradually increases with the spell of rise and fall. From 1996 to 2003 mean annual temperature is highly increase and it is highest during 2000. The data confirm the global warming trend affecting the Himalaya glaciers. As the mountainous environment is highly sensitive to little change in temperature so, the increase in temperature increases the frequency of anomalies and associated hazards. A study conducted by Bhutiyani *et al.*, (2007) revealed that the maximum temperature is increasing for mountainous environment especially for Himalaya ranges. The study showed about 1.6 °C increased in temperature for Hindu Kush Himalaya and winter maximum temperatures more rise than summer. In Pakistan northern mountain ranges experienced 1.3 °C rise in temperature after 2001 (Rasul *et al.*, 2011) Many studies carried out in India, Nepal, China and Bhutan (Singh and Kumar, 1997: Hewitt 2005: Shrestha and Aryal 2011: Immerzeel *et al.*, 2013: Lutz *et al.*, 2014) confirmed that Himalaya ranges are facing more temperature rise than other part of world. A study was conducted by Nogués *et al.*, (2007) to show the response of global mountains to climate change found that the mountains in the region of Asia have greatest increased in temperature than the mountains in other part of the world.



Mean maximum temperature ,1975-2017

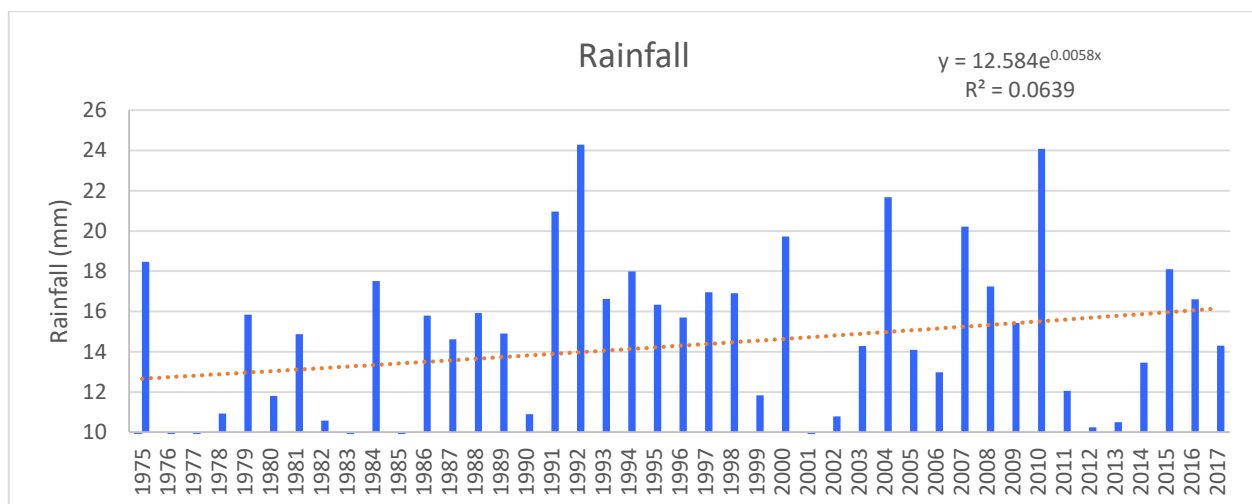
The mean minimum temperature recorded for district Chitral in past forty-two years shows a decreasing trend. The lowest mean minimum temperature of 6.6 °C was recorded in 2004 and highest mean minimum temperature experienced in 2007 was 9.6 °C. The study area has a mountainous environment in which winter coldest temperature favor the formation of ice during the month of December and January, but due to the change in weather winter months are not receiving heavy snow fall. According to Wibig and Glowicki, (2002) the minimum temperature showed a decreasing trend mostly in winter months because mostly in winter days the minimum temperature remains below 0 °C. The number of cold days decreased in spring and the month like March shows an increase in minimum temperature and again in summer minimum temperature

recorded in high mountainous areas shows a decreasing trend. Dash *et al.*, (2007) also found that minimum temperature in western Himalaya show decreasing trend in past few decades.



Mean minimum temperature, 1975-2017

The data of monthly mean precipitation mm trend for Chitral station shows that precipitation increased in past forty years in the study area. The precipitation occurs in form of rain but the snowfall decreased. Snowfall pattern shifts from early winter to late winter months and the snow that fall immediately melts down in the month of March. The December month became drier and the precipitation trend increased in the month of February. So, the time required for conversion of snow into ice does not complete and ice in glaciers not accumulate and glaciers in warmer summer months start forming lakes causing outburst floods. Some anomalies also associated with this increase in precipitation. According to Shrestha *et al.*, (2000) the precipitation in Himalaya increased in monsoon period and cause severe flooding in rivers and streams of India and Pakistan Bhutiyani, *et al* (2010).



Chitral Mean precipitation mm, 1975-2017

The fluctuations in temperature and precipitation and the resulting anomalies are making catastrophic events more severe in Chitral. In winter months avalanches in valleys now became usual events. Many valleys are prone to avalanches and many are flood prone. The study area of Reshun

valley is highly prone to Glacier Lake Outburst Flood (GLOF) due to its geographic location. Two debris type glaciers are located just above the valley (Owen *et al.*, 2002). The field survey carried out in the study area through questionnaire, personal observations and groups interviews showed that the flood has caused severe damaged to infrastructure and property. Majority of the people were farmers and belonged to low-income group. Flood washed away their farmlands. Many people lost their homes and were living in shelter houses. The same GLOFs events occur in other parts Himalaya, Attabad Lake in Gilgit Baltistan developed in 2010 as a result of Glacier Lake Outburst Flood affected thousands of people block the Hunza River for at least five months and in 2012 Gayari sector accident was also link with changes in glacier geology. The increased melting of glaciers and formation of Glacier Lakes due to changes in climatic conditions are making northern areas of Pakistan highly venerable to natural disasters.

According to Riaz et al., (2014) recent research of GLOF project in Pakistan under the domain of Pakistan Meteorological Department in northern districts of the country to assess the likelihood GLOF events and to identify people at higher risk in the localities of glaciers. The research highlighted district Chitral is at high risk to natural hazards. Many studies all over the world showed glacier lake Outburst floods are the most dominate glacier related hazard. Theses floods have killed thousands of people damaging property and infrastructure (Clarke, 1982: Clague and Evans, 2000: Richardson and Reynolds, 2000: Huggel et al., 2004: Carey, 2005)

Summary and findings

The analysis revealed Chitral valley is highly vulnerable to climate changes due to presence of glaciers. The analyses of climatic data show that the maximum temperature and precipitation in form of rainfall (mm) has increased during past forty years. Chitral is a home of many glaciers, and the increasing temperature and precipitation caused the melting of these glaciers and formation of Glacier Lakes in high mountains. These Glacier Lakes caused Outburst floods in adjacent valleys. Similar Glacier Lake Outburst Flood in Reshun valley, Booni and Gohker caused severe destructions. These valleys also have previous history of such type of floods due to their geographic location. The recent flood has affected more than 500 households in the areas. Many houses were completely washed away. Flood damaged road access to the areas and cut off the electricity supply by damaging two power houses. These power houses were supplying electricity to whole Mastuj Tehsil of district Chitral which are still not repair. The damages to the standing crops and orchards were also very high. After flood people are living in very difficult situation without basic necessity of daily life. Almost two years after flood they still lack the facility of clean drinking water. The trend of increasing temperature predicts future flooding in the areas.

Development of Sustainable Stormwater Management Plan for Mehran UET Jamshoro under Climate Change Scenario

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Abstract

Climate change poses a significant challenge to stormwater management, causing flooding risks to areas without storing water for different purposes. To tailor these specific needs and challenges, this research aims to develop a sustainable stormwater management plan under a climate change scenario considering Mehran UET, Jamshoro, as a study area by establishing a set of objectives. Initially, current stormwater management and drainage practices were assessed through field surveys, interviews, and spatiotemporal mapping of rainfall events by utilizing various GIS tools through geospatial data. After that, the evaluation of previous and impervious land cover was estimated through a supervised classification process. To develop a proper stormwater management plan in MUET Jamshoro, the physiochemical analysis, hydrology of the area, percentage of previous and impervious cover, and elevation of the selected area were calculated. The results have shown that with time, pH, TSS, and Turbidity of rainfall decreased, whereas the temperature was mostly stable at 30° C. The findings of this research will offer practical guidance and endorsements for the Policymakers of the university and local authorities in the best possible way to develop and implement a sustainable stormwater management strategy that considers climate change and identifies the best drainage routes for effective stormwater management.

Keywords: Climate Change, Stormwater Management, Sustainable Infrastructure

1. Introduction

Supportable urban stormwater management(SUSM) is a complete and incorporated way to deal with overseeing urban water, which tends to sanitary perspectives, yet additionally environmental and personal satisfaction issues SUSM is certainly not another idea, as many high-level and notably specialized arrangements as of now exist, however, contains all them (e.g. alternative techniques, compensatory techniques integrated urban water management(IUWM) best management practices(BMP), low impact urban design and development(LIUDD) sustainable urban water management(SUWM) low impact development(LID), water sensitive urban design (WSUD), green infrastructure(GI), nature-based solutions(NBS), and the sustainable urban drainage system(SUDS). Regardless of the adopted concept, the goals are similar: managing urban stormwater in a more sustainable way[1]. The management of surface runoff from impermeable regions, both quantitatively and qualitatively, is currently under intense discussion considering potential changes. Urbanization-related land use changes include the loss of vegetation sustainable urban water management (SUWM) and the replacement of pervious areas with impervious ones. These changes affect the surface runoff hydrograph's features and increase stormwater runoff volumes and peak flows. Wastes and pollutants produced by anthropogenic activity in urban areas end up on catchment surfaces where they might end

up in water bodies during storms. Also included are any industrial or domestic wastewater. To ensure the operation of the built sites and to safeguard public health, drainage systems must be established. Recently in monsoon rains, Pakistan was badly affected. It caused havoc economically, infrastructure, human lives, agriculture, etc. As per the Meteorological Department of Pakistan, 33 million people migrated[2]. Among all provinces, Sindh was the most affected. Pakistan metrological department recorded 247mm in 15 Days of rain in Hyderabad and Jamshoro, which exposed the failure of drainage and raised the need for a Stormwater Management System[3]. This study is focused on Mehran University of Engineering and Technology, Jamshoro area, where there is no proper facility except a few small open drain areas, which are of no use. Because the water stored by rain is not used for any purpose such as watering trees, washing roads, and other needs of departments and there are a lot of impervious surfaces available in Mehran UET, which may be converted to pervious or semipervious stormwater can be stored by the soil through which water table will be maintained. Therefore, suitable practices and software including GIS need to be used to improve the stormwater management system of MEHRAN UET, Jamshoro through spatial modeling.

1.1 Stormwater Management:

Understanding how water behaves at various stages of the hydrologic cycle is shown as stormwater management. To build the best system that can be used at any given moment, the majority of management work is done in light of precipitation events. Applications for this concept, plan technique, and work maintenance include water transportation, agricultural waste management, flood prevention, and lake management. Water has been effectively blended into the urban environment using this stormwater control method. Additionally, this water has served as a catalyst for revitalizing urban cores and a source of water supply in certain desert regions[4].

Integration of all technical, social, and environmental variables is referred to as "integrated water management" (IWM). Many of the issues with catchment area health and water supply concerns confronting modern metropolitan communities have been successfully addressed with this strategy. IWM, also known as low-impact development, offers a freshwater source to supplement the supply of potable water and can enhance runoff quality, reduce the likelihood and effects of floods, and reduce flood risk[5].

Importance of Stormwater Management:

- Preserve the Natural Hydrologic Cycle
- Flood Prevention
- Stream Erosion Control
- Water Quality Protection

Practices To Manage Stormwater:

- Integrated Stormwater Management
- Best Management Practice (BMP)
- Low Impact Development (LID)

2. STUDY AREA

Jamshoro, known as the "City of Breezes," is situated on the eastern bank of the Indus River and is the host of three of Sindh's most distinguished universities. Mehran University of Engineering and

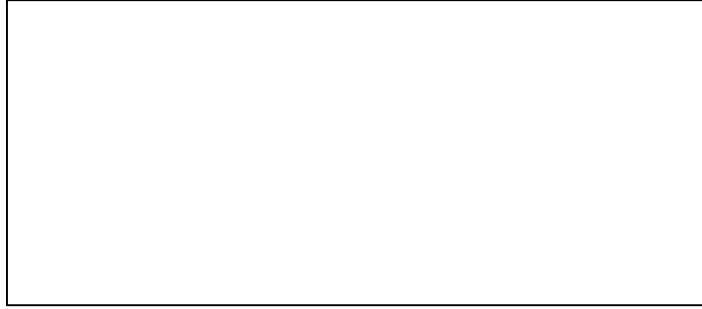


Fig 1: Study area

Technology (MUET) is selected as a study area which is situated at Longitude $68^{\circ}15'35.79''$ East and Latitude $25^{\circ}24'54.64''$ North as shown in Fig 1 and 2. Typically, the university experiences hot, humid, dry, windy summers and sort, mild winters with Temperatures varying from 45°C to 8°C and wind speeds varying between 4 to 3 mph from summer to winter, respectively. MUET is situated at a median height of 58 meters above mean sea level (MSL)[6].

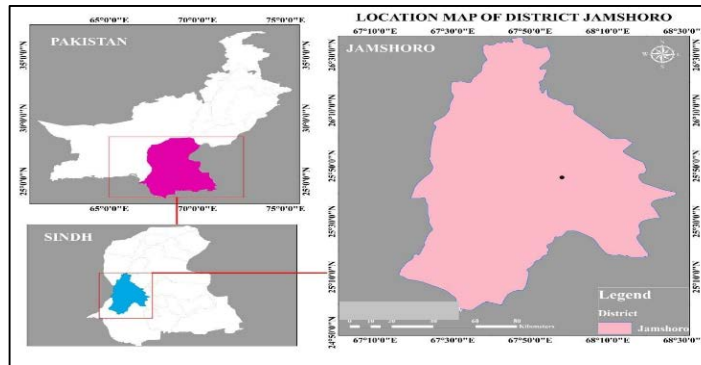


Fig 2: Study area in raster format

3. METHODOLOGY

The development of a sustainable stormwater management plan for Mehran UET, Jamshoro, under the climate change scenario was carried out using GIS and remote sensing-based supervised classification, which identified the existing stormwater drainage path and impervious cover through spatial data using the contour, stream flow mapping, and supervised classification.

3.1 METHODOLOGICAL FRAMEWORK

The methodological framework adopted for developing a sustainable stormwater management plan under a climate change scenario considers Mehran UET, Jamshoro, as a study area as shown in Fig 3. Initially, current stormwater management and drainage practices were assessed through field surveys, interviews, and spatiotemporal mapping of rainfall events by utilizing various GIS tools through geospatial data. After that, the evaluation of pervious and impervious land cover was estimated through a supervised classification that utilized the digital elevation model (DEM) to construct a contour mapping. To develop a proper stormwater management plan in MUET Jamshoro, the physiochemical analysis, hydrology of the area, impervious cover, and elevation of the selected area were calculated[7].

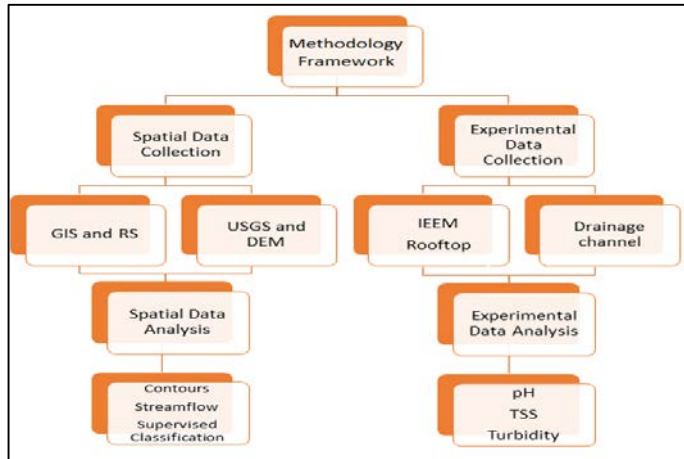


Fig 3: Methodology Framework

3.2 SPATIAL DATA COLLECTION

For the collection of spatial data, the power of GIS, remote sensing, and Google Earth was employed. These technologies were used to acquire SHAP files, satellite imagery, and digital elevation models from USGS. The downloaded satellite imagery data was exploited in GIS, to create stream flow mapping, contour maps and conducted a supervised classification process to categorize land types[8].

3.2.1 GEOGRAPHIC INFORMATION SYSTEM

Geographic Information System (GIS) is a powerful tool that enables the collection, analysis, and visualization of spatial data. Its significance in stormwater analysis lies in its ability to provide valuable insights by integrating geographical information, helping in compelling informed decisions for effective stormwater management, flood control, and environmental protection[9].

3.2.2 REMOTE SENSING

Remote sensing (RS) is the technique of acquiring information about the Earth's surface and atmosphere from a distance, typically through satellite or aerial imagery. Its importance in stormwater management plans lies in its capacity to monitor and assess changes in land cover and precipitation patterns aiding in the development of effective strategies for flood mitigation and water resource management[10].

3.2.3 DIGITAL ELEVATION MODELS

The Digital Elevation Model (DEM) is a representation of the Earth's terrain, providing elevation information for specific geographic locations. DEMs are crucial for contour mapping and supervised classification in GIS, as they serve as the foundation for accurately depicting landforms, identifying drainage patterns, and delineating different land cover types, contributing to precise spatial analysis, and planning[11].

3.3 EXPERIMENTAL DATA COLLECTION

To analyze the quality and characteristics of stormwater for sustainable usage two specific sampling sites were chosen: the rooftop of the IEEM Building and the drainage channel beside USPCAS-W. A total of 14 samples were collected 10 from the rooftop of the IEEM building and 4 from the drainage channel at a 5-minute time interval as shown in Fig. 4. The discharge rate and physiochemical analysis were carried out for the collected samples which helped in gaining insights into the dynamics of stormwater flow and the accurate measurement of discharge rates, contributing to effective stormwater management and planning.

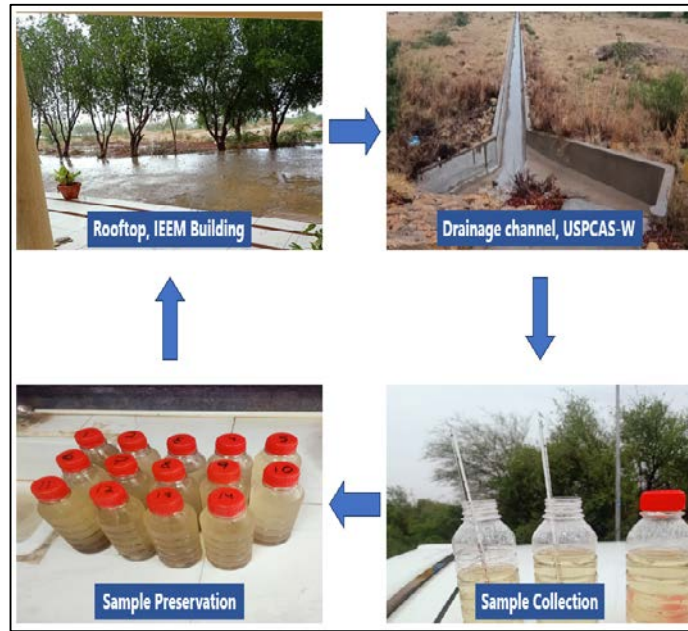


Fig 4: Experimental Data Collection

3.4 SPATIAL DATA ANALYSIS

The collected spatial data was utilized for developing contours, streamflow, and a supervised classification model for a sustainable stormwater management plan for Mehran UET under the climate change scenario. The methodology of spatial data analysis is segmented into three distinct phases[12].

- A. Data Acquisition
- B. Data Pre-processing
- C. Data Transformation

3.4.1 DATA ACQUISITION

Data acquisition serves as the primary and essential step in establishing contours, streamflow, and supervised classification models. This phase entailed the retrieval of historical monthly data on land cover and land features for MUE'T Jamshoro, obtained from satellites such as Sentinel-1 and Sentinel-2. Furthermore, historical monthly water integration data was acquired from the USGS, which continuously gathers live data from satellites like Landsat 8 and Landsat 9. Additionally, the Shapefile of Pakistan was downloaded from DIVA GIS. These comprehensive datasets were gathered over two years, spanning from 2021 to 2023. Satellite data from Landsat and Sentinel was affected by cloud cover limiting the quality of imagery and hindering accurate analysis, for which the data pre-processing was carried out[13]–[15].

3.4.2 DATA PRE-PROCESSING

The initial dataset, comprising historical monthly land cover, land features, and water integration data from Sentinel 1 and 2, Landsat 8 and 9, exhibited issues such as pixel breakage and cloud cover. To improve the data quality and efficiency for the supervised classification model, data preprocessing was conducted. This involved techniques like mosaicking and SAR command to address cloud cover issues. Additionally, a Digital Elevation Model (DEM) was utilized for contour mapping, extracting land features, and hydrology mapping purposes[16], [17].

3.4.3 DATA TRANSFORMATION

After the initial data preprocessing, a subsequent data transformation step was implemented to further enhance the dataset's utility. This involved an in-depth analysis of the dataset's features to facilitate contour and stream flow mapping, a process executed using ArcGIS[18]. This transformation phase allowed for a more comprehensive understanding of the terrain and hydrological characteristics, enabling precise contour mapping and the identification of stream flow patterns within the MUET Jamshoro.

3.4.3.1 CONTOUR MAPPING

Contour mapping, a cartographic technique was utilized to represent the three-dimensional surface of the MUET Jamshoro on a two-dimensional map using a digital elevation model which helped in mapping contour lines. These contour lines connected points of equal elevation provided a visual representation of the land's topography and allowed for the visualization of changes in terrain, such as elevations and slopes[19].

3.4.3.2 STREAM FLOW MAPPING

The stream flow analysis of MUET Jamshoro in ArcGIS involved a systematic process to understand and quantify the flow patterns of water within the study area. Initially, the study area's pre-processed spatial and environmental datasets were collected, including digital elevation models (DEM) and satellite imagery[20]. The DEM was crucial for generating a precise representation of the terrain, enabling the identification of drainage patterns and flow pathways. Subsequently, in ArcGIS, a series of geospatial tools and techniques were employed, including hydrological modeling and flow accumulation analysis. These processes allowed for the delineation of watersheds, the computation of flow direction, and the creation of stream networks. Moreover, the integration of observed hydrological data with GIS tools enhanced the accuracy of the stream flow analysis. The resulting stream flow maps provided valuable insights into the distribution of watercourses, which are essential for water resource management and flood risk assessments in MUET Jamshoro[21].

3.5 SUPERVISED CLASSIFICATION

The utilization of supervised classification plays a pivotal role in crafting a sustainable stormwater management plan for Mehran UET. The process begins with the creation of composite bands, which combine multiple spectral bands from 1 to 7 of satellite or aerial imagery to enhance the discrimination of different land cover types[22]. These composite bands are then used to generate accurate and detailed land cover classification maps. By applying supervised classification techniques in GIS, the imagery was categorized into distinct classes, such as impervious surfaces, vegetation, and water bodies[23]. To tailor the analysis specifically to Mehran UET, the area of interest is clipped from the broader dataset of Jamshoro city, ensuring that the information is site-specific. This detailed land use and land cover classification is crucial for understanding the dynamics of stormwater runoff, which, in turn, informs the development of a comprehensive stormwater management plan that not only addresses immediate needs but also promotes long-term sustainability and resilience in the face of climate change.

3.6 EXPERIMENTAL DATA ANALYSIS

Following the collection of 14 samples, with 10 taken from the rooftop of the IEEM Building and 4 from the drainage channel beside USPCAS-W, a thorough examination of water quality was undertaken in the IEEM laboratory. This examination covered a wide range of aspects, including both physicochemical and heavy metal assessments. The physicochemical analysis involved the measurement of parameters like pH, turbidity, and TSS. Furthermore, a detailed heavy metal analysis was carried out,

specifically examining the presence and concentrations of chromium, cadmium, copper, and lead in the collected samples during the rainfall event[24], [25].

3.5.1 pH ANALYSIS

It is the measure of the acidity or basicity of aqueous or other liquid solutions. The pH meter was utilized to measure the pH of both stormwater collected samples as shown in Fig. 5



Fig 5: pH analysis

3.5.2 TSS ANALYSIS

Total Suspended Solids (TSS) in the context of stormwater refers to the total quantity of solid particles suspended in water during or after a storm or rainfall event. These particles include sediment, organic matter, debris, and other pollutants that become entrained in stormwater runoff and were analyzed using a TSS meter for both collected samples as shown in Fig. 6.



Fig 6: TSS analysis

3.5.3 TURBIDITY ANALYSIS

Turbidity is the cloudiness or haziness of water caused by the presence of suspended particles, such as silt, sediment, and other fine solids. During storm events, rainfall can wash various pollutants, debris, and sediments into water bodies. The increased turbidity in stormwater runoff is an indication of the elevated levels of suspended particles and it was measured using a turbidity meter for both samples as shown in Fig 7.



4. RESULTS and DISCUSSIONS

The development of a sustainable stormwater management plan for Mehran UET under the climate change scenario was carried out using GIS and remote sensing-based supervised classification which identified the existing stormwater drainage path and impervious cover through spatial data and evaluated stormwater quality.

4.1 EXISTING STORMWATER DRAINAGE PATH IN MUET

An evaluation of the current stormwater drainage system at MUET Jamshoro involved a comprehensive approach, combining field surveys and the use of a Digital Elevation Model (DEM). Through this process, the existing drainage patterns, flow pathways, directions, and accumulation of water were analyzed. This assessment revealed that an inadequate drainage path exists adjacent to the USPCAS-W building. Surprisingly, the water collected within this drainage pathway is not effectively utilized, as it primarily infiltrated into the soil. Moreover, the broader issue of the absence of a well-defined stormwater management plan for the entire university was brought to light as shown in Fig. 8-9. Addressing these findings is crucial to enhance the efficiency of stormwater control and mitigate potential water-related challenges across the university campus.

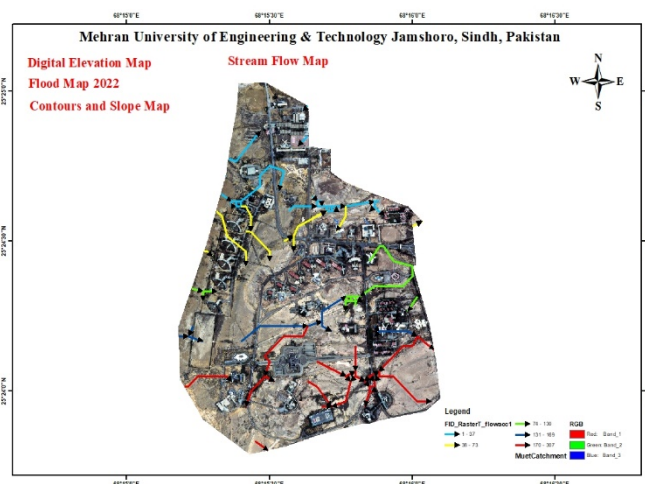
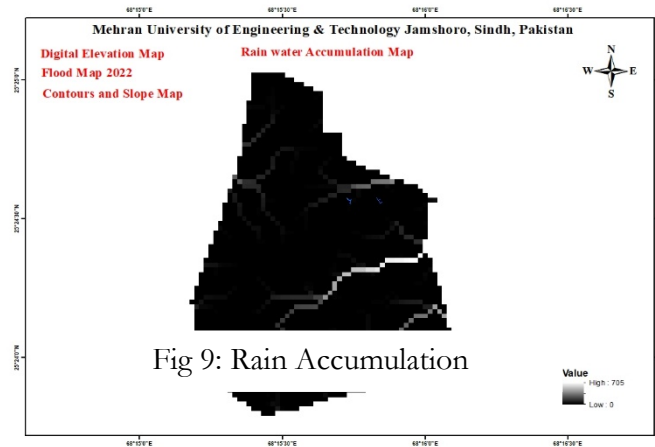
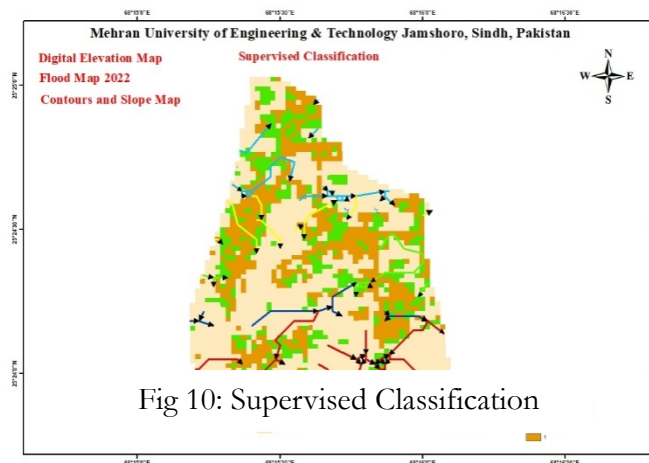


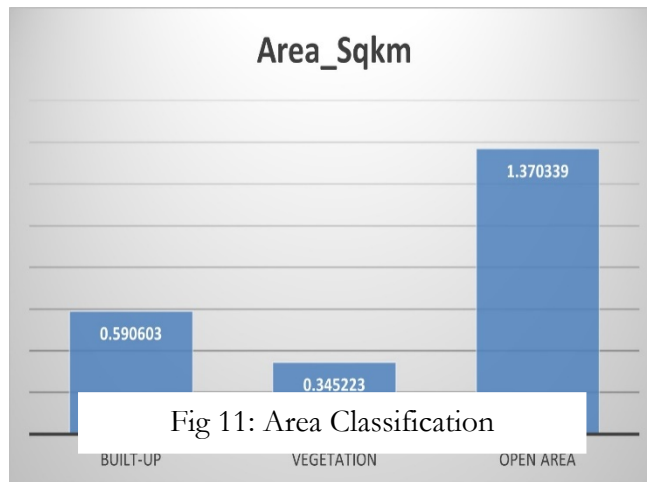
Fig 8: Rain Flow



4.2 IDENTIFICATION OF LAND COVERS

To assess the land use and land covers of MUET Jamshoro, supervised classification was conducted using ArcGIS in two distinct scenarios: during a rainfall event and in a dry condition. The results of the supervised classification model allowed for the identification of built-up areas, vegetation, and open spaces within MUET as shown in Fig. 10 – 11. These identified land cover categories were subsequently overlaid on a streamflow map, enabling the evaluation and determination of stormwater flow patterns and directions, particularly within built-up areas. This mapping and analysis provide valuable insights for the university's management, aiding in the development of catchment areas with a high concentration of stormwater built-up as shown in Fig. 1.9. Such information is instrumental in devising effective stormwater management strategies tailored to the university's specific needs and conditions.





4.3 STORMWATER MANAGEMENT PLAN

In the development of an effective and sustainable stormwater management plan for MUET Jamshoro, contour mapping played a crucial role. This method precisely outlined the geographic boundaries of MUET Jamshoro, enabling the accurate identification of existing drainage patterns, flow pathways, and accumulation areas. Moreover, land cover classification was undertaken to distinguish between pervious and impervious surfaces. The analysis revealed three robust stormwater pathways within MUET Jamshoro suitable for the installation of catchment reservoirs as shown in Fig. 12. The first pathway, commencing near the USPCAS-W building and concluding in the adjacent empty plot near the girl's hostel, presents an ideal location for a catchment area due to the substantial stormwater quantity, which can be repurposed for landscaping. The second prominent stormwater pathway, starting beside the Transportation office building and concluding near the newly constructed girls' hostel, offers another strategic location for a catchment reservoir. Lastly, a minor stormwater pathway begins from both the Main Auditorium building and the Science & Technology Park, terminating beside the main gate of MUET, providing another opportunity for a catchment reservoir.



Fig 12: Stormwater Plan

4.3.1 HYDROLOGICAL STUDY OF STORMWATER

Following the completion of the streamflow mapping, two specific sampling sites were chosen: the rooftop of the IEEM Building and the drainage channel beside USPCAS-W. These locations were

selected for a hydrological study of stormwater, during which the discharge rates were calculated for 14 samples at a 5-minute time interval as. This in-depth analysis is crucial for gaining insights into the dynamics of stormwater flow and the accurate measurement of discharge rates, contributing to effective stormwater management and planning.

4.4 WATER QUALITY ANALYSIS OF STORMWATER

After collecting samples from both locations, from the rooftop of the IEEM Building and the drainage channel beside USPCAS-W, a comprehensive water quality analysis was performed. This analysis encompassed both physicochemical and heavy metal assessments. In the physicochemical analysis, parameters such as pH, turbidity, and TSS were measured. Additionally, heavy metal analysis was conducted, focusing on the presence and concentrations of chromium, cadmium, copper, and lead in both samples during the rainfall event. These analyses provide valuable insights into the quality of stormwater guiding further actions in stormwater management.

4.4.1 PHYSIOCHEMICAL ANALYSIS

In the physicochemical analysis, parameters such as pH, turbidity, and TSS were analyzed to identify the quality of stormwater.

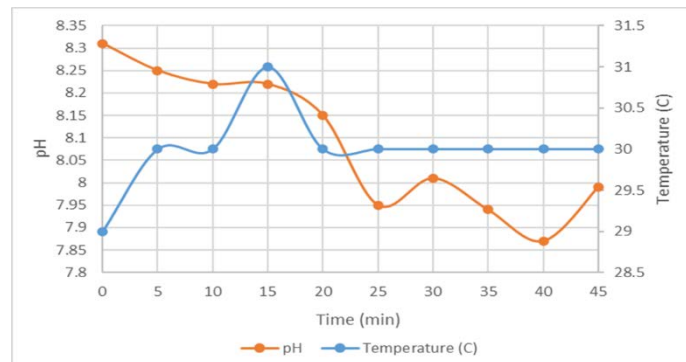


Fig 13: Rooftop pH-Temperature

The results from Fig. 13 show a strong correlation between the pH and temperature of stormwater. As the temperature increases, the pH decreases. This is because water molecules are more likely to split into hydrogen and hydroxide ions at higher temperatures. After all, warmer temperatures increase the amount of carbon dioxide

(CO₂) that dissolves in water. CO₂ reacts with water to form carbonic acid, which lowers the pH of the water and this decrease in pH is known as acidification.

4.4.1.2 Rooftop TSS-Discharge

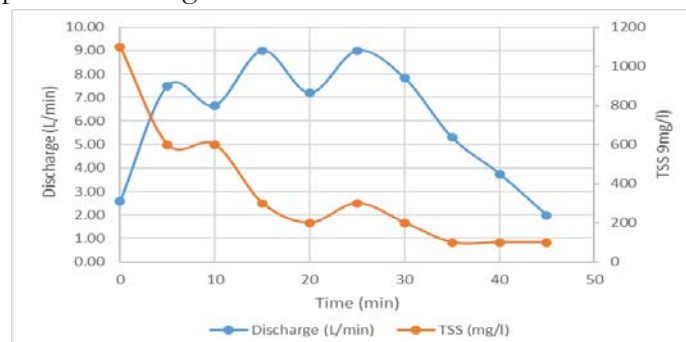


Fig 14: Rooftop TSS-Discharge

Fig. 14 shows the total suspended solids (TSS) concentration of stormwater over 45 minutes during a rainfall event. The results from Fig 4.8 show that the TSS concentration of the stormwater increases rapidly during the first 15 minutes of the rainfall event and then decreases gradually until the end of the event. The peak TSS concentration was 1100 mg/L, which is relatively high because precipitation generates more stormwater runoff, and this runoff is more likely to pick up TSS from the ground this increase in TSS concentration is a concern because it can have several negative impacts on the groundwater quality.

4.4.1.3 Rooftop Turbidity-Discharge

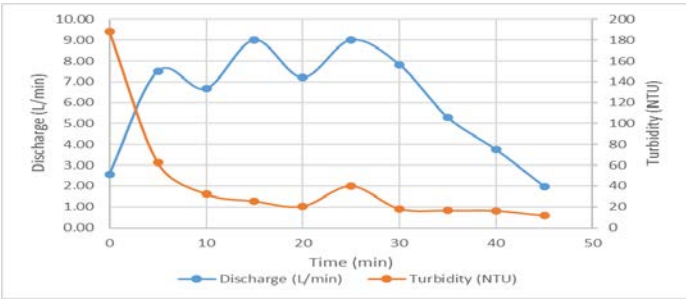


Fig 15: Rooftop Turbidity-Discharge

Fig. 15 represents a scatter plot that shows the relationship between rainfall intensity and turbidity for stormwater samples collected from the rooftop of IEEM MUET. The results from Fig 2.4 show a negative correlation between rainfall intensity and turbidity, which means that turbidity tends to decrease as rainfall intensity increases.

4.4.1.4 Drainage Channel pH-Temperature

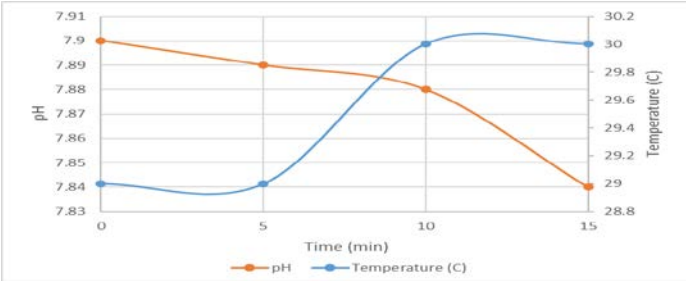


Fig 16: Drainage Channel pH-

The results from Fig. 16 show that the pH of the stormwater was relatively stable at around 7.91 for the first 5 minutes. Then, it started to decrease slowly, reaching 7.83 at the 15-minute mark. It continued to decrease slightly until the end of the experiment.

4.4.1.5 Drainage Channel TSS-Discharge

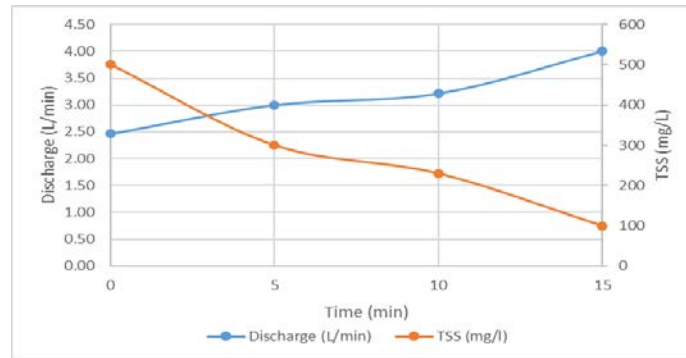


Fig 17: *Drainage Channel TSS-*

The results from Fig.17 show an increase in TSS at the beginning due to the washing of pollutants. The results from Fig 2.6 show that the TSS concentration of the stormwater decreased rapidly as the discharge rate increased.

4.4.1.6 Drainage Channel Turbidity-Discharge

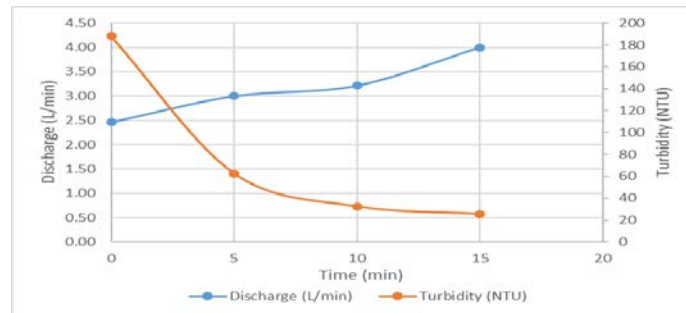


Fig 18: *Drainage Channel Turbidity-*

The results from Fig. 18 show a declining trend in turbidity due to the washing of pollutants. The results from Fig 2.7 show that the turbidity present in the stormwater decreased rapidly as the discharge rate increased.

5. Conclusion And Future Work

The assessment revealed a drainage deficiency near the USPCAS-W building at MUET Jamshoro, with underutilized water seeping into the soil. A broader issue surfaced – the absence of a defined stormwater management plan for the university. Employing ArcGIS, supervised classification identified built-up areas, **vegetation**, and open spaces, superimposed onto a streamflow map. This aided in assessing stormwater flow patterns, especially in built-up regions. Contour mapping defined MUET's boundaries, identifying drainage patterns and areas of water accumulation. Land cover classification distinguished pervious and impervious surfaces, unveiling three resilient stormwater pathways. Strategic catchment reservoir locations were pinpointed near the USPCAS-W building, Transportation office, and Main Auditorium/Science and technology Park.

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Climatic Changes and Pakistan's Approach to Tackle Major Floods of its History (1970-2010): A Case Study of July-August 2010 flood

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Abstract

As Pakistan is situated in an exceptional geo-climatic zone. About country's 60 % is vulnerable to floods. This study tries to investigate floods tackling approach of the country since 1970 till 2010 with special reference to July-August 2010 flood. Quantitative assessment revealed that Pakistan has been the victim of 17 floods over the last 37 years, among these 50 % has been identified as mega floods. The study has used both Quantitative and Qualitative methods of data collection. This study finds out that 1973 flood demolished three million houses and killed 160 persons. Death tolls during August 1976 flood were 425, during 1988 were 508. Number of affected people during 1992 flood were 10 million and during 2010 were 20 million. The study analysis that Pakistan wishes to fight against floods, for the purpose Indus River System has been supported by huge dams like Tarbela, barrages like Rasul and an extensive network of inundation canals. FFC was established (1977) in response to major floods of 1973 and 1976. NDMA was established in 2005 to fight against natural disasters. Pakistan uses both engineering and non-engineering approaches to mitigate floods. Telemetric system of WAPDA is one of the significant sources of the hydrological data for Pakistan. Introduction of radars system, construction of irrigation infrastructure has been the efforts to mitigate floods. In Pakistan, the Ministry of Water and Power issues flood forecasts and Warnings. Flood Forecasting Network (FFN) sends flood related information to country's flood prone regions. Both quantitative and qualitative approaches were used to reach the conclusion that in the presence of all of these, Why Pakistan the Super flood of 2010 was so horrible for the people and economic structure of the country; even then there were floods in Pakistan in successive years too.

Key Words: inundations, magnitudes, vulnerability, damages, and disasters.

Maneuvering Digital Information: Adoption of Information & Communication Technology (ICTs) to Comprehend Impact of Climate Change among University Graduates in Pakistan

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Abstract

Climate change is an alarming situation which is affecting agriculture, biodiversity, forests, water, social and economic aspects of the people. Underdeveloped and the least developed countries are more amenable due to hazardous impacts of climate change relatively with the developed countries. Improving people's knowledge about the impacts of climate change through information and communication technology (ICTs) is an imperative measure to convince public at various tiers in the society to indulge them actively in minimizing and adapting the influences of the climate change. So, it is supreme to probe out the university scholars' adoption of information and communication technology (ICTs) tools to create awareness regarding climate change since it is prone to manipulate how the university scholars and class instructor's demeanor knowledge transferring in their classrooms. The research study is primarily developed to scrutinize the role of information and communication technology (ICTs) to understand the effects of climate change among university students in the study area. The research work was completed in major universities across Pakistan. A well-organized questionnaire was constructed to take information from graduates which are affecting the awareness level and knowledge of climate change and its effects. According to the findings of research, the access to television, access to smart phone, access to agricultural magazine, news bulletin or newspaper, access to computer/laptop are influencing significantly to create awareness about the effects of climate change among the university graduates whereas the access to radio and access towards internet connectivity are affecting non significantly towards creation or understanding of climate change awareness in the study area. Public and private sectors should be involved more rigorously to play an imperative role by involving or collaborating with research organizations and academic institutes in this regard.

Keywords: Climate change, information and communication technology, university graduates

**Use of GIS and RS Tools for Analysis of Land Use Land Cover and Land Surface
Temperature: A Case Study of District Khairpur, Pakistan
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Abstract:

Land use and land cover (LULC) monitoring plays an important role in sustainable planning and management of resources. This research focuses on analysing historical LULC changes over the Khairpur district of Sindh province of Pakistan. Remote Sensing and Geographic Information System (RS & GIS) tools have been employed using the maximum likelihood algorithm of the supervised classification method. Temporal data of the latest high-resolution satellite imagery provided by NASA GLCF (Global Land Cover Facility), Landsat 8 Operational Land Imager (OLI), and Landsat 4, 5 Thematic Mapper (TM) for 2001, 2010, 2015, and 2020 were acquired from Earth Explorer of United States Geological Survey (USGS). The study area is classified into four major classes namely Barren Land, Vegetation, Built-up areas, and Water Bodies. Analysis revealed that for 2001 and 2005 there was no change in barren land area, whereas in 2010 slight decrease in barren land was found which further decreased for the analysis period of 2020, overall barren land class decreased at a rate of 07% (i.e., 74% to 67%) during the analysis period. Also, vegetation and water bodies classes experienced variations throughout the analysis period, however built-up areas showed constant increase throughout the analysis period where built-up area classes increased from 9% to 15%. Whereas land surface temperature (LST) throughout the analysis period showed increasing trends, for both high ranges and low ranges. It was analysed that the areas having dominancy of the barren land class experienced the highest temperature ranges whereas low temperature ranges were discernible in the areas having vegetation covers. It can be concluded from the study that barren land covers the major area of the study area and there is an increase in built-up areas which can further enhance the LST in the study area.

Keywords: USGS; ArcGIS, NASA GLCF; Built-up; Barren Land; Vegetation, Water Bodies

Introduction

Land cover land use change (LCLUC) has been identified as a factor influencing environmental change in the landscape on a worldwide scale in recent years (Kharazmi et al., 2018). Land use and Land cover are used to manage natural resources and track ecological changes. (Xie et al. 2008; Ibharim et al. 2015; Kantakumar and Neelamsetti 2015; Lin et al. 2015). One of the primary causes of the Earth system's land degradation processes is changes in land use and cover. LULC (Verburg et al. 2011).

Nevertheless, multitemporal satellite photos images have not been as widely utilized for LULC change planning assessment and monitoring in semi-arid and dry arid regions (Aredehey et al., 2018). These days, a lot of researchers investigate the relationship between LST, NDVI, and land use/cover using GIS and remote sensing RS techniques (Dong, et al. 2018)

Furthermore, because LULC modifications typically impose have an imminent negative influence on the state and integrity of ecosystem functioning, they need greater consideration in land management (Quintas-Soriano et al. 2016). The availability of Landsat data facilitates better land cover monitoring and assessment of huge areas in fast-developing regions. (Kharazmi et al. 2018). The physical characteristics of the land's surface, such as forests, rivers, agriculture, and urban infrastructure, are referred to as land cover (LC). On the other hand, Landuse (LU) is the alteration of LC according to human needs and behaviour. LC is a reliable predictor of LU.(Udin & Zahuri, 2017).

Study Area

The study area will be bounded by the Khairpur district of middle and northern Sindh Pakistan. It was situated on the left side of the River Indus. The co-ordinate of Khairpur district is 27°31'46.13" N 68°45'42.12"E. The district of Khairpur is situated on a smooth plain and consists of eight tehsils: Khairpur (District headquarters), Kangri, Gambat, Sobhadero, Kot Diji, Nara, Thari Mirwah, and Faiz Gunj. The district of Khairpur is bounded on the east by India, on the north, Shikarpur and Sukkur, South Sanghar and Shaheed Benazeerabad, and the West Larkana and Noshoro Feroz. The climate of Khairpur was typically that of the upper Sindh region. There are two well-defined seasons, hot and cold. The former begins at the end of March and extends till October. May, June, and July are the hottest months. During this period, the mean maximum and minimum temperatures are about 42°C and 27°C, respectively. December, January, and February were the coldest months. During this period, the mean maximum and minimum temperatures were about 25°C and 7°C, respectively.

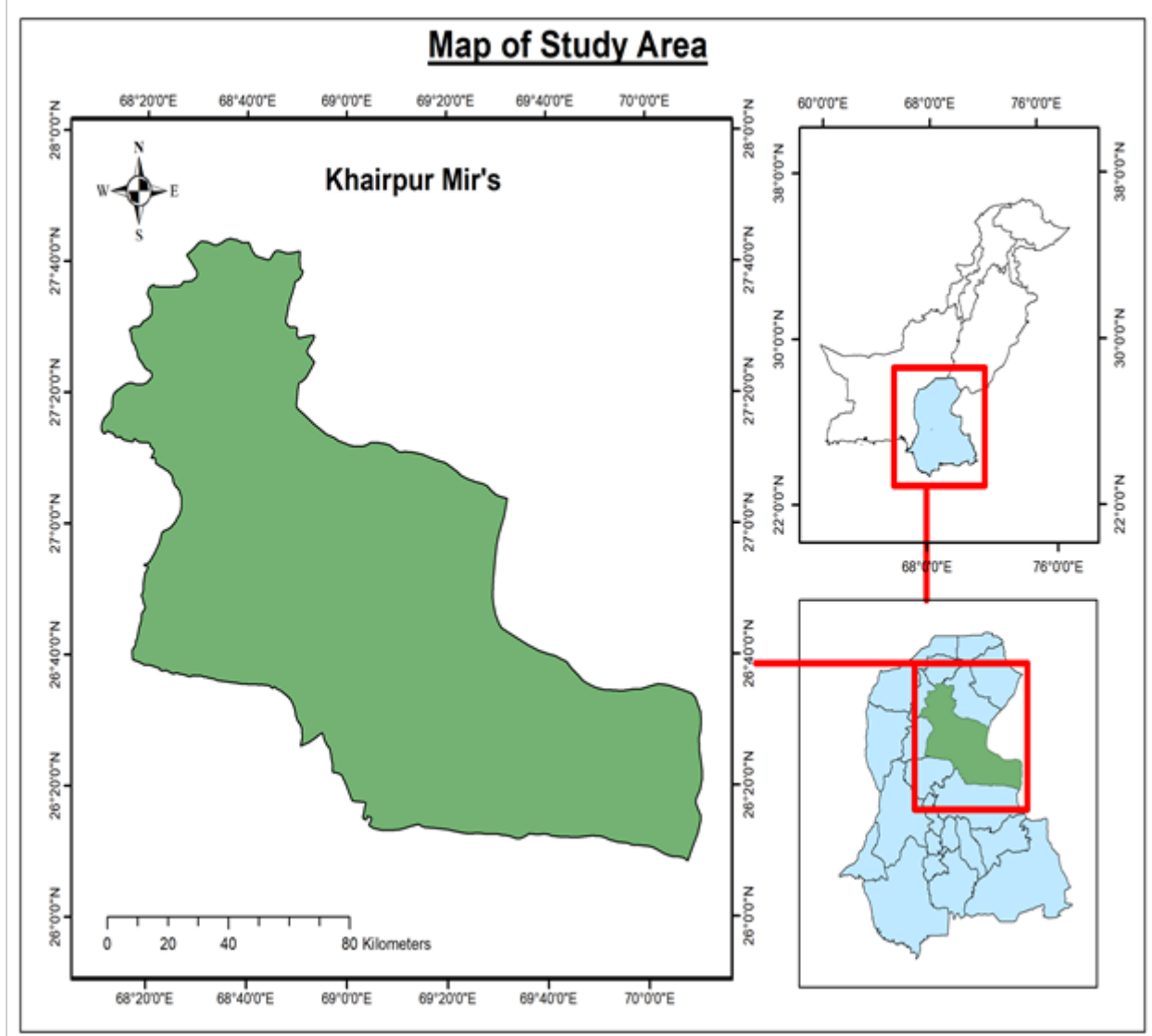


Fig. 1: The Study Area (District Khairpur)

Estimation of NDVI and NDBI

The vegetation characteristic like NDVI will be estimated for mentioned vegetation area duration for every study year. To calculate the vegetation indices, NDVI is estimated as follows.

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)}$$

Where NIR near-infrared band (TM and ETM band 4, OLI band 5) and R is the red band (TM and ETM band 3, OLI band 4).

NDBI will be calculated by using Arc GIS 10.3 software following.

$$NDBI = \frac{(MIR - NIR)}{(MIR + NIR)}$$

Where MIR is the middle infrared band (TM and ETM band 5, OLI band 6) and NIR is the near-infrared band (TM and ETM band 4, OLI band 5).

Conclusion

As this study focused on analyzing LULC and LST of Khairpur district, in LULC four major classes were identified i.e., Barren land, vegetation, built-up and water bodies.

It was found that for the period of 2001 and 2010 there was no change in barren land class, whereas in 2015 and 2020 slight decrease in barren land found, overall barren land class decreased from 70% to 69% during the analysis period.

Vegetation and water bodies classes experienced variations throughout the analysis period, however built-up areas showed constant increase throughout the analysis period where built-up area class increase from 8% to 21%.

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Abstract

A human-centric drive entails a multi-dimensional concept, granting priority to non-traditional aspects of security. Climate change linked to the depletion of water resources, resulting in the risk posed to food security is a key security concern. With Climate Change posing risks to water, energy, and food availability (W.E.F nexus), resource management remains the only criteria for Climate Change adaptation and risk aversion strategies. Employing qualitative methodology with content analysis as the research tool, the study explores the interlinkages between water conservation and food security. The study focuses on the following aspects for review and analysis a): factors responsible for water depletion in relation to and resulting from the menace of Climate Change: b) role of water conservation to provide for food security as a measure of climate change adaptability. The study has argued that technological advancement in water conservation schemes can mitigate the risks posed to food security in relation to Climate change. The study holds academic value in generating awareness on climate induced risks resulting in water resource depletion and the role conservation strategies can play in effective management to provide food security.

Keywords: Adaptability, Resource, Depletion, Conservation, Management

Exploring Water and Environmental Legislation in Pakistan: A Comprehensive Analysis

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Abstract:

In the context of the increasing global emphasis on sustainable development, this abstract delves into the complex arena of water management and environmental laws within Pakistan. The country faces growing challenges related to water scarcity, pollution, and the impacts of climate change, making the examination of effective legal frameworks imperative. The research scrutinizes the historical development of policies governing water and their integration into broader environmental contexts in Pakistan. Key legal instruments, including the Water Apportionment Accord and the Pakistan Environmental Protection Act, are analyzed for their roles in regulating water allocation, maintaining water quality, and preserving ecosystems. Through a thorough examination of statutes, regulations, and international agreements, the study highlights the strengths and weaknesses inherent in the current legal framework. Additionally, the abstract investigates the practical implementation of water and environmental laws in Pakistan, assessing the roles of governmental institutions, the efficacy of regulatory mechanisms, and the challenges faced in enforcing compliance. The research evaluates the impact of these laws on addressing critical environmental issues such as industrial pollution, deforestation, and the depletion of water resources. Concluding with a forward-looking perspective, the abstract proposes recommendations to enhance the effectiveness of existing legislation. It underscores the importance of integrated water resource management, community involvement, and the alignment of legal provisions with contemporary environmental challenges. The research findings contribute valuable insights to the global dialogue on sustainable development, offering recommendations that can inform policy decisions for safeguarding Pakistan's essential water resources and fostering environmental resilience.

1. Introduction

The Republic of Pakistan stands at a critical juncture in its quest for sustainable development, particularly in the realms of water management and environmental protection. This South Asian nation, characterized by its diverse ecosystems ranging from arid deserts to lush mountains, faces significant environmental challenges. Among these, water scarcity, pollution, and the adverse impacts of climate change are particularly pressing. These issues not only threaten the country's environmental sustainability but also its socio-economic stability, affecting millions of lives and the overall development trajectory.

In response to these challenges, Pakistan has developed a complex legal and institutional framework aimed at managing its water resources and safeguarding its environment. The significance of legal frameworks in addressing these issues cannot be overstated. Effective legislation serves not only as a tool for regulation and control but also as a foundation for sustainable development, aligning national priorities with global environmental goals.

The exploration of water management and environmental laws in Pakistan is thus not only a study of legal texts and institutions but a critical examination of how these frameworks contribute to the broader objectives of sustainable development. This article delves into the historical evolution of environmental legislation in Pakistan, analyzes key legal instruments, evaluates the practical implementation of these laws, and proposes recommendations for enhancing their effectiveness. Through this comprehensive analysis, the article aims to contribute valuable insights to the global dialogue on sustainable development and environmental resilience.

2. Historical Development of Water and Environmental Laws

The legislative landscape governing water resources and environmental management in Pakistan has evolved significantly over the years, marked by several key milestones. This evolution reflects Pakistan's growing recognition of environmental issues and the need for sustainable water management practices amidst changing global and regional contexts.

2.1. Early Legislation and Policies

The foundation for water and environmental legislation in Pakistan was laid shortly after its independence in 1947. Initial policies focused primarily on water distribution for agricultural purposes, given the country's agrarian economy. The **Indus Water Treaty** of 1960, brokered with India and facilitated by the World Bank, was a landmark agreement that allocated the waters of the Indus River and its tributaries, laying down the framework for water management between the two countries.

2.2. The Water Apportionment Accord of 1991

A significant milestone in Pakistan's water legislation is the **Water Apportionment Accord (WAA)** of 1991. This inter-provincial agreement was crucial for the equitable distribution of water resources among Pakistan's provinces, based on a formula that took into account historical uses and needs. The WAA represents a consensus-driven approach to water management, acknowledging the diverse water requirements of different regions.

2.3. The Pakistan Environmental Protection Act of 1997

In response to the escalating environmental challenges and the global push towards sustainable development, Pakistan enacted the **Pakistan Environmental Protection Act (PEPA)** in 1997. This comprehensive legislation marked a paradigm shift towards integrating environmental concerns into developmental policies. PEPA established the legal framework for pollution control, conservation of natural resources, and enforcement of environmental standards.

2.4. Recent Developments

In recent years, Pakistan has continued to update its legal and policy frameworks to better address the complexities of water management and environmental protection. This includes the formulation of the **National Water Policy** in 2018, which emphasizes integrated water resources management, climate change adaptation, and the importance of water for socio-economic development. Additionally, various provincial environmental protection acts and policies have been introduced, reflecting the devolved nature of environmental governance in Pakistan.

These legislative and policy measures illustrate Pakistan's evolving approach to water and environmental management, shifting from sectoral and piecemeal efforts to more integrated and holistic strategies. However, the implementation of these laws and the achievement of their intended outcomes continue to pose significant challenges.

3. Analysis of Key Legal Instruments

The effectiveness of water management and environmental protection in Pakistan heavily relies on the strength and implementation of its key legal instruments. Among these, the Water Apportionment

Accord (WAA) of 1991 and the Pakistan Environmental Protection Act (PEPA) of 1997 stand out for their pivotal roles. Analyzing these instruments sheds light on their contributions to sustainable development and the challenges that persist in achieving their full potential.

3.1. Water Apportionment Accord of 1991

The WAA was a groundbreaking step towards addressing inter-provincial water distribution conflicts, a critical issue for a country dependent on agriculture as a major part of its economy. The Accord established a formula for the distribution of waters from the Indus River System among the provinces, aiming for a fair and equitable allocation.

Strengths:

Facilitated a cooperative framework for water sharing among provinces.

Recognized the need for sustainable water management practices.

Provided a basis for future water-related negotiations and policies.

Weaknesses:

Implementation challenges, particularly in accurately measuring water distribution and ensuring compliance.

Lack of mechanisms to address the impacts of climate change on water availability.

Inadequate provisions for the environmental flows necessary to sustain ecosystems.

3.2. Pakistan Environmental Protection Act of 1997

PEPA represents a comprehensive approach to environmental protection, covering aspects such as pollution control, conservation, and the establishment of environmental quality standards.

Strengths:

Established the legal framework for environmental protection and conservation.

Created institutions like the Pakistan Environmental Protection Agency (EPA) for the enforcement of environmental standards.

Facilitated the integration of environmental considerations into development projects through the Environmental Impact Assessment (EIA) process.

Weaknesses:

Enforcement and compliance issues, with limited resources and capacity for monitoring and implementation.

Challenges in effectively engaging stakeholders, including industries and local communities, in environmental governance.

Inadequate attention to emerging environmental issues, such as climate change and water scarcity, in its provisions.

4. Practical Implementation and Challenges

The practical implementation of these legal instruments reveals a complex interplay of challenges. Governmental institutions like the Pakistan EPA have a critical role in enforcing environmental

standards, yet they often face constraints in terms of resources, capacity, and political support. Regulatory mechanisms, such as EIAs, are crucial for integrating environmental considerations into development projects, but their effectiveness is hindered by issues of compliance, transparency, and stakeholder engagement.

Furthermore, the enforcement of laws is complicated by socio-economic factors, including industrial pollution, agricultural practices, and urban development, which frequently outpace regulatory capacities. The challenges in enforcing compliance highlight a gap between the formulation of laws and their practical application, underscoring the need for strengthened institutional frameworks, enhanced capacity building, and greater public awareness and participation.

5. Impact of Laws on Environmental Issues

The legal frameworks established by the Water Apportionment Accord and the Pakistan Environmental Protection Act have had a significant impact on addressing various environmental issues in Pakistan. These laws have laid the groundwork for managing water resources more sustainably and protecting the environment from further degradation. However, the effectiveness of these laws in mitigating environmental challenges such as industrial pollution, deforestation, and the depletion of water resources varies, highlighting both achievements and areas needing improvement.

5.1. Addressing Industrial Pollution

The PEPA has provided a legal basis for controlling industrial pollution through the establishment of environmental standards and the requirement for Environmental Impact Assessments (EIAs) for industrial projects. While there have been successes in regulating some sources of pollution, enforcement remains inconsistent. Industrial sectors in many regions continue to discharge pollutants into water bodies and the atmosphere, largely due to inadequate monitoring, limited resources for enforcement agencies, and the challenges of ensuring compliance among a vast number of small and medium-sized enterprises.

5.2. Combating Deforestation

Legal and policy efforts to combat deforestation, including afforestation initiatives and regulations on land use, have seen varied success. Projects like the Billion Tree Tsunami have garnered international recognition and contributed to reforestation efforts. However, deforestation continues at an alarming rate in many areas, driven by agricultural expansion, illegal logging, and infrastructure development. The effectiveness of legal measures is often undermined by weak enforcement, corruption, and the lack of integration between environmental policies and land use planning.

5.3. Managing the Depletion of Water Resources

The Water Apportionment Accord aimed to distribute water resources equitably among provinces, which is crucial for addressing water scarcity. While the Accord has helped prevent major disputes over water allocation, the challenge of water scarcity is exacerbated by inefficient water use in agriculture, unregulated groundwater extraction, and the impacts of climate change. Efforts to manage water resources sustainably are further complicated by the lack of comprehensive data on water availability and use, and the slow pace of adopting modern water-saving technologies.

6. Recommendations for Enhancing Legislation

To enhance the effectiveness of existing legislation and better address environmental challenges, the following recommendations are proposed:

6.1. Strengthening Institutional Capacities: Enhancing the capacities of environmental regulatory bodies is critical for improving enforcement and compliance. This includes providing adequate resources, training, and technology for monitoring and enforcement activities.

6.2. Community Involvement and Awareness: Engaging communities in environmental governance and raising public awareness about environmental issues can drive collective action and support for sustainable practices.

6.3. Integrating Environmental Considerations into All Sectors: Policies and legal frameworks should promote the integration of environmental considerations into all development planning and economic sectors, ensuring a holistic approach to sustainable development.

6.4. Updating Legal Frameworks to Address Emerging Challenges: Laws should be regularly reviewed and updated to address new environmental challenges, including climate change and water scarcity, ensuring they remain relevant and effective.

7. Conclusion

The comprehensive analysis of water and environmental legislation in Pakistan reveals a complex picture of achievements and ongoing challenges. While significant strides have been made in establishing legal and institutional frameworks for environmental protection and water management, the effective implementation and enforcement of these laws remain critical hurdles. By addressing these challenges through strengthened legal frameworks, enhanced institutional capacities, and greater community involvement, Pakistan can make substantial progress towards sustainable development and environmental resilience. This research contributes to the global dialogue on sustainable development, offering insights and recommendations that can inform policy decisions not only in Pakistan but in other countries facing similar challenges.

Assessing Impact of Cultivation Practices, Water Conservation Strategies, and yield of sunflower in Sujawal District

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Abstract

Sujawal District, located in the Lower Indus Basin of the Sindh province, faces challenges stemming from water scarcity and soil salinity, which adversely affect crop production. This study addresses these issues by concentrating on the advancement of sunflower cultivation as a sustainable solution. Highlighting the adaptability of sunflowers to limited water resources, the research delves into efficient irrigation methods, enhanced farming practices, and research-backed insights to boost agricultural productivity while preserving water resources. A comprehensive multistage sampling design is employed to ensure the inclusive collection of data, strategically identifying Talukas, union councils, and villages known for their substantial involvement in sunflower cultivation. Collaborating with the agriculture department ensures alignment with research objectives, thereby enhancing the study's credibility. The data collection process utilizes a semi-structured questionnaire, providing flexibility in responses within a defined framework. The questionnaire encompasses both predetermined questions for consistency and open-ended inquiries, allowing participants to articulate their experiences. The study aims to offer valuable insights into sunflower cultivation practices, water conservation, and economic impacts, with potential implications for sustainable agriculture in regions confronting similar challenges. This research contributes to a more comprehensive understanding of sunflower cultivation dynamics in regions with water scarcity, presenting innovative water management techniques and advocating for drought-tolerant sunflower varieties. Through alleviating the impact of water stress, farmers can enhance productivity, resilience, and overall sustainability, thereby fostering economic prosperity and environmental conservation in the Lower Indus Basin.

Keywords: Sunflower cultivation, water conservation, agricultural practices, multistage sampling design, sustainable agriculture.

Impacts of Climate Intervention on Projected Malaria Distribution in South Asia

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Abstract

Malaria is a disease that has a significant influence on public health and affects individuals all over the world. Climate considerations affect the disease's distribution and activity levels. The capacity to control the disease locally also matters. This study aimed to examine the hazards related to malaria re-distribution due to climate intervention on the degree of malaria transmission in South Asia. The growing severity of the climate disaster brings about a type of climatic change never before seen. We can observe high temperatures in colder parts of the world, or there are unpredictable and frequent precipitation in some parts of the world. In the same way, when temperatures rise, malaria transmission has also been noted in the cooler areas. This is because malaria requires favorable conditions that is, neither too hot nor too cold for a parasite to thrive. Precipitation is the cause of it, particularly in swampy places. We aim to create intentional trade-offs for malaria re-distribution through effective climate intervention. The amount of precipitation has a significant impact on mosquito density for larvae formation. With the use of the dynamical-numerical malaria model VECTRI, the simulations reveal several scenarios that investigated the effects of precipitation and temperature on malaria transmission referred to as Entomological Inoculation Rate (EIR). We are considering the climate intervention via sulfate injection in the stratosphere. This will cause the Earth's temperature to drop by 1.5°C by reflecting a tiny amount of sunlight into space. The impacts of this prevalent risk at the regional level are examined, for the period of 2035-2069, using temperature and precipitation from the CEMS2 climate model under various climate intervention scenarios. As a result of climate intervention via sulfate injection, a reduction in both frequency and intensity of EIR at the same spatial locations is noted across South Asia relative to no climate intervention case.

Prediction of malaria transmission in changing climate of Pakistan

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Abstract

Malaria is an endemic disease, and multiple studies are carried out to detect the malaria endemic regions throughout the world. This study is carried out to determine the change in the spatiotemporal transmission of malaria intensity in Pakistan using a dynamical malaria model: VECtor borne disease community model of ICTP, TRIeste (VECTRI). The VECTRI malaria model takes into account the climatic parameters of temperature and precipitation. Thus, the impact of climate change on malaria transmission intensity is estimated over the data sparse region of Pakistan at the administrative level of districts. The temperature and precipitation data were derived from an ensemble of Coupled Model Intercomparison Project phase 5 and phase 6 climate models that simulated the climate of Pakistan comparatively better. The Entomological Inoculation Rate (EIR) is considered as a measure of the intensity of malaria transmission. Standardized anomaly of projected malaria cases in Pakistan is considered to compare it with the observed cases count for the recent decade of 2010–2019. It is noted that during the months of August–October, Pakistan has the largest number of malaria cases, whereas the lowest malaria cases occur during the months of December–March. As a consequence of changing climate, the severity and duration of malaria transmission season in the northern regions of Pakistan are projected to increase in the coming decades, as quantified in terms of EIR. Implementing proactive vector control measures, including insecticide-treated bed nets and indoor residual spraying, in high-transmission regions during peak transmission months (August–October) can help reduce the burden of malaria. Additionally, a prototype strategy is presented for scaling up of climate-resilient healthcare infrastructure and for promotion of community awareness and early diagnosis; both being crucial for effective prevention and control.

Implications of urban development on Groundwater Resources: A step towards urban resilience

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Abstract

One of the major anthropogenic changes to the environmental framework is urbanization. Increase in urban population has significant impact on natural resources particularly the groundwater, which aggravates the development of new research methods for sustainable management of groundwater. Groundwater is the main source of water for agriculture and homes for about 2 billion people around the world that comes from groundwater aquifers. The present study aims to comprehend the spatiotemporal characteristics of urban growth and its implications for the hydro-meteorological parameters in the Lahore and Faisalabad Districts of Pakistan. Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI) satellites with a spatial resolution of 30 m and a temporal resolution of 16 days is utilized for Land Use Land Cover (LULC) analysis for the period of 20 years (2000–2020). The study area is classified using Random Forest (RF) supervised classification technique, and the LULC changes are analyzed using the Post Classification Comparison (PCC) technique. The precipitation data is obtained from Pakistan Meteorological Department (PMD) and The Land Surface Temperature (LST) data is obtained from MODIS Terra LST and emissivity daily global 1 Kilometer (km) spatial resolution. Daily LST and emissivity readings are provided in a 1200×1200 km grid by the MOD11A1 version 6.1 product. The groundwater wells data is obtained from Pakistan Council of Research in Water Resources (PCRWR) and used to assess groundwater depth of given wells. Variations in groundwater levels on the north, northwest, and southwest sides of the Lahore district area have been affected due to rise in urban built-up over the past two decades nearly, and results of future projected groundwater levels have also showed the same pattern. likewise in the north, northeast, and southwest sides of the Faisalabad district area. The results of Kendall's tau test information on temperature, precipitation, and groundwater show a stronger link between the local climatic variables and groundwater of both district Lahore and Faisalabad. In both district areas, there is evidence of urban sprawl or shrinkage, which indicates an increase in the urban setting and consequent damage to the environment. This study could be beneficial in developing the water management policy to understand the influence of urbanization on groundwater table at regional scale.

Theme 3

WATER PRODUCTIVITY: WATER FOOD ENERGY NEXUS & HYDRO DIPLOMACY

Sustainable Strategies of Water and Energy use for Agriculture Products

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The water-energy-food nexus is the study of the relationships between these resources and the synergies, conflicts, and trade-offs that arise from how they are managed. Water is food, food is water, energy is water, water is energy, food is energy, energy is food. Water, food and energy are the central hubs of sustainable development. World population growth, rapid urbanization, and economic growth are rapidly increasing demand for all three. Access to these resources and their effective management supports development progress. To ensure food self-sufficiency, steps must be taken to encourage farmers to increase food production by providing subsidies for irrigation, energy, and fertilizers. Efficiency measures along agriculture and the entire food chain can help save water and energy by: Precise irrigation based on information from water suppliers and protecting ecosystems alongside agriculture and energy production can ensure environmental integrity. Giving subsidies to farmer on installation of solar power system and installation of high efficiency irrigation system (such as drip or sprinkle system) for agriculture fields, that get energy from natural source (solar power system) for the running the irrigation system that save energy as well as water and increase the food productivity. Hydro diplomacy is a tool for applying integrated water resources management at national and transboundary levels, in line with a model of cooperation aimed at peace among riparian states. The world's rapid socio-economic development is leading to increased water stress, foreshadowing the possibility of a water crisis. Therefore, there is a need to envision and propose clear legal frameworks and strong agreements between riparian countries, along with strong programs and comprehensive policies to efficiently address the impacts of climate change.

Key words:

Environmental integrity, High efficiency irrigation system, Legal frameworks, Riparian countries

Trans-boundary Energy and Water Security nexus in South Asia: (in)Action of Pakistan

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Abstract

Pakistan will face absolute water scarcity by 2025 according to UNDP and Pakistan Council of Research in Water Resources (PCRWR). This water scarcity is owing to multiple factors such as Population explosion, poor farming, water management crisis, rapid and unchecked urbanization etc. Pakistan's economy is dependent on agriculture and water insecurity is directly linked to food insecurity. Unfortunately, despite such an alarming situation the state of Pakistan has not come up with any concrete measures. On the other hand, the last decade has witnessed rapid energy cooperation between

Bangladesh, Bhutan, India and Nepal sub region of South Asia. These states have been bilaterally engaging in trans-boundary cooperation and conflict resolution. Recently, electric grid interconnections and hydroelectric cooperation is shifting from bilateral to multilateral arrangements. This shows immense potential for trans-boundary water governance. Four areas are of particular importance and will be examined in this study. Firstly, technical cooperation to manage and regulate water, secondly, Indian hydro-hegemony prospect, thirdly, interstate energy inter-dependencies and lastly, regional cooperation and economic prospects. In this scenario Pakistan is isolated due the (in) action of state to resolve its traditional security challenges. The study will investigate employing content analysis whether Pakistan can continue to ignore nontraditional security challenges and its future implications.

Keywords: Water resources, water management, South Asia, conflict resolution, trans-boundary, non-traditional security.

Water Productivity: Water, Energy, Food Nexus & Hydro Diplomacy

Maidah Khan, Salman Yusuf

Abstract

Water is inextricably linked to pillars of sustainable development by crosscutting the UN Sustainable Development Goals (SDGs) through its close links with climate. Though not very sudden, but incremental spike in the resources-usage, coupled with “climate change” over last few decades, particularly in the emerging economies of Pakistan, lead us all the way to resource scarcity. Climate is a global phenomenon that has already started to impact Pakistan in various ways. The country's geographical location makes it vulnerable to a range of climate-related hazards, including floods, droughts, and heatwaves. According to the Global Climate Risk Index 2021, Pakistan is the fifth most affected country by climate change in the world. Resonating impact of the resource's unavailability will not be very far in future rather colloquial of “no water”, “no energy” and

“hungry stomachs” are already common place. There is need for moving away from silo thinking in policy making parlance, towards more holistic framework i.e. Water, Energy and Food-Nexus.

Water: According to United Nations “The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.” Water is key to food security.

Energy: International Energy Agency defines energy security as “the uninterrupted availability of energy sources at an affordable price”. Energy security has many dimensions: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and sustainable environmental needs.

Food: Food and Agriculture Organization definition of food insecurity is: “A situation that exists when people secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life.

Hydro Diplomacy: In navigating this intricate nexus, hydro diplomacy emerges as a critical element, fostering cooperation, negotiation, and peaceful resolution of conflicts among nations to ensure equitable access and sustainable management of these shared resources. Foreign relations involve the use of diplomatic instruments to make shared water sources a domain for peace and cooperation rather than for conflict, Water diplomacy concerns water-related challenges and conflicts through negotiation, cooperation, and collaboration among various stakeholders, including nations, organizations, and communities.

Further, the nexus model has been used as a suggestive framework for the policy- making for the realization of UN-SDGs. For this paper, Rawalpindi City Water Supply System under Developing Resilient Environments and Advancing Municipal Services (DREAMS) has been the case study.

Keywords

Water, Energy, Food, Hydro Diplomacy, Agriculture, Security, Crops, Global, Natural Resources, Water Quality, Climate, Organizations, National Policies, Commercial consumers, Domestic consumers, Dams, District, Ground water, Khanpur Dam, Metropolitan Corporation, Million Gallon Per Day, Rawal Dam, Rawalpindi, Rawalpindi Water and Sanitation Agency (R-WASA), Water demand, Water supply.

Introduction

Climate change is having significant social and economic impacts in Pakistan. The country has a large population living in poverty, and climate change is exacerbating their vulnerability. The debate around climate change is a multifaceted one. While climate change is real, current debates in the body of literature argue that the global COVID-19 pandemic has raised public awareness on the importance of universal and equitable access to water, sanitation, and hygiene as a critical issue for public health (Fu et al. 2021a)¹. As a result of the new challenges, developing countries have become unlikely to implement integrated water management by 2030 due to water scarcity, water shortage, and water pollution induced by climate change over the past years because of human involvement (Fekete et al. 2022)². Intergovernmental Panel on Climate Change (IPCC), the Millennium Ecosystem Assessment (2005)⁴, or the Planetary Boundaries paper. The nexus concept also benefited from efforts to conceptualize the Green Economy and Sustainable Development

Goals (SDGs) that rose to prominence during the preparation phase of the United Nations Conference on Sustainable Development, held in Rio de Janeiro in June, 2012 or Rio+20⁶. It was also popularized in several wide-reaching events and reports, including, in particular, the Bonn 2011 Nexus conference⁷ and its supporting background paper as well as the Global Risks 2011 report of the World Economic Forum (WEF 2011).⁸ As Climate Change and Variability Mitigation and Adaptation are included in the dialogues, the Nexus approach makes the necessary planning processes more transparent and easier for the stakeholder community to understand and accept because of the integrative nature of the dialogues. The Nexus approach contributes to enhancing resilience and to addressing disaster risk (for example, water floods can be stored in the dam and released for agricultural and energy production purposes later).

Water, energy, and food are critical[basic] needs for humanity (Maslow 1943)⁹. Whilst this is an “*objective*” statement, a reality check vividly says that not every geographical region has an equitable and adequate supply. An arid/semi-arid region will have energy but might lack water and domestic food production capabilities (Middle East). Some regions have water but lack food production infrastructure (Bangladesh-South East Asia), while other countries have the capability to produce food but lack access to adequate energy (Central Europe). Other countries without natural reserves of fossil fuels are compelled (China) to purchase costly oil and gas and need to produce food for export to maintain their balance of payments (Anik et al 2014).¹⁰ So the equation is not harmonized globally.

The water–energy–food nexus in Pakistan

Table 1: Material consequences of five categories of food-water activities and two energy options:

Approach	Water perspective	Energy perspective	Food perspective
(1) Increase crop area and water use	Risk of higher water demand and demand exceeding supply. Potential for irrigation demands to be affected by hydropower requirements.	Agricultural demand for energy is low relative to other sectors, but hydropower vs. irrigation tensions could be heightened under this option.	Higher crop production, with higher dependence on affordable and reliable water and energy supply.
(2) Increase yield per unit water; or (3) swap to lower water use crops	Potential to lower agricultural water demand, but only if system rebounds are managed.	Potential to lower agricultural dependence on energy supply, but only if system rebounds are managed.	Potential for same production with lower dependence on energy and water.
(4) Import more food, export less; or (5) slower	Lower demand for irrigation water.	Lower agricultural demand for energy, and potential to ease tensions between	Potential to ease demand for food from agricultural sector.
population growth		hydropower and irrigation requirements.	

(6) More hydropower from (a) large dams and/or (b) local barrages	May help or hinder provision of irrigation water depending on dam locations and operations.	improves energy supply. Option (b) may help build local supplies without large investment in new grid infrastructure.	Linked to water. May ease other barriers to food access (e.g. opening new livelihood options, more reliable cold storage).
(7) Import more energy	Relieves constraints that hydro places on irrigation water.	Increases dependence on affordable and reliable energy markets.	Linked to water. May ease other barriers to food access (e.g. opening new livelihood options, more reliable cold storage).

Water: Water is key to food security. Crops and livestock need water to grow. Agriculture requires large quantities of water for irrigation and of good quality for various production processes. While feeding the world and producing a diverse range of non-food crops such as cotton, rubber and industrial oils in an increasingly productive way, agriculture also confirmed its position as the biggest user of water on the globe. Irrigation now claims close to 70 percent of all freshwater appropriated for human use. However, access to adequate food in the rural areas of many developing countries depends heavily on access to natural resources, including water, that are necessary to produce food.

Falkenmark introduced an indicator for water stress that expresses the level of water scarcity in a certain region. Amount of freshwater that is available for each person each year. It eventually became known as the Falkenmark Indicator, and is not only one of the earliest, but also one of the most widely used indicators.

Main Worries: Availability of Water in Pakistan Table 2:

>1700M ³	Water Scarcity Rare (Normal Conditions)
<1700M ³	Country faces seasonal or regular water stress conditions
<1000M ³	Water shortages hamper health and wellbeing of the human beings – Economics activities are affected (Water Scarce Conditions)

<500M ³	Shortages are severe constraints to human life (Absolute Scarcity)		
Sr. #	Year of Census	Population	Water Availability (M ³ /Person/ Annum)
1	1951	33,740,000	5,260
2	1961	42,880,000	3,888
3	1972	65,309,000	2,751
4	1981	84,254,000	2129
5	1991	115,000,000	1565

6	2002	139,500,000	1282
7	2010	173,510,000	1030
8	2017	207,774,550	850

Water has always played a central role in human societies. Water is quite literally a source of life and prosperity and a cause of death and devastation; Water as a Source of Destruction and Poverty as in our case mostly due to mis-planning and wrong priorities; It is a Source of Production and Growth in most of the countries; Water is a key driver of sustainable growth and poverty alleviation as an input to almost all production, in agriculture, industry, energy, transport, by healthy people in healthy ecosystems; Achieving basic water security, harnessing the productive potential of water and limiting its destructive impacts, has been a constant struggle since the origins of human society.

Reasons for Water Scarcity in Pakistan includes: Rapid increase in population; Decrease in Surface Water / Fresh Water Supplies; Overexploitation of the Ground Water; Loss of Storage Capacities owing to silt deposition in reservoirs; Limited water storage capacities; Climate change and its impact on water resources; Limited Rainwater Harvesting; Disposal of untreated wastewater into water bodies and Wastage of drinking / municipal water owing to poor awareness & non metering practices. According to the World Bank, the average annual temperature has by 0.5°C since the 1960s, and it is projected to increase by 1.5-2.5°C by the end of this. The country is already facing climate-related threats to its water resources as is evident from the change in monsoon patterns, receding glaciers, rising temperatures and recurrence of extreme floods (World Bank, 2020)¹¹. Pakistan has already crossed the water stress line below 1700m³ per capita availability during 1990s, crossed scarcity line below 1000 m³ per capita during 2020 and will be crossing the extreme water scarcity line.

i.e. below 600-700 m³ per capita water availability by 2025 (Qureshi et al, 2011)¹².

Energy: Climate change is also aggravating Pakistan's energy crisis, which is already a significant challenge for the country. The ability of a nation to secure sufficient, affordable and consistent energy supplies for its domestic, industrial, transport and military requirements is termed Energy Security. It means that current and future energy needs have a high probability of being met, irrespective of economic or political instability. Pakistan relies heavily on fossil fuels for its energy needs, which has led to high levels of air pollution and greenhouse gas emissions. However, climate change is now affecting the country's hydroelectric power generation, which accounts for over 30% of its electricity supply. As glaciers melt, the water flow in rivers is becoming more erratic, reducing the capacity of hydroelectric plants to generate electricity. Food: If people lack secure access to above then it is Food Insecurity. The three components of food security—availability (having sufficient quantities of appropriate food available), access (having adequate income or other resources to access food), and utilization/consumption (having adequate dietary intake and the ability to absorb and use nutrients in the body). It is also worth mentioning that the 2022 Pakistan floods mainly caused by increased precipitation and glaciers melting fueled by climate change, destroyed around 50% of the crops of Pakistan what can lead to food shortages. Similarly, droughts have become more frequent, affecting millions of people and exacerbating food insecurity in the country. Hydro Diplomacy: Hydro diplomacy serves as a brokered agreement, facilitating dialogue and collaboration to address complex challenges and promote global stability. Water diplomacy concerns water-related challenges and conflicts through negotiation, cooperation, and collaboration among various stakeholders, including nations, organizations, and communities. The Ups and Downs being faced in managing the transboundary water relations between Pakistan and India since the independence of the two countries in 1947. Despite the Indus Waters Treaty (IWT) signed in 1960, differences between both the countries started re-emerging in 1970s over interpretation of various clauses of the Treaty and the design of infrastructure projects by India on the rivers allocated to Pakistan.

Indus Waters Treaty, treaty, signed on September 19, 1960, between India and Pakistan and brokered by the World Bank. The treaty fixed and delimited the rights and obligations of both countries concerning the use of the waters of the Indus River system. Surface-water resources in

Pakistan are based on the flows of the Indus River and its tributaries (Jhelum, Chenab, Ravi, Sutlej, and Beas to the east and the Kabul River to the west). The Indus River has a total length of 2900 km and a drainage area of ~966,000. The treaty allows India to use the western river waters for limited irrigation use and unlimited non-consumptive use such as power generation, navigation, floating of property, fish culture, etc. It lays down detailed regulations for India in building projects over the western rivers. The preamble of the treaty recognizes the rights and obligations of each country in the optimum use of water from the Indus system in a spirit of goodwill, friendship and cooperation.

Indus Water Treaty is in its true sense a means of peaceful survival between the two countries. Respecting its conditions and implementation with making the regular up-gradation and reforms that are based on the changing geographical, political and environmental challenges of the South Asia region.

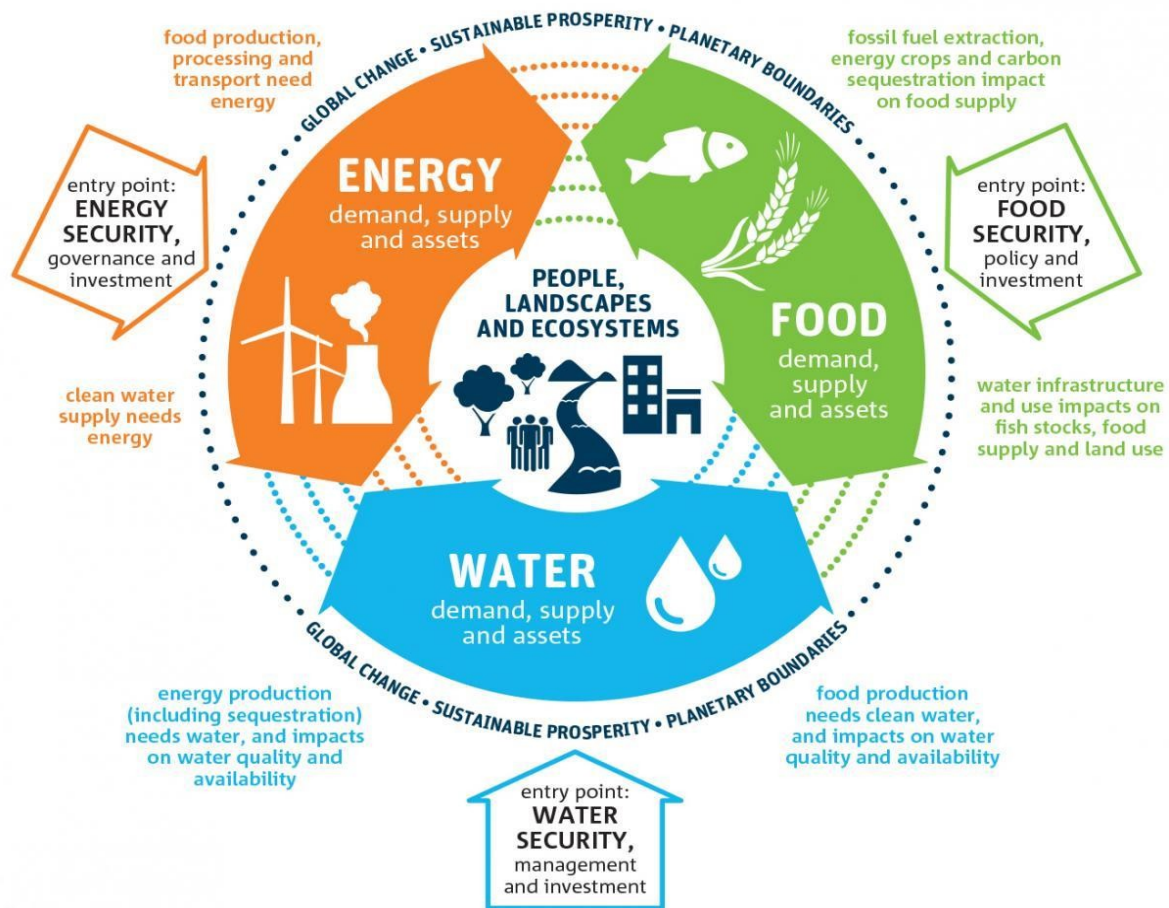
The Linkages

Water security, energy security, and food security are intimately linked. In simple terms, food production demands water; water extraction, treatment and redistribution demand energy; and energy production requires water. Energy inputs via fertilizers, tillage, harvest, transport, irrigation and processing have their influence on food prices. Environmental pressures and climatic changes, as well as growing economies and populations both intensify the existing relations between the three sectors (Mohtar, Daher, 2012). Founded on a series of understandings that nature is inherently connected in all its entirety, the resources must be affecting each other directly/indirectly, the integrated approaches to resource use emerged. The emphasis is longer-term social and ecological sustainability while offering operational means to internalize externalities, foresee and mitigate unintended consequences, and above all, strengthen resilience through outcome-oriented and institutional change.

Yet this is a tall order, and while specific transition pathways that often emerge gradually must be seized rapidly, the conceptual development and tools application processes have benefitted from a decade or more of innovation and experimentation. The ‘nexus’ of multiple resources, in essence, means, governance and policy frameworks, that are embedded in broader political processes. The nexus conceptually links multiple resource-use practices and serves paradigmatically to understand interrelations among such practices that were previously considered in isolation (Scot et al (2015)¹⁴.

Water – Energy – Food Nexus Table 3:

Population and Environment	Food production needs to be doubled by 2050 to meet demand of people and focus will be on reducing GHG emissions
Water supply crunch	Impact of water shortages (from 2020 2/3 of population is in water stressed countries)
Climate change and variability	Frequent droughts, floods, temperature extremes and weather variations in many regions
Energy supply crunch	Agriculture – energy dependent for oil, fertilisers, farming, storage or transport Push to Bio-fuel demand reducing food area
Price rise and volatility	Inevitable as a result of shortages and protectionism



Sustainable Development and its Goals

The United Nations (UN) defines the “Sustainable Development” as “The development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It calls for concerted efforts towards building an inclusive, sustainable and resilient future for people and planet. For sustainable development to be achieved, it is crucial to harmonize three core elements: economic growth, social inclusion and environmental protection. These elements are interconnected, and all are crucial for the well-being of individuals and societies.

Eradicating poverty in all its forms and dimensions is an indispensable requirement for sustainable development. To this end, there must be promotion of sustainable, inclusive and equitable economic growth, creating greater opportunities for all, reducing inequalities, raising basic standards of living, fostering equitable social development and inclusion, and promoting integrated and sustainable management of natural resources and ecosystems. (UN Sustainable Development Agenda).¹⁵

On 1 January 2016, the 17 Sustainable Development Goals (SDGs)¹⁶ of the 2030 Agenda for Sustainable Development — adopted by world leaders in September 2015 at an historic UN Summit — officially came into force. Over the next fifteen years, with these new Goals that universally apply to all, countries will mobilize efforts to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind.

The SDGs build on the success of the Millennium Development Goals (MDGs)¹⁷ and aim to go further to end all forms of poverty. The new Goals are unique in that they call for action by all countries, poor, rich and middle-income to promote prosperity while protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth

and addresses a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection.

SDGs for Water, Energy & Food against the respective Global Status Quo

Resilient economies require coherent and effective planning of water, energy and food that balances consumption, production and trade requirements against the country's natural resource endowments. To achieve this coherence, one crucial and neglected part of development planning is to forge a shared perspective within government on where a country stands within the framework of resource scarcity and abundance, and how this relates to the country's development goals.

Water Goals

Freshwater source all over the globe are glaciers. Unprecedented changes in the temperature due climate change resulted in its speedy melting. This gives rise to risks of flooding and the fast-paced vanishing of glaciers, an alarm for water scarcity. Glaciers are considered and understood as banks holding fresh water, but with climate change and global warming these banks are running out of cash(water) (David Suzuki)¹⁸. Water infrastructure, to deal with supply of water, storm water system, sewerage system, the whole infrastructure is designed to deal with normal conditions. But with the advent of global warming, the in-place infrastructure has been witnessed as incapable to deal with the anomaly, resulting in billions of losses to it and further billions for more investment into it, hence financing can be major and catastrophic burden on various urban communities around the globe.

Table 4:

SDG-Water	Global Status Quo
• By 2030, achieve universal and equitable access to safe and affordable drinking water for all • By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations • By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	• 2.6 billion people have gained access to improved drinking water sources since 1990, but 663 million people are still without • At least 1.8 billion people globally use a source of drinking water that is fecally contaminated • Between 1990 and 2015, the proportion of the global population using an improved drinking water source has increased from 76 per cent to 91 per cent • Water scarcity affects more than 40 per cent of the global population and is projected to rise. Over 1.7 billion people are currently living in river basins where water use exceeds recharge

• By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity • By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate • By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes • By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies • Support and strengthen the participation of local communities in improving water and sanitation management	• 2.4 billion people lack access to basic sanitation services, such as toilets or latrines • More than 80 per cent of wastewater resulting from human activities is discharged into rivers or sea without any pollution removal • Each day, nearly 1,000 children die due to preventable water and sanitation-related diarrheal diseases • Hydropower is the most important and widely-used renewable source of energy and as of 2011, represented 16 per cent of total electricity production worldwide • Approximately 70 per cent of all water abstracted from rivers, lakes and aquifers is used for irrigation • Floods and other water-related disasters account for 70 per cent of all deaths related to natural disasters¹⁹
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Goals for Energy

Elevated water and air temperatures reduce the efficiency of power plant generation and pose risks for power plant operators of exceeding regulations on thermal pollution released to receiving water bodies. Electricity transmission is less efficient with higher air temperatures, weakening the capacity of grid infrastructure. -Climate change is projected to decrease water availability in many semi-arid and arid regions, with shifting rainfall patterns and intensified droughts threatening water resources necessary for different inputs of energy supply. Increasingly numerous and intense floods in areas close to energy plants can cause severe harm to power production and energy delivery infrastructure and can result in more frequent blackouts.

Table 5:

SDG- Energy	Global Status Quo
• By 2030, ensure universal access to affordable, reliable and modern energy services • By 2030, increase substantially the share of renewable energy in the global energy mix • By 2030, double the global rate of improvement in energy efficiency • By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology • By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programs of support²⁰	• One in five people still lacks access to modern electricity • 3 billion people rely on wood, coal, charcoal or animal waste for cooking and heating • Energy is the dominant contributor to climate change, accounting for around 60 per cent of total global greenhouse gas emissions • Reducing the carbon intensity of energy is a key objective in long-term climate goals.

Food Goals

Impacts on food production will affect food supply at the global and local levels. In theory, higher yields in temperate regions could offset lower yields in tropical regions. However, because many low-income countries have limited financial capacity to trade and depend largely on their own production to cover food requirements, it may not be possible to offset declines in the local food supply without increasing reliance on food aid. Impacts on all forms of agricultural production will affect livelihoods, incomes and therefore access to food. Producers that are less able to deal with negative effects from climate change, such as the rural poor in developing countries, risk having their safety and welfare compromised. Processing, distribution, acquisition, preparation and consumption of food, are similarly important for its security.

Table 6:

SDG-Food	Global Status Quo
• By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round • By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons • By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial	• Globally, one in nine people in the world today (795 million) are undernourished • The vast majority of the world's hungry people live in developing countries, where 12.9 per cent of the population is undernourished. • Asia is the continent with the hungriest people – two thirds of the total. The percentage in southern Asia has fallen in recent years but in western Asia it has increased slightly. • Southern Asia faces the greatest hunger burden, with about 281 million undernourished people. In sub-Saharan Africa, projections for the 2014-2016 period indicate a rate of undernourishment of almost 23 per cent. • Poor nutrition causes nearly half (45 per cent) of deaths in children under five – 3.1 million

services, markets and opportunities for value addition and non-farm employment • By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality • By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.	children each year. • One in four of the world's children suffer stunted growth. In developing countries, the proportion can rise to one in three. • 66 million primary school-age children attend classes hungry across the developing world, with 23 million in Africa alone. • Agriculture is the single largest employer in the world, providing livelihoods for 40 per cent of today's global population. It is the largest source of income and jobs for poor rural households. • 500 million small farms worldwide, most still rainfed, provide up to 80 per cent of food consumed in a large part of the developing world. Investing in smallholder women and men is an important way to increase food security and nutrition for the poorest, as well as food production for local and global markets
• Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries. • Correct and prevent trade restrictions and distortions in	• Since the 1900s, some 75 per cent of crop diversity has been lost from farmers' fields. Better use of agricultural biodiversity can contribute to more nutritious diets, enhanced livelihoods for farming communities and more resilient and sustainable farming systems. • If women farmers had the same access to resources as men, the number of hungry in the world could be reduced by up to 150 million.

world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round. • Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information • Including on food reserves, in order to help limit extreme food price volatility²¹	• 1.4 billion people have no access to electricity worldwide – most of whom live in rural areas of the developing world. Energy poverty in many regions is a fundamental barrier to reducing hunger and ensuring that the world can produce enough food to meet future demand.
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Climate Change and its effects on Water – Energy – Food

Table 7:

Climate Change and Water – Energy – Food		
Water	Energy	Food
Freshwater source all over the globe are glaciers. With unprecedented changes in the temperature due climate change resulted in its speedy melting. This give rise to risks of flooding and the fast paced vanishing of glaciers- an alarm for water scarcity. -Glaciers are considered and understood as banks holding fresh water, but with climate	Elevated water and air temperatures reduce the efficiency of power plant generation and pose risks for power plant operators of exceeding regulations on thermal pollution released to receiving water bodies. Electricity transmission is less efficient with higher air temperatures, weakening the capacity of grid infrastructure. -Climate change is projected to decrease water availability in many semi-arid and arid regions (IPCC,2008)²³,	Impacts on food production will affect food supply at the global and local levels. In theory, higher yields in temperate regions could offset lower yields in tropical regions. However, because many low-income countries have limited financial capacity to trade and depend largely on their own production to cover food requirements, it may not be possible to offset declines in the

change and global warming these banks are running out of cash(water) (David Suzuki)²² -Water infrastructure, to deal with supply of water, storm water system, sewerage system, the whole infrastructure is designed to deal with normal conditions. But with the advent of global warming, the in-place infrastructure has been witnessed as incapable to deal with the anomaly, resulting in billions of losses to it and further billions for more investment into it, hence financing can be major and catastrophic burden on various urban communities around the globe.	with shifting rainfall patterns and intensified droughts threatening water resources necessary for different inputs of energy supply. -Increasingly numerous and intense floods in areas close to energy plants can cause severe harm to power production and energy delivery infrastructure, and can result in more frequent blackouts (Pakistan floods 2010)²⁴	local food supply without increasing reliance on food aid. -Impacts on all forms of agricultural production will affect livelihoods, incomes and therefore access to food. Producer that are less able to deal with negative effects from climate change, such as the rural poor in developing countries, risk having their safety and welfare compromised. -Processing, distribution, acquisition, preparation and consumption of food, are similarly important for its security. (FAO2008a)²⁵
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Pakistan Vision 2025

- Meeting the basic needs of this growing population, including in particular their access to essential services—health, education, energy, water, and sanitation.
- Providing the social, legal, and physical infrastructure needed to empower people and ensure that they are able to live their lives with dignity, and that human rights are protected, lives are secure, there is full employment (i.e., over 1.5 million additional decent jobs are created every year), women are empowered, and that poverty and hunger are eliminated. A responsible and accountable government and public sector
- An entrepreneurial private sector that can generate the required number of jobs.
- Ensuring that the economy can engage effectively with and benefit from the opportunities emerging outside the borders, especially regional opportunities.
- Ensuring competitiveness in the modern world that has shifted towards a knowledge economy.
- Protecting natural resources and addressing climate change.
- Perhaps most importantly, ensuring rapid growth of the GDP in order to generate
- the required number of jobs, with an emphasis on ‘inclusive growth’,

mindful of the regional and social inequalities which exist in our economy. A concerted effort to create balanced growth and provide equal opportunities to all Pakistanis.²⁶



Nexus Approach Adaptation

Given the complex interplay of water, energy, and food demand and supply, numerous challenges and opportunities exist to minimize trade-offs and promote synergies to formulate effective adaptation options. The nexus approach provides a framework for addressing competition for resources and enhancing resource use efficiency. The goals and principles of the nexus approach and of climate change adaptation are closely linked and interconnected, as are the focus and strategies. Effective adaptation and nexus approaches share many common features. Management of water, energy, and food security has an impact on adaptation, and the strategies and policies aimed at climate mitigation and adaptation have significant implications for nexus challenges. While some adaptation measures such as water-use efficiency, renewable energy, and growing biofuels on wasteland might have positive implications for water, energy, and food resources, other measures for adaptation and mitigation such as extensive groundwater pumping, desalination plants, inter-basin transfers of water to deal with water scarcity, and growing biofuels to deal with fuel scarcity, may increase nexus challenges.

Case Study

Rawalpindi, district and city in the Potwar Plateau of province of Punjab, Pakistan is

275 km to North-West of Lahore and 14 km South West of the national capital Islamabad. It covers an area of 5,285 square kilometer and consists of seven Tehsils. Population of Rawalpindi is approximately 6,118,263 in 2022. Of this population 2,396,672 live in rural areas and 3,005,708 in urban areas. The water supply in Rawalpindi city relies on ground water as well as surface water from Rawal Dam and Khanpur Dam. The total water demand of Rawalpindi Water and Sanitation Agency (R-WASA) is 68 million gallons per day (MGD). However, the total water available for R-WASA commercial and domestic consumers is 51 MGD against the demand of 68 MGD.

As climate change has a direct impact on water cycle and hence the availability of water, it also has a direct impact on clean drinking water supply and sanitation services. Impacts of climate change

are likely to further aggravate the already questionable situation of WASH services (Howard, Calow, Macdonald, & Bartram)

Climate Change and Water and Sanitation: Likely Impacts and Emerging (Trends for Action, 2016)²⁸, (WASH Services and Climate Change: Impacts and Responses, 2018)²⁹, (IFRC, 2021)³⁰. A significant correlation has been established between high/low rainfall, increasing ambient temperature and increasing cases waterborne diseases. Changes in rainfall and temperature can lead to flood and droughts which can affect the concentration of bacterium and subsequently human health (Altizer, Ostfeld, Johnson, Kutz, & Harvell, 2013)³¹, (Asadgol, Mohammadi, Kermani, Badirzadeh, & Gholami, 2019)³². Reduced availability of water due to climate change threatens WASH services and infrastructure (Jones, Bouzid, Few, Hunter, & Lake, 2020)³³. Pipes for water supply can easily break due to the pressure from heavy flooding (Howard, et al., 2010)³⁴. The impact of climate change on water and sanitation services will affect all aspects of service delivery and undermine the achievement of Sustainable Development Goal (SDG) (Howard, Calow, Macdonald, & Bartram, 2016). The provision of basic WASH services must be a priority, particularly as progress made in this sector is threatened by climate change (Jimenez, 2020)³⁵.

The study of Climate Change Profile of Pakistan by (Chaudhry, 2017)³⁶ identified the district of Rawalpindi City, Punjab, Pakistan to be at high risk to floods and medium risk to droughts. Moreover, Rawalpindi has been subjected to severe rainfalls during the monsoon seasons for the past few years, often leading to urban flooding. On the other hand, after the monsoon rainfalls, little water supply is received for the remaining months (Hafeez M. 2021)³⁷.

Current Water Resources Situation of Rawalpindi

Rawalpindi is facing water scarcity the challenge with limited availability of freshwater supply, prompting them to diversify their water sources and minimize reliance on groundwater to become more resilient. Increase reliance on surface water demands various options for surface water treatment technologies in order to ensure that the water supplied is of the highest possible quality. Must develop an Integrated Water Resource Management strategy for Rawalpindi. Strengthen R-WASA water quality testing laboratories with necessary equipment and testing materials including improved sample collection procedures. Develop water safety plans that includes risk management strategies.

Although R-WASA is providing 75 percent of the total city demand to 85 percent of the target population. Yet the distribution of this water is inequitable and inconsistent. In the absence of the water, the population of the deprived areas depends on water from the R-WASA and private water tankers service. The R-WASA tankers charges PKR 740 for 1000 gallons tanker and PKR 500 for 550 gallons tanker for domestic consumers. Whereas, the private tankers in Rawalpindi city charges between PKR 1,500 to 3,000 for 800 gallons tankers, depends on the location of the consumer and distance from the source.

Preparation of a climate informed reform plan for WASA Rawalpindi that enhances the provision of sustainable water supply services in Rawalpindi city. Objective of the study is; review existing system for water quality management and how water safety planning services are being executed. Evaluate consumer engagement, social mobilization and community engagement in planning, implementation and review and to develop a roadmap for water safety planning to enhance the effectiveness and efficiency of Rawalpindi WASA.

Present and Future Water Availability and Demand by R-WASA

Table 8:

Sr.No	Water Source	Water Production
	211	
	Present Available Sources	
1	Rawal Dam	23 MGD (10 MGD for R-WASA Consumers and 13 for bulk

2	Khanpur Dam	6 MGD
3	Tube-wells	35 MGD
	Total Water Available for R-WASA Consumers	51 MGD
	Present Water Demand for 1.7 million target population	68 MGD
	Deficit in Present Supply and Demand	-17 MGD
	Future Projects	
1	Rehabilitation of Rawal Dam and old transmission line	5 MGD
2	Replacement of Machinery of Khanpur Dam	8 MGD
3	Conduction of Water from Indus River System	100 MGD
4	Chahan Dam	12 MGD
5	Dadhocha Dam	35 MGD
	Total Water Expected from Future Projects	160 MGD

“Developing Resilient Environment and Advancing Municipal Services (DREAMS)”

Project primarily targeting Rawalpindi for reducing drinking water deficit which includes, Climate-resilient water supply infrastructure and services provided in Rawalpindi, it will build new water supply systems and water supply networks using surface water resource which will add 25.6 MGD additional water for existing and new systems. Furthermore, Institutional and capacity development for climate resilience, gender inclusiveness, and sustainability will be improved.

Scope

- Developing Resilient Environment and Advancing Municipal Services (DREAMS) aims to improve urban environments, living conditions, protect natural ecosystems, mitigate climate change and build sustainable, resilient and low-carbon municipal services in Punjab cities.
- DREAMS-I project primarily aims to overhaul municipal services in the City of Rawalpindi.
 - ✓ Objectives include improving Enhancing water supply services in Rawalpindi by rehabilitating and expanding the current infrastructure and developing new water sources.

Project Benefits

- Population served: 725,000
- Water supply systems and water supply networks using surface water resource.
- Upgrading of water pumps and transmission mains to augment water supply from surface water resource Rawal (5 MGD) and Khanpur dams (8.6 MGD).
- Non-Revenue Water will be reduced through system improvement, more metered connections and paid customers to R-WASA's network.
- Establishment of 3 pilot district metering area (DMA) with supervisory control and data acquisition (SCADA) system.
- Use of Solar Energy (20 MW) reducing burden on Government exchequer.
- Financial Sustainability (Improvement in O&M).
- Social Benefits.
- Health Benefits.

Outcomes

Output 1: Climate-smart water supply infrastructure rehabilitated and services provided.

This output will diversify water supply resources and upgrade the water supply network and its efficiency in Rawalpindi to provide reliable drinking water to 725,000 residents, including 400,000 previously unserved residents. Meanwhile, 89,000 residents will be fully served with 24/7 pressurized water supply.

Output 2: Institutional and capacity development for climate resilience, gender inclusiveness, and sustainability improved.

This output will support the implementation of both utilities' business models to improve their operational efficiency, financial sustainability, and O&M, and will facilitate overall capacity development. A roadmap for institutional strengthening and legal reform, including a new gender responsive WASH policy, SWM sector strategy, and tariff restructuring, will be formulated and implemented in phases.

Vision for Decarbonization Roadmap

- In Rawalpindi shifting towards solar-system of 20 MW, will significantly reduce its greenhouse gas emissions, solarization can help to mitigate climate change.
- Renewable Energy Source (RES) Carbon credits is under consideration to avert the climate crisis
- Collaboration with White Rice partnered with UNICEF Pakistan to develop a multi-channel behavior change campaign for the Punjab Government under the umbrella of Clean & Green Pakistan on:
 - ✓ initiatives for water and energy conservation, ultimately enhancing climate resilience at the household level

Pathways for Water Supply Systems for Rawalpindi Table 9:

Immediate-Term Options DREAMS Project (2021-25)	• Chahan Dam (12 MGD) + Solarization • Rehabilitation of Conductance Main of Rawal Filtration Plant (5 MGD) • Water Distribution System for Khyaban-e-Sir Syed + Solarization (8.6 MGD)	• Sustainable access to adequate quantities of water (SDG 6) • Acceptable quality ensuring protection against water-borne diseases (SDG 3) • Availability of sufficient energy at an affordable price through solarization and significantly reduces Greenhouse Gas emissions (SDG 7)	• Asian Development Bank (80%) + Government of the Punjab (20%)
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Short-term Options (2026-30)	• Ground Storage Reservoirs • Replacement of 30-year old Distribution Network, Installation of Smart Water Meters & detection of illegal consumer • Development of 2nd surface water source/Dadocha Dam 35 MGD • Augmentation of Rawal lake Filtration Plant	• Achieve economic developments (SDG12 Circular Economy) and sustainable environmental needs • Access to water - energy and food (through improvement in existing infrastructure and construction of water intake structures from Dams)	• Donor Agencies + Government of Punjab
Mid-term Options (2031-40)	• Ground Storage Reservoirs • Development of 3rd water source/Tarbella Dam 100 MGD • Water Distribution Network •	• Sustainable access to adequate quantities of water (SDG 6) • Access to water - energy and food (through improvement in existing infrastructure and construction of water intake structures from Dams)	• Donor Agency + Government of Punjab + Government of Pakistan

The W-E-F Nexus approach in the context of Consensus Policies

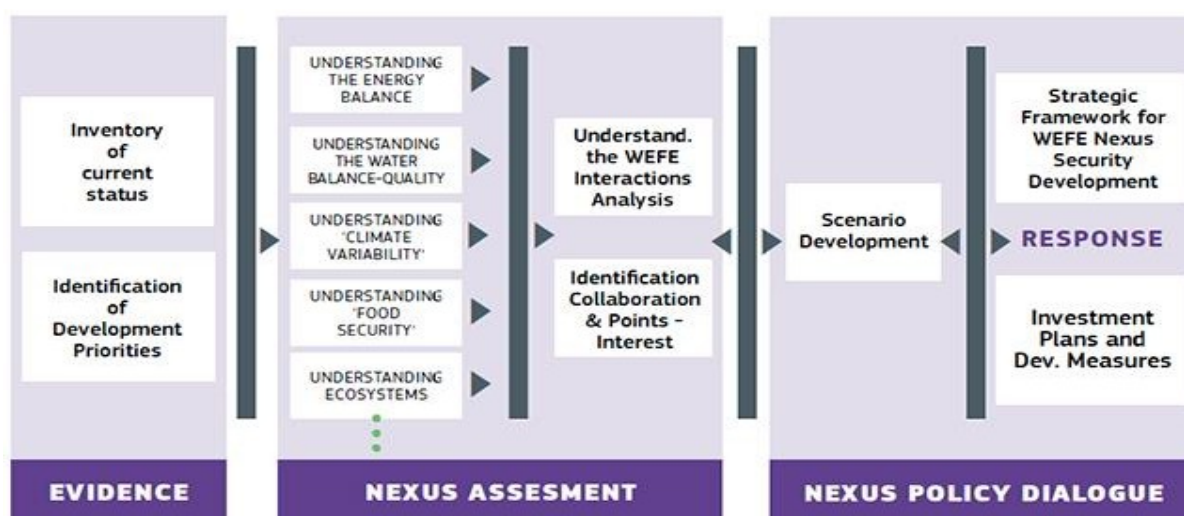
The Consensus on Development document sets out strategic approaches to improve Pakistan's impact in the implementation of the Pakistan Vision 2025 and 2030. Some of these Consensus policy statements point to concrete actions that can be entry points for facilitating the implementation of a Water, Energy and Food Nexus approach at a strategic level.

To develop an outlined overall methodology and mechanisms. Key questions must be explored, possible sources of data and data collection. Must identified comprehensive operating framework and key challenges & gaps. Review documents which ADB's Strategy 2030: Achieving a Prosperous, Inclusive, Resilient, and Sustainable Asia and the Pacific, ADB's Safe Space for Humanity: The Nexus of Food, Water, Energy, and Climate, National Drinking Water Policy 2009; National Climate Change Policy 2021; Vision 2025, Ministry of Planning, Development and Reforms, Government of Pakistan; Punjab Development of Cities Government Act 1976, Punjab Water Policy 2018, Punjab Drinking Water Policy 2011, Punjab Water Act, 2019, Punjab Ab-e-Pak Authority 2019, Punjab WASH Sector Development Plan 2014-2024, Punjab Development Statistics 2020, Pakistan Vision 2025, Sustainable Development Goals and WASH joint sector review report of Punjab. A further review and analysis of secondary data will be conducted to understand the current coverage and access, both in terms of services as well as sector investment. This includes: National Environmental Quality Standards (NEQS) and Pakistan Council of Research in Water Resources (PCRWR).

Relative priority of water uses: The priorities for the consumptive and non-consumptive uses of water includes: Drinking and Sanitation (WASH); Irrigation including land reclamation; Livestock, fisheries & wildlife; Hydropower; Industry & mining; Environment, river system, wetlands, aquatic life; Forestry including social forestry; Recreation & sports and Navigation. Top Priorities are Water, Food & Renewable Energy. Same exists in Punjab Water Policy.

While the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for the achievement of the 17 Goals. Countries have the primary responsibility for follow-up and review of the progress.

made in implementing the Goals, which will require quality, accessible and timely data collection. Regional follow-up and review will be based on national-level analyses and contribute to follow-up and review at the global level.



Discussion

- Despite the strong linkages among Water, Energy and Food, a continuity of approach in the developmental sector over the decades, has always been in the “silos”. To maximize Water, Energy and Food in its output from resource perspective, a mechanism of awareness on part of policy makers is very important. Governments must re-evaluate the agricultural investments. This paradigm shift, in its essence, is reactionary in approach, but it paved way for thinking in the interconnectivity of resources and the complexity of linkages of food with energy, climate change and water. The SDGs will be the first litmus test for the nexus model and the resources linkages.
- Curbing subsidies in all the resource sectors i.e. Water, Food, and energy, instead paving way for accessibility of it. Apart from the fact the subsidies are directly proportionate to the resource it often leads to unintended consequences for other sectors. e.g. with large-scale groundwater depletion as a result of free electricity access for irrigators in India (Shruti Sharma et al 2015).³⁸ Thus, a nexus approach is to review, identify and scrutinize the trade-offs in the context of “*At the cost of what*”.
- Water pricing is a major factor. Most irrigators, who use about 70 percent of global freshwater resources either do not pay at all or only nominal amounts for water and payments are in most cases not linked to the volumes of water used. In the domestic and industrial sectors, accounting for about 30 percent of water withdrawn and 20 percent of water depleted, payments are generally volumetric, but even here water charges are often too low to affect behavior(Pimentel et al, 2004).³⁹ For more than a decade, the concept of virtual water has been used to relate water, food and trade(Allan J.A 1998).⁴⁰ Water- scarce countries can substitute food imports for domestic irrigated production (so-called imports of virtual water) and allocate these resources to other, higher-valued uses. Hence, the whole science of relevancy in policy making, rests on the choices made, and that can rightly be done if priorities are set right and its far sighted. This possibility is more explicit in the nexus model of the Water, Energy and Food resources.
- The lesson in Reisner's “Cadillac Desert” (Reisner 1986)⁴¹ about the over-development of water resources in the American West has documented it very well, how the shift can be negative. Reforming water institutions and adopting more efficient irrigation technologies are usually perceived as good substitutes for water-infrastructure investments across the globe (Xie et al 2016)⁹⁴ This leads to very deductive conclusion that the answer is not always building on more water reservoirs rather the efficient use of it, the governance of water infrastructures.
- Use trade, regional integration and foreign policy to manage nexus trade- offs more effectively, and contribute further to resilience at both country and global levels. (WWF2014)⁴². Energy will have long term effects on food and water. By-product of trade i.e. regional peace and stability is another important contributing factor.
- More than ever, Pakistan’s policy makers and government institutions needs to think and devise policies in the resource scarce county, where lack and absence of water and energy can sooner than later will have catastrophic effect on its agriculture and food sector.
- The policy tilt has always been towards ‘*Supply*’, it has never looked into conservation. Conservation can be key to green economy in future and the resource sustainability can be assured, which is a national and global goal. With

the advent of renewable technologies in energy sector and the technological adaptation mechanisms in agriculture sector (drip irrigation instead of canal water) can be useful tools in achieving the resources sustainability.

Conclusions

After going through analytical research and reviewing many national and international report it is safely concluded that Pakistan is a victim of climate change, and the impacts of this phenomenon already being felt across the country. The increasing frequency and severity of extreme weather events, glacial melting, and energy insecurity are just some of the challenges that Pakistan is facing.

Water, Energy & Food Nexus Model, in its actuality as a concept, has not been very old, but with the announcement of Sustainable Development Goals (SDGs) in September 2015 subsequently United Nation Climate Change Conferences (COPs) has made academicians and policy makers to think more on integrated modelling of natural resources. Hitherto, results have shown that model have some vivid deliverables for decision makers e.g. In Qatar, the implications of increasing food security (independence from imports) from 10 to 20 % was analyzed by quantifying the increased food production, considering the costs of energy, carbon, and water footprints. The water-energy-transportation nexus in Texas is analyzed using a scenario-based approach by examining sustainability indices to create an economic-environmental-social index because the sustainability of energy production in the state is of high priority. The approach has implications for policy, regulation, subsidy, the development and transfer of new technology and changing behaviors regarding how these issues are approached (WEF Nexus Research Group 2015).⁴³ Study shows that the nexus is a very relevant approach in the Mekong River Basin, as the nexus components form the basis for social and economic development in the riparian countries and are closely interlinked. The impacts from hydropower development are likely to be much more severe than those from changing climate. Such impacts are likely to lead to radical reductions in ecosystem productivity and, consequently, in the Tonle Sap (In Cambodia) fisheries (UN ESCAPE 2013).⁴⁴ With the advent of ICT (Information Communication Technology), data availability, and further analysis of nexus model, a now software tools are available, which can give, using scenario modeling and other required data input, to give the best possible results for the decision makers.⁴⁵ SDGs when announced, did managed to have its very sound full critics, who were in unison in attributing them as 'Catch All',⁴⁶ but lessons learnt from MDG (*Millennium Development Goals*) were, the journey must begin now, there is no other option.

Groundwater Level Change Prediction using Machine Learning in the semi-Arid Urbanized city of Quetta, Pakistan

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Abstract:

Quetta is the capital and the most urbanized city of the province of Balochistan, and 10th populous city in Pakistan. Quetta is heavily reliant on groundwater where groundwater level is depleting continuously due to human and climate change activities. The current population is experiencing an insufficient supply of water to meet their varying needs, including domestic, industrial, and agricultural. Sparse past research is available on water, more is required. Machine learning (ML), a subset of artificial intelligence (AI), centers on creating algorithms and statistical models. Its main objective is to allow computers to acquire knowledge from data, enabling them to make predictions or decisions based on this acquired learning. In this study two machine learning models will be used to predict the groundwater level. 1995-2020 data will be used, 3 monitoring wells data (observed groundwater level) has been collected from the water and sanitation agency (WASA) and remotely sensed rainfall, temperature data. The rate of depletion of groundwater level from well data was found out to be average 1.5-2 meter/year. These datasets will be used to predict the groundwater level and the effect of climatic variables; rainfall and temperature on groundwater level will be analyzed. The performance of the model will be evaluated using metrics; root mean squared error (RMSE), mean absolute error (MAE) and coefficient of determination (R²). This study will help better water management practices in future.

Keywords: Machine learning; ANN; Groundwater; Remotely Sensed.

Introduction

Water is indispensable for life, supporting health, agriculture, industry, and ecosystems. Its significance extends to economic development, cultural heritage, and environmental balance. The groundwater is the limited water resource, around 1.69% of total earth's water is the groundwater (United States Geological Survey, USGS). Although Pakistan has an abundance of water resources, they are not preserved and are contaminated due to poor management (Dawood et al., 2021).

There are 18 river basins in Baluchistan province of Pakistan, out of which Pishin Lora Basin (PLB) is the major river basin which sustains the livelihood of the most of the population of the Baluchistan province. Quetta which is the sub basin of PLB, groundwater is the main source for its domestic, industrial and agricultural purpose. The only source of water for rural and urban water delivery systems is the valley's aquifers (Durrani et al., 2018). Due to rapid urbanization of the Quetta valley and installation of uncontrolled aquifers the aquifers of the valley are declining at the faster rate. The per capita availability of water has sharply decreased in numerous countries worldwide, particularly in regions with low rainfall (Khair et al., 2010). Quetta is an arid region, generally the annual rainfall received is not enough to fulfil the needs and to recharge the groundwater level. The uncontrolled installation of tube wells has led to the excessive extraction of water continuously, this proliferation of tube wells has resulted in a significant water scarcity issue in Quetta district (Khair et al., 2018). Agriculture, livestock, and Orchards are the major sources of income in Quetta valley, water scarcity has a great impact on the economic and social life of people. According to the agriculture department of Baluchistan, the available water supply is insufficient to meet the demand for agriculture as well as domestic purposes.

Recently, machine learning (ML) have emerged for accurate modeling, particularly in identifying intricate structures, including irregular data, and developing forecast and predictive models (Olden et al., 2008). Furthermore, ML demonstrate notably higher prediction accuracy compared to conventional statistical models (Chen et al., 2018). In the past decade the researchers have took so much interest in the machine learning techniques, specially in the field of hydrogeological studies the ML technique has been used extensively. The models Linear Regression (LR), Support Vector Machines (SVM), Gaussian Processes Regression (GPR), and Neural Network (NN) were used in a study for the groundwater level prediction (Sapitang et al., 2021). One of study conducted in Quetta to assess the groundwater potential where six ML algorithms were used, where XGBOOST, RF and ANN performed best (Rasool et al., 2022). In another study of Quetta the deep learning approach was adopted for the groundwater forecasting (Pamir et al., 2023). In this study we used two ML models i.e. random forest (RF) (Li et al., 2023), and multiple linear regression (MLR) (Sahoo & Jha, 2013). The RF model is widely used these days in hydrogeological studies, due to its ability to effectively handle nonlinear data. On the other hand MLR model assumes a linear relationship between the variables and aims to minimize the difference them.

The main objectives of this study are 1) To adopt the data driven approach of machine learning alternatively to the conventionally used models for the hydrogeological studies 2) Implementation of two machine learning algorithm i.e. Random forest and Multiple linear regression using groundwater level and climate data for the groundwater level prediction 3) Comparison of the both machine learning models using statistical metrics. This study will be conducted for the Quetta valley which is the most urbanized area of Baluchistan province. Extensive research in the field of hydrogeology is essential to improve policy-making and water management practices in the Quetta valley.

Study Area

Quetta, the capital of Baluchistan province and comes in the top ten biggest cities of Pakistan. Quetta, a rapidly growing city, lies between latitudes 30°–03' N and 30°–27' N and longitudes 66°–44' E and 67°–18' E , situated at the height of 1,676 m above the sea level (Dawood et al., 2021). Quetta Valley spread over a geographical area of 1,794 Km² (Ali & Aftab, 2022). The Quetta is surrounded by four mountain ranges. The elevation rises towards the northeast peaks of Zarghoon Range at 3,519m and Takatu at 3,401m, Chiltan at 3,261m, and Murder Range at 3,134m above sea level. Quetta is an arid zone (Ali & Aftab, 2022). The average annual temperature and rainfall is 15.8°C and 244 mm in Quetta respectively (Dawood et al., 2021). The fig.1 (a & b) shows the study area where (a) is the Pakistan's map showing the Quetta city and (b) is the Quetta city's map with the location of two groundwater wells.

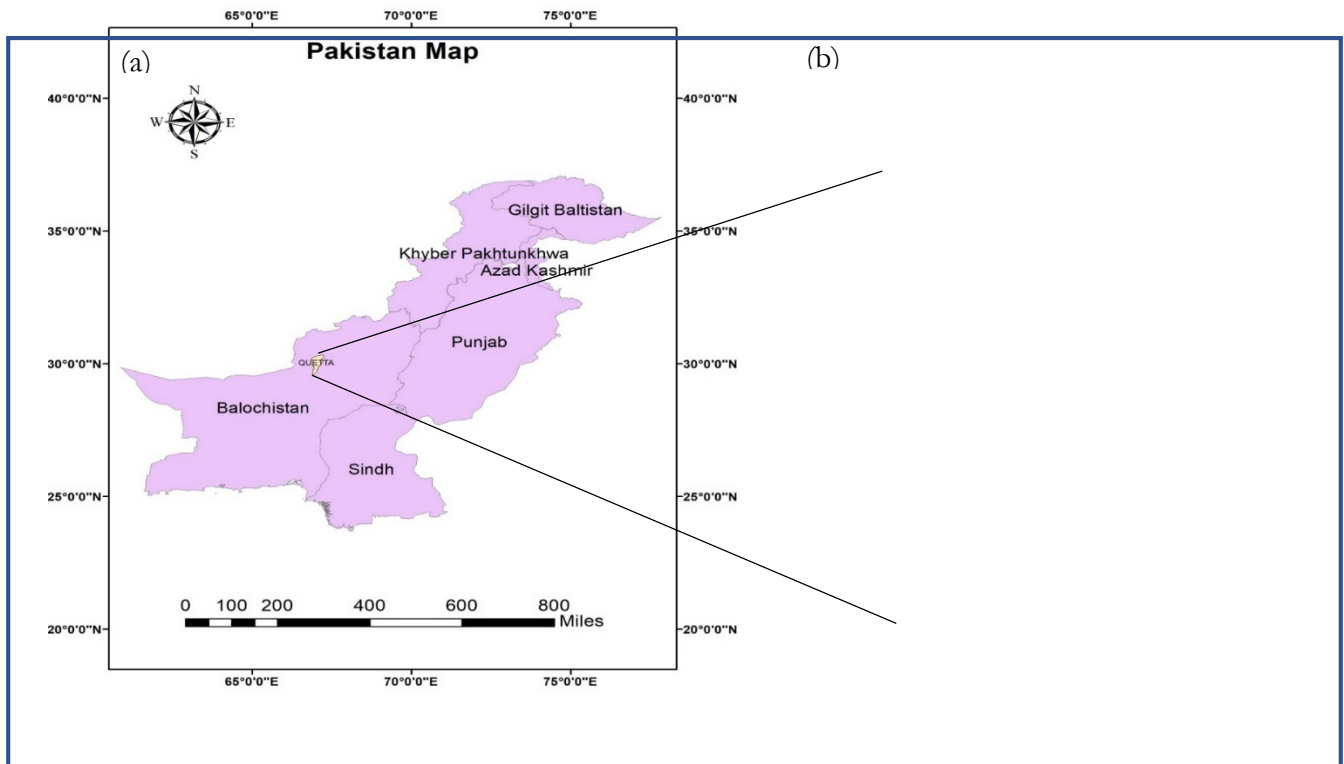


Fig.1 (a & b)

Methodology

Data Collection

The three datasets were used in this study i.e. rainfall in mm, temperature in celsius and groundwater level data in meter. The data source as shown in table.1, for rainfall and temperature the data were obtained through the remote sensing. Modern Era Retrospective analysis for Research and Applications, Version-2 (MERRA-2) satellite data were downloaded for rainfall and temperature. MERRA-2 offers an alternative approach to monitor precipitation and helps in hydrological studies specially in the region where data are irregular (Hamal et al., 2020). Whereas, the groundwater level data of the two water wells were obtained from the organization of water and sanitation agency (WASA). The 26 years datasets were used in this study table.1.

Table.1 Data used in this study

Data	Data Source	Period
Rainfall	MERRA-2 Satellite	1995-2020
Temperature	MERRA-2 Satellite	1995-2020
Groundwater level	Water and sanitation agency (WASA)	1995-2020

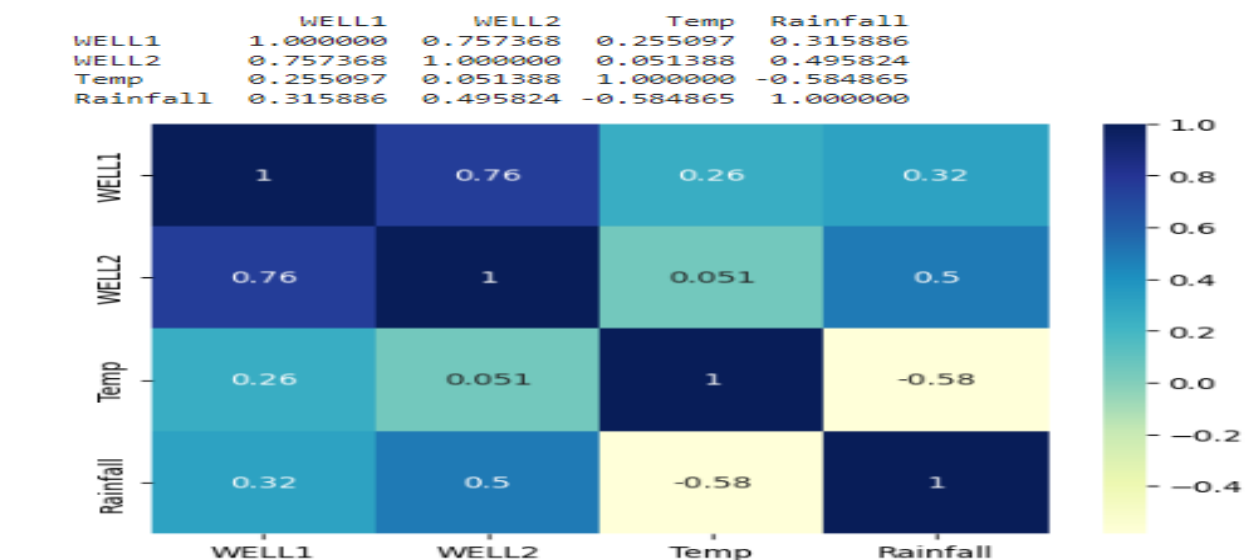


Fig.2 Heat map showing Pearson correlation among used dataset.

The datasets spanning 26 years were divided into training and testing sets for the models. The data were split into 70% for the training and the 30% for the testing of the models. The inputs used in the models were observed rainfall, temperature and well2 data and the output was the well1 dataset as mentioned in fig.2, where well1 and well2 are the groundwater level datasets. The models will be developed using python programming.

Normalization of data

There are many scalars used for data normalization, here MinMaxScaler was selected to normalize the data. This method of data preprocessing transforms the original data into a predefined range, typically ranges from 0 to 1. This simplifies the data processing for machine learning algorithms (Shah et al., 2023). Equation of MinMaxScaler as follows,

$$X_{sc} = \frac{(X - X_{min})}{(X_{max} - X_{min})} \quad (1)$$

Where X_{sc} is the scaled input, X is the unscaled observed input, X_{min} and X_{max} are the minimum and maximum values of the unscaled data.

Metrics for the models evaluation

The metrics used in this study as shown in table.2, three metrics MAE, RMSE and R^2 for the purpose of performance evaluation of the models. These metrics are widely utilized for the model's assessment. Where MAE and RMSE are assessed if the values obtained are nearer to 0, the value 0 shows the perfect model, in actual a perfect model does not exist. For the R^2 the values typically ranges between 0-1, where near 1 means perfect model, above 0.7 is considered good and less than 0.5 is considered poor model's performance.

Table.2 The statistical metrics

Performance criteria for evaluation of both models		
MAE	Mean absolute error	$\frac{1}{N} \sum_{i=1}^n \text{observed}_i - \text{predicted}_i $
RMSE	Root mean squared error	$\sqrt{\sum_{i=1}^n (\text{predicted}_i - \text{observed}_i)^2 / N}$
R^2	Coefficient of determination	$1 - \frac{\sum_{i=1}^n (\text{predicted}_i - \overline{\text{observed}})^2}{\sum_{i=1}^n (\text{observed}_i - \overline{\text{observed}})^2}$

Where N is the total number of samples, observed_i is an observed value for the i th data, predicted_i is a predicted value for the i th data, $\overline{\text{observed}}$ is the mean of an observed data. The equation numbers for three metrics as shown in table.2 are (2), (3) and (4).

Machine learning models

Random forest

In this study the random forest regression was utilized. Random Forest is an ensemble learning technique commonly used for classification and prediction tasks (Talukdar et al., 2023). Random forest (RF) constructs a forest using bootstrap samples of observed data. After generating multiple decision trees during training, RF is designed to produce an output by averaging the results of the individual tree method, particularly for regression tasks (Breiman, 2001). In a regression tree (RT), each non-leaf node holds a collection of decision rules, while each leaf node represents a prediction outcome (Wang et al., 2018). Many researchers have used random forest in the field of hydrogeology, for groundwater studies this model has been widely used for example (Wang et al., 2018; Arshad et al., 2024; Li et al., 2023; Pham et al., 2023). Random forests require tuning of two parameters: the number of trees (ntree) and the number of variables (mtry) (Naghbi et al., 2017).

Multiple Linear Equation

MLR is the approach used to find the linearity of relationship between two or more independent variables and one dependent variable. This method has been used by the researcher in the field of

hydrogeological studies for example (Sahoo & Jha, 2013; Ehteram & Banadkooki, 2023; Sahoo & Jha, 2015; Dogan et al., 2008). The equation for MLR can be written as,

$$f(x_i) = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n + e \quad (5)$$

where $f(x_i)$ is a independent variable, x_i 's are multiple dependent variables, b_i are regression multipliers, and e is a random error (Poursaeid et al., 2022).

Results and Discussion

The results obtained shows the RF model performed better than conceptual model MLR. The statistical parameters for the model's evaluation as in table.3, shows the coefficient of determination R^2 for RF and MLR in training period were 0.932 and 0.634, for testing period were 0.914 and 0.513 respectively table.3. The R^2 values showed the superiority of RF model over MLR model for the groundwater level prediction using observed groundwater level, rainfall and temperature data.

Table.3 The statistical analysis of models

Performance of both models						
Model	Training			Testing		
	R^2	RMSE	MAE	R^2	RMSE	MAE
RF	0.932	0.0565	0.0307	0.914	0.0369	0.0293
MLR	0.634	0.1319	0.1012	0.513	0.0879	0.0743

Whereas, the MAE and RMSE values showed the suitability of both the models table.3, values were nearer to 0 for both training and testing period. For RF the training period RMSE and MAE were 0.0565 and 0.0307, for testing 0.0369 and 0.0293 respectively. Similarly for MLR the RMSE and MAE values for training and testing were 0.1319, 0.1012 and 0.0879, 0.0743 respectively. It can be observed all values for RF and MLR model are near to 0 which shows good prediction ability of both models in terms of RMSE and MAE metrics.

The line plots and scatter plots are widely used for the interpretation of machine learning models. For the models used in this study the fig.3 (a & c) graphs shows the line plot for the RF and MLR model, with the predicted groundwater level data during the testing period. The line plot for RF shows the true and predicted line, which means the true(observed data) used as a reference data which was compared with the predicted data of the model. The both true and predicted lines for the RF are nearly closer to each other whereas, the line plot for the MLR model shows the true and predicted are not aligned well. The greater the alignment between the true and predicted lines, the stronger the model's predictive capability.

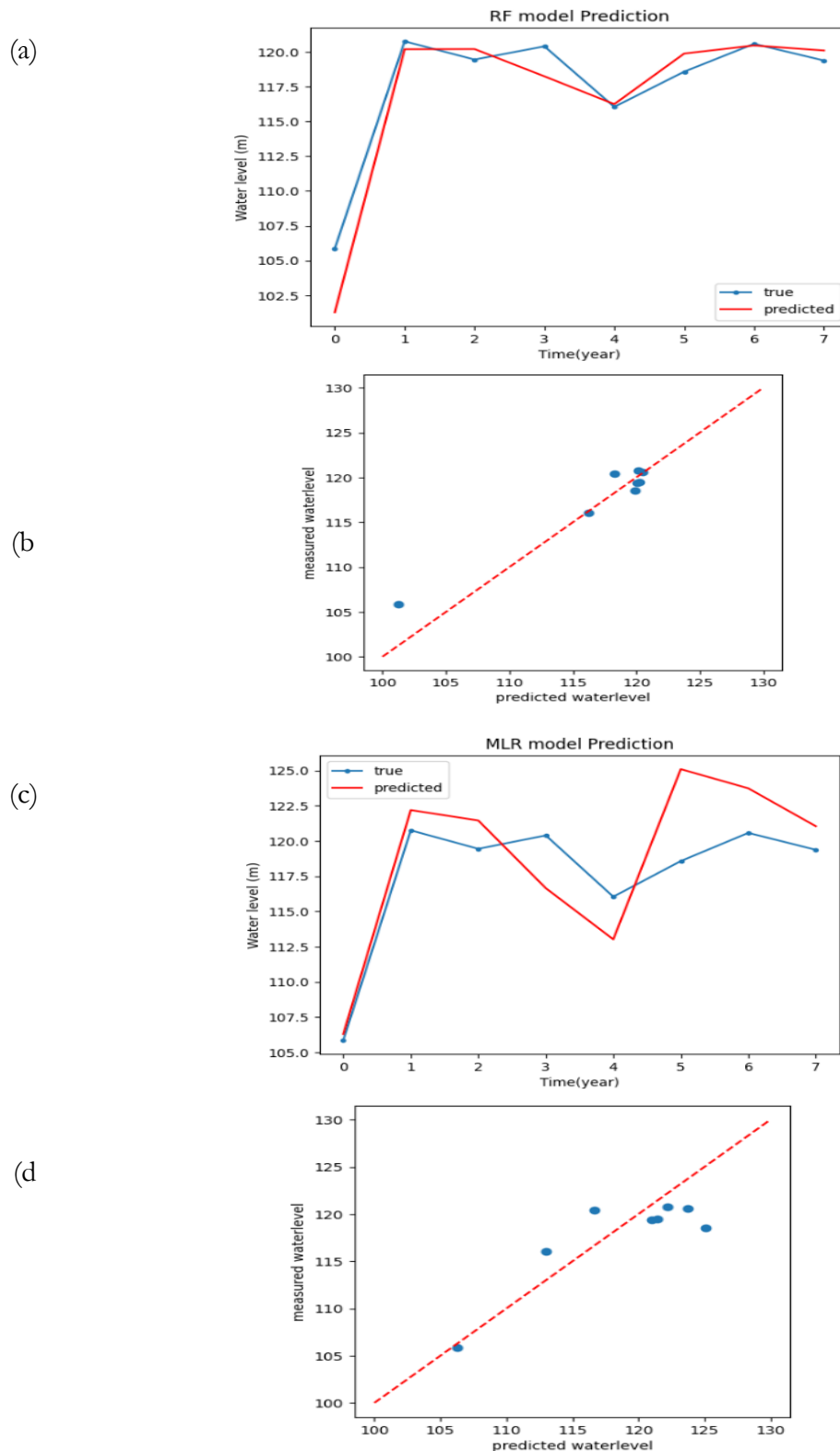


Fig.3 (a-d) The line plot and scatter plot for the RF and MLR predictions of testing data

On the other hand the scatter plots for the RF and MLR fig.3 (c & d) models shows the predicted groundwater level data from the testing period. The scatter plot shows the correlation between the two variables, here the two variables are measured groundwater level and predicted water level. The red line is called the best fit line and the blue dots are the data points. If the data points align closely with the best-fit line, the model is deemed to be best, whereas if they deviate, the model's

performance is not considered best. Therefore, by observing the scatter plots for RF and MLR it can be deemed that RF predicted better than MLR. The data points exhibit a high degree of alignment in the scatter plot for the random forest (RF) model. fig.3 (b).

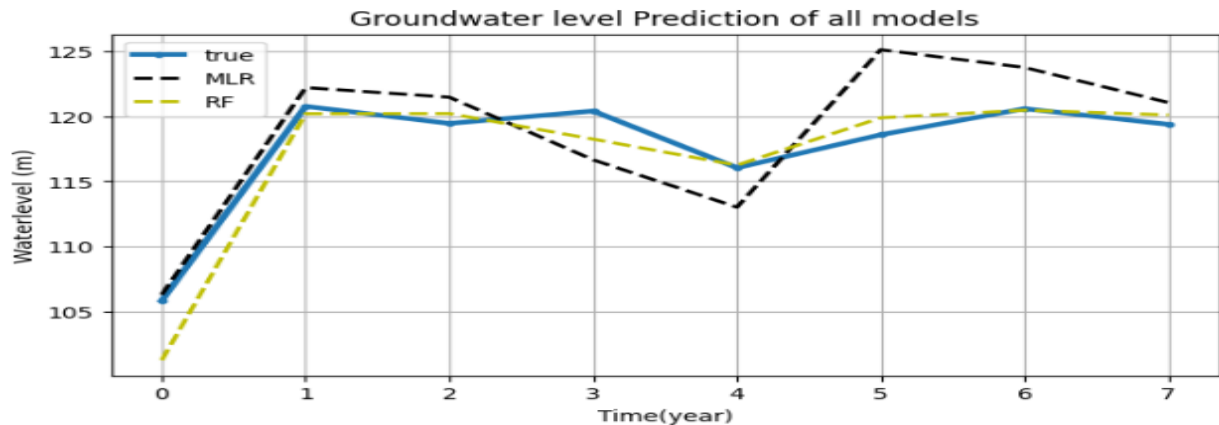


Fig.4 Line plot showing the comparison of RF and MLR

Ultimately, the comparison between both models utilized in this study can be conducted based on the obtained results. The fig.4 was utilized to draw a clear comparison of both models in terms of predictability. Three lines i.e. blue line (observed groundwater level), black (MLR groundwater level prediction) and yellow (RF groundwater level prediction) were compared. The model's ability to predict groundwater in this study will be determined by how closely both lines align with the observed groundwater line. It can be observed the RF line is closer to observed data line.

Conclusion

Groundwater level prediction was carried out using the data driven machine learning (ML) approach. The study was conducted for the urbanized part of Quetta valley is situated in a semi-arid region where the annual rainfall varies, and most of the rainfall received is insufficient to replenish the groundwater levels. As the Quetta depends on the groundwater mostly for its livelihood, the groundwater level is declining at very faster rate. From the wells data we used in this study the average 1.5-2 meter/year groundwater level is declining. In this study, a machine learning approach was employed to predict the future scenarios of groundwater levels in Quetta. For that purpose two machine learning models were utilized i.e. random forest (RF) and multiple linear regression (MLR). The data used in this study were two wells data (groundwater level) and climate data (rainfall and temperature). The input to the models were observed well2, rainfall and output was well1. The results obtained after training and testing of data showed the superiority of RF model over the MLR model. It can be inferred that incorporating observed well and climate data into the Random Forest model improves the accuracy of predicting the groundwater level. Moreover, researchers can utilize this study to evaluate prospective scenarios concerning groundwater studies in Quetta or similar regions. Researchers can narrow down the research gap in groundwater related studies in the region by conducting studies using various input parameters and models. Ultimately, this research will provide insights for policymakers and water managers to implement sustainable groundwater practices.

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Reduced Food Security Risks from Climate Change through Sustainable Agriculture in Pakistan

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Abstract:

Pakistan is greatly affected due to climate change. Extreme climatic conditions are danger for food security. Food systems are affected by climate change. Crop production effects due to cooler or warmer temperature, changes in rainfall pattern led to length of season increases. Farmers can adopt strategies to increase the yield by changing planting date, fertilizer types and crop varieties. In this study growing threats are deeply investigate the food security issues across the country due to climate change. If significant action is not made to address this worrying issue, it is predicted that Pakistan may lose almost US\$20 billion by the middle of this century because of climate change in the production of wheat and rice crops. In order to inform the relevant authorities to take prompt action in order to prepare for, adapt to, and reduce climate change before it is too late, the research closes with recommendations for mitigating and adapting to climate change as well as measures to address food security. Major research methods for addressing risk include developing advance water-efficient technology, agronomic research, organic farming, zone specific, research on groundwater quality and recharge applying simulation models. In this way crop yield increased.

Keywords: Climate change, food security, crop production methods, simulation models

Extraction of Pesticides from Water using Transition Metal Oxide Nanoparticles Decorated Chitosan Nanostructures (TMODCNs) Loaded Solid Phase Extraction Cartridge

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Abstract

The present study aims to prepare chitosan-transition metal oxide nanoparticles (Ch-MO NPs), namely, chitosan-zinc oxide nanoparticles (Ch-ZnO NPs) and chitosan-zinc oxide nanoparticles (Ch-ZnO NPs), using sol-gel precipitation method, and test them as new adsorbent materials for clean-up and extraction of atrazine pesticides from water. The characterizations of the prepared nanoparticles were investigated using Fourier transform infrared spectrometry (FT-IR), scanning electron microscopy (SEM), and X-ray diffraction (XRD). FT-IR confirmed the interaction between chitosan, metal oxide, and the crosslinking mechanism. SEM confirmed the surface morphology of chitosan-zinc oxide nanoparticles (Zn-O-NPs) having one of the dimensions lying in 50 nm. The experiment was carried out at a pH 7, at temperature of 25°C, and agitation time of 25 min. The solid phase extraction (SPE) cartridges were then packed with Ch-MO NPs, and atrazine pesticide was extracted from water samples and removal was determined by a UV-visible Spectrophotometer. The amount of loaded nanomaterial inside the cartridge was 100 mg. The atrazine concentrations were 10 ppm, 20 ppm, 30 ppm, 40 ppm, and 50 ppm. The results of the UV-Spectrophotometer showed that the extraction efficiency of SPE cartridge was achieved nearer to (80-85%) in normal conditions without optimized parameters) which shows that by applying the optimized parameters in the future the results will reach above 90 % efficiency. These results showed that this method achieves rapid and simple extraction in small quantities of adsorbents (Chitosan Zinc Oxide Nanoparticles), and this method is highly selective for pesticides, less usage of organic solvents, and low cost.

Keywords: Pesticides, Solid Phase Extraction, SPE Cartridge Fabrication, Atrazine Removal

1. Introduction

The most widely applied organic chemical compounds are pesticides, frequently found in drinking water, surface water, and soil. Pesticides are categorized into various categories according to their specific groups, such as organophosphorus, pyrethroids, organochlorine, neonicotinoids, and carbamates, which extensively contaminate the water, soil, agricultural fields, and atmosphere [1].

Atrazine belongs to the herbicide triazine class and is an organic chemical compound with the chemical nomenclature ((2-chloro-4-ethylamino-6-isopropylamino-1, 3, 5-triazine) most frequently applied in the US in the range of about 80 million lbs in agriculture. In Pakistan, the atrazine application rate was recorded as 2 kg per hectare for the specific crop (maize crop) per cultivated area of 1.13 million hectares [2,3].

Atrazine is a multi-risk compound for humans and animals that alters the hormonal cycle of pregnant women by consuming atrazine-contaminated water. The other effects are poor child growth by retardation, lungs, and respiratory cancer in humans [2].

Therefore, due to its severe toxicity for human and aquatic life, the US EPA set the maximum permissible limit in drinking water ($0.3 \mu\text{g L}^{-1}$) and the European standard for permissible residual limit $0.1 \mu\text{g L}^{-1}$ for groundwater [3].

The analytical procedures such as sample preparation and pesticide removal have a sensitive focusing problem because of different chemical structures, sensitive detection, and selectivity by appropriate analytical techniques. For this, many already existing techniques are available including, Liquid-Liquid Extraction, Solid-Phase microextraction (SPME), Stir bar sorptive extraction, dispersible solid-phase extraction (d-SPE), and Solid-phase extraction [1].

From all the analytical techniques mentioned above, the highly recommended and traditional extraction technique is solid-phase extraction (SPE) Technology [6], due to its global acceptance award for organic compound extraction from contaminated water. The SPE process worked through the adsorption phenomena of target pesticides according to the specific mechanism reaction with functional groups of solid sorbents selected for the extraction and determination of herbicides pesticides from water. Therefore, the basic dominant procedure for SPE depends on the adsorption, such as physical adsorption and chemical adsorption for pesticide removal, respectively.

Moreover, the adsorption process in a solid-phase extraction bed (SPE matrix) is mainly influenced by adsorption affinities. In physical adsorption, the adsorption affinities between pesticides and sorbents are weak, such as Vander Waals attraction force. In chemical adsorption, the chemical electronic structures between sorbent and pesticide are changed due to bond formation or chemical bond breaking, and high affinity exists [7].

There are various metal oxide polymeric nanomaterial sorbents for solid phase extraction are present in literature, such as copper oxide and chitosan copper oxide, chitosan zinc oxide, octadecyl-siloxane (C18), Alumina, Primary Secondary amine (PSA), etc. [1]. Recently, the metal oxide polymeric-based frameworks existed highly reactive, low-cost properties with high removal efficiency, and the chitosan biopolymer (poly-(1→4)-2-amino-2-deoxy-D-glucose) has been considered one of the most applicable and efficient materials for pesticides removal and adsorption applications [1].

By comparing other existing polymers, the most attractive and more considerable polymer is chitosan because it contains -OH and -NH₂ functional groups. Therefore, the chitosan-based nanomaterial framework such as Chitosan-ZnO can effectively extract toxic pollutants from water like pesticides, heavy metals, and dyes because of their high surface area, greater porosity, and crystalline structure [8]. This biopolymer is a natural organic polymer with attractive features such as biodegradation, antibacterial activity, biocompatibility, and hydrophilic attraction [5].

In this study, Transition Metal oxide decorated chitosan nanostructures (TMODCNs) were synthesized using cross-linking with the sol-gel precipitation method. After that, the TMODCNs were used to fabricate the solid-phase extraction syringe cartridge for pesticide extraction and removal. The work is environment-friendly, cost-effective, time-saving, has less solvent and chemical usage, and is highly efficient in solid phase transition metal oxide loaded nonmaterial. The SPE Syringe cartridge loaded with TMODCNs was used to extract the atrazine pesticide from synthetic water.

2 Materials and Methods

2.1 Synthesis of Transition-Metal Oxide Nanostructures for Solid Phase Extraction Cartridge

2.1.1 Materials: Chemicals.

Acid-soluble chitosan having low weight (88 % degree of deacetylation), Epichlorohydrin (50%), Glutaraldehyde (99%) Zinc oxide (ZnO). Acetic acid, Nitric acid, Sodium hydroxide (NaOH), HPLC-grade Acetonitrile, Methanol purchased from Sigma-Aldrich, and Atrazine (99.7%) purity was purchased from Merck. Atrazine salt standard 1 gram has 215.68 molecular weight [1].

2.1.2 Equipment

UV-visible spectrophotometer, Analytical Weight balance, Solid-Phase Extraction Assembly.

2.3 Methodology

2.3.1 Preparation of polymer and metal oxide solution

For the preparation of the chitosan polymer solution known as Solution A, 4-gram of chitosan polymer was added into 100 ml acetic acid (aqueous solution) of (1%, v/v) and dissolved with the help of a magnetic stirrer for 2 hours (40rpm) mentioned in figure 1.

In the next step, the transition metal oxide (ZnO) solution, known as solution B, was prepared by dissolving 8 grams of ZnO powder into 10 ml of concentrated nitric acid. After that, mix these two solutions (Solution B) were slowly and gradually mixed dropwise with the help of a syringe into chitosan solution (solution A) under continuous stirring with the help of a magnetic stirrer bar for 2 hours up to the formation of chitosan-zinc oxide polymers after conjugation of metal ions with chitosan polymer as shown in figure 1.

2.3.2 Cross-linking of Chitosan- Zinc oxide polymer

For the cross-linking of chitosan-ZnO polymer, In the first stage cross-linking agent, Glutaraldehyde of 12 ml concentration (50%, v/v) was added into chitosan-ZnO polymer solution dropwise under vigorous stirring, and the hard-spherical shape of nanoparticles was formed by cross-linking of glutaraldehyde through the chemical reaction of amino (NH-) group of chitosan. In the second stage, the second cross-linking agent, 8 ml Epichlorohydrin (99%), was added to the mixture with continuous stirring, as shown in Figure 2. Epichlorohydrin makes nanoparticles harder by reducing the hydrophilicity of chitosan.

2.3.3 pH Maintenance

The mixture's pH was maintained by adding dropwise NaOH (1N) under continuous stirring until the pH reading reached up to 10, as shown in Figure 3.

2.3.4 Sonication

The reaction mixture was sonicated for 15 min in an ultrasonic sonicator at a 10 KHZ sonicator speed and pulses or cycles with 9 cycles/seconds.

2.3.5 Water Bath for Precipitation

Finally, the transition metal oxide-chitosan cross-linked solution was stored in a water bath for 3h at a temperature of 60 °C until the precipitates were formed, as shown in Figure 3.

2.3.6 Filtration, Drying and Grinding

Then, the precipitate was filtered with Whatman filter paper and washed with D.I. water. The moisture content of nanoparticles were reduced in the oven for 3 hours at 70 °C as shown in figure 3. Finally, the Transition metal oxide loaded nanostructures yield was achieved in a dark yellowish color shown in figure 4 , as a Cartridge material for pesticide extraction.

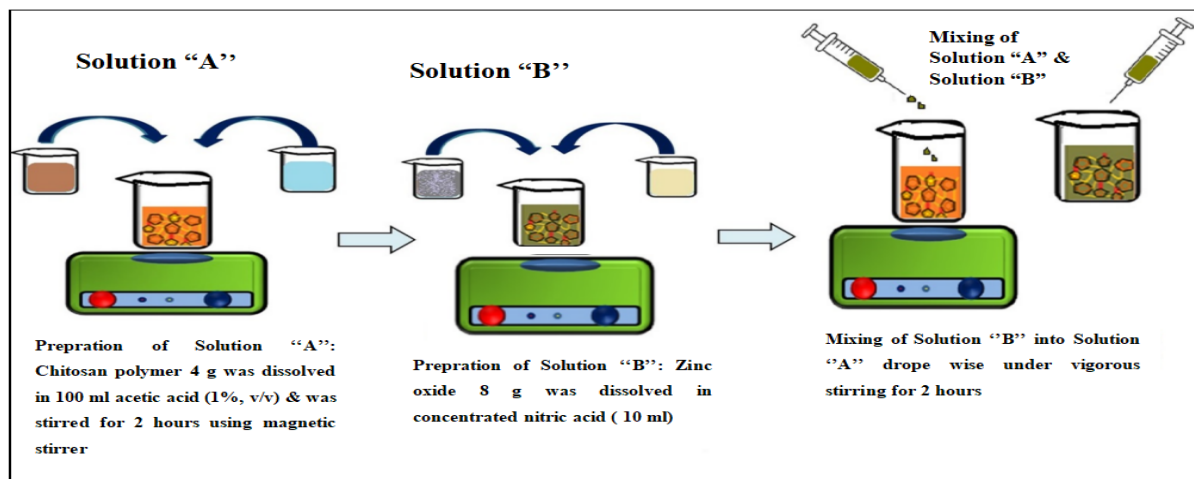


Figure 1: Schematic diagram Preparation of Solution (A) of chitosan polymer in Acetic acid and solution (B) of Zinc oxide in nitric acid.

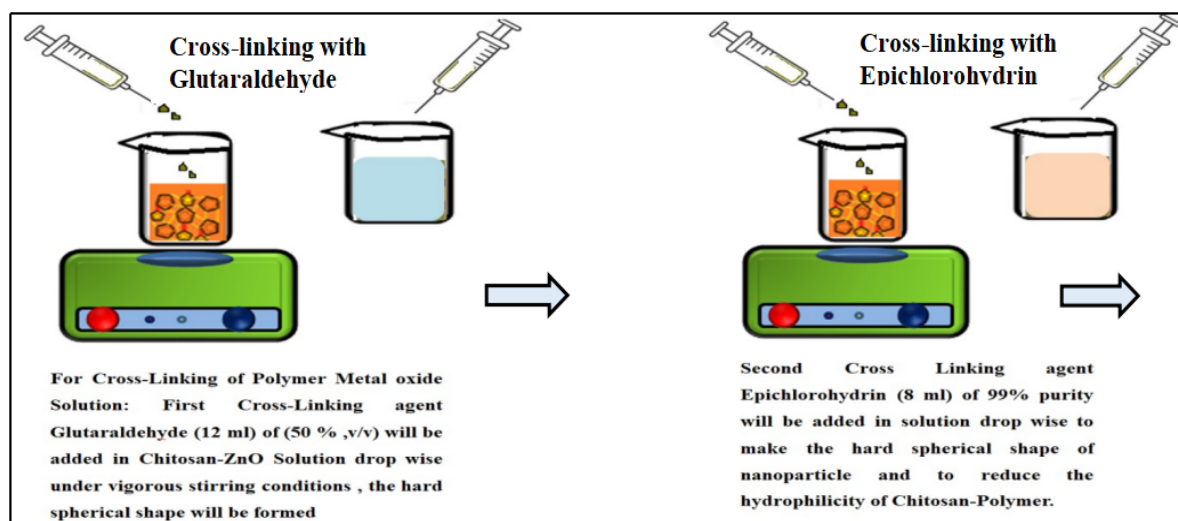


Figure 2: Schematic diagram of Preparation steps of Transition metal oxide solution A, Solution B, and Cross-linking with polymers.

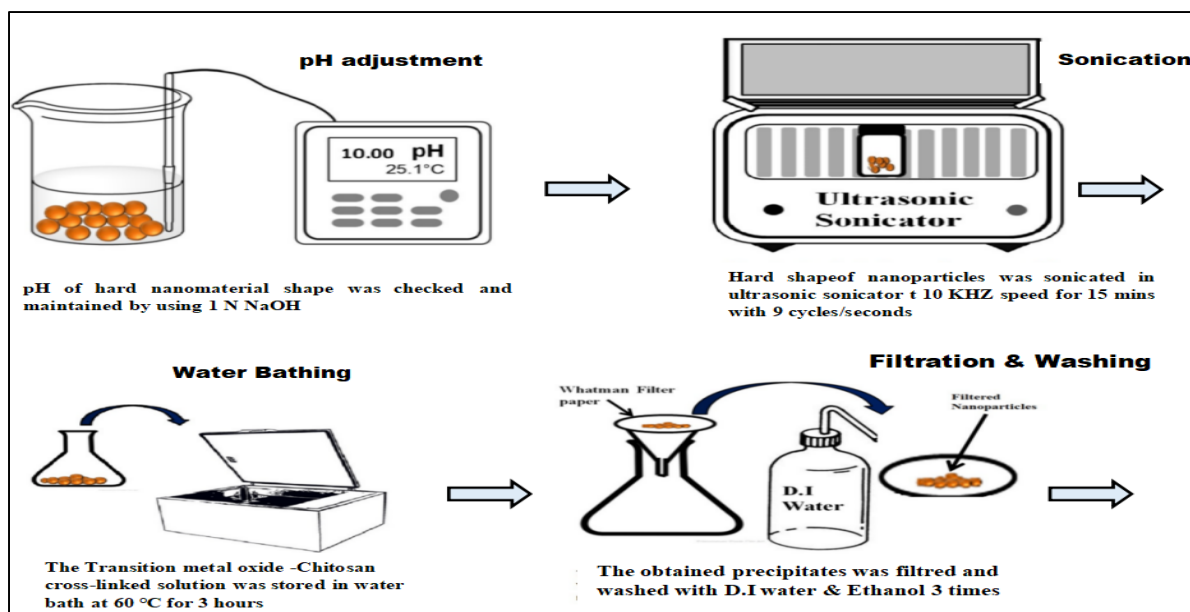


Figure 3: Schematic diagram of pH adjustment, sonication, water bath and precipitates washing and filtration.

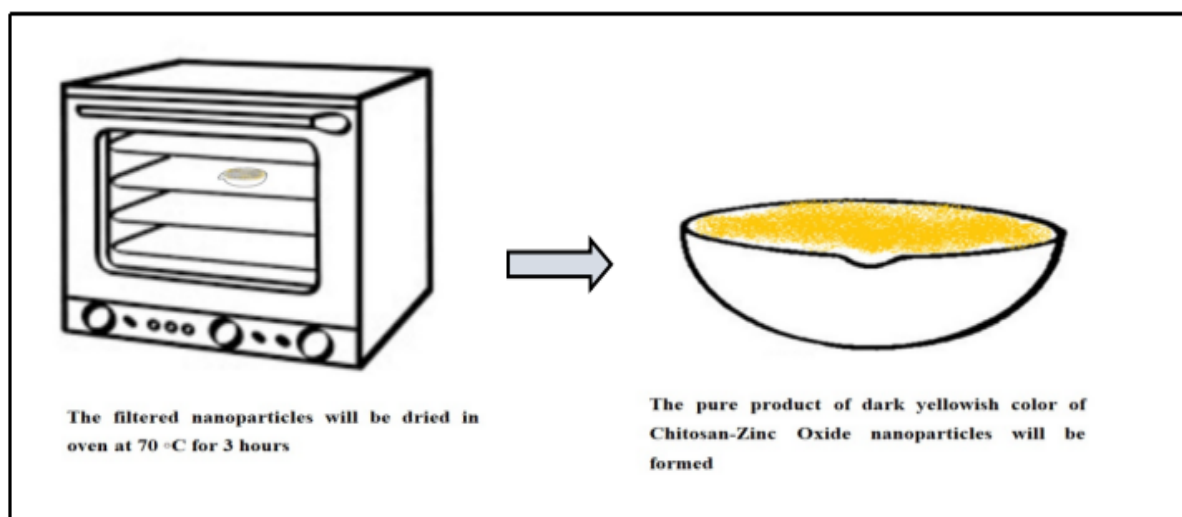


Figure 4: Schematic diagram of oven drying and Transition Metal Oxide Decorated Chitosan Nanostructures (TMODCNs) yield in dark yellowish color.

2. Atrazine stock Preparation calculations

Atrazine (99.7%) was purchased from Merck. Atrazine salt standard 1 gram has 215.68 molecular weight. After calculating molar weight from its molecular weight by this formula, molar weight = $1 \text{ gram} / 215.68 \text{ MW}$, atrazine molar concentration was calculated as 0.0046 gram, then converted into 4.6 mg. So, finally, the atrazine concentration was calculated in parts per million. Parts per million of 4.6 mg atrazine is 1000 ppm. Therefore, the atrazine salt stock of 4.6 mg was measured at 1000 ppm.

4. Experimental Design for atrazine dilutions

From the above stock, 1 mg of atrazine powder in 100 ml (50:50) methanol and D.I water was dissolved to prepare an atrazine stock solution of 1000 ppm. From the 1000 ppm stock, two serial dilutions of 100 ppm and 10 ppm were made in 100 ml (50:50) of MeOH:D.I separately. The five pre-concentrations made by dilution were 10 ppm, 20 ppm, 30 ppm, 40 ppm, and 50 ppm, respectively. After that, the standard solution and dilution concentrations were stored in the freezer at -20°C [9].

5. Column-based Study for Atrazine removal

After that, the column was filled up by compressing 0.22 μm filter paper in the bottom of the syringe and then adding 100 mg weight of Transition Metal Oxide Loaded Nanostructures (TMOLNSS) on stopcock filter paper and putting filter paper on the upper side of solid matrix without gaps shown in figure 5. Finally, this cartridge was used for the solid phase extraction (SPE) assembly to extract herbicide (S- triazine) herbicides pesticides from samples.

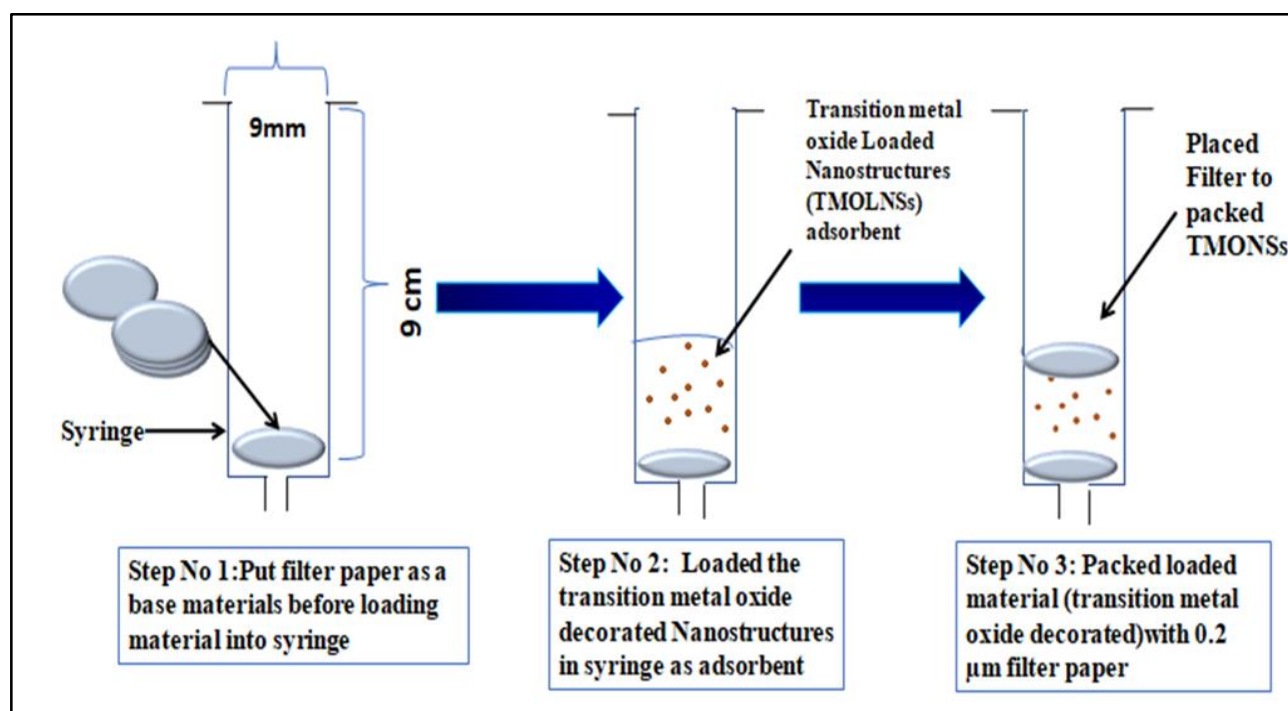


Figure 5: Solid Phase Extraction Cartridge Fabrication using Transition Metal Oxide Decorated Chitosan Loaded Nanostructures.

6. Solid Phase Extraction Assembly

The prepared dilutions of Atrazine stock 5 pre-concentrations of 10 ppm, 20 ppm, 30 ppm, 40 ppm, and 50 ppm were allowed to pass separately through the SPE cartridge. The flow rate was set to 1 ml/ minute. The pH of all concentrations was 7, and the time was 25 minutes for 25 ml of the volume of each concentration at 25°C room temperature respectively.

The conditioning or activation of the functional groups of TMODCNs cartridge material was initiated by passing the 5 ml methanol from the solid matrix, followed by washing it in the second step with de-ionized water. The adsorbed amount of atrazine pesticide concentration was

recovered by passing 5 ml acetonitrile and methanol (1:1), v/v ratio after the elution step mentioned in figure 6 [1].

After that, the eluted/recovered amount of atrazine was run on a UV-visible Spectrophotometer to detect atrazine using the removal efficiency formula.

$$\text{Removal Efficiency (\%)} = \frac{C_0 - C_e}{C_0} \times 100 \text{ [8].}$$

Where C_0 represents the Initial absorbance concentration before passing from the cartridge, and C_e represents the final absorbance concentration after extraction through the cartridge.

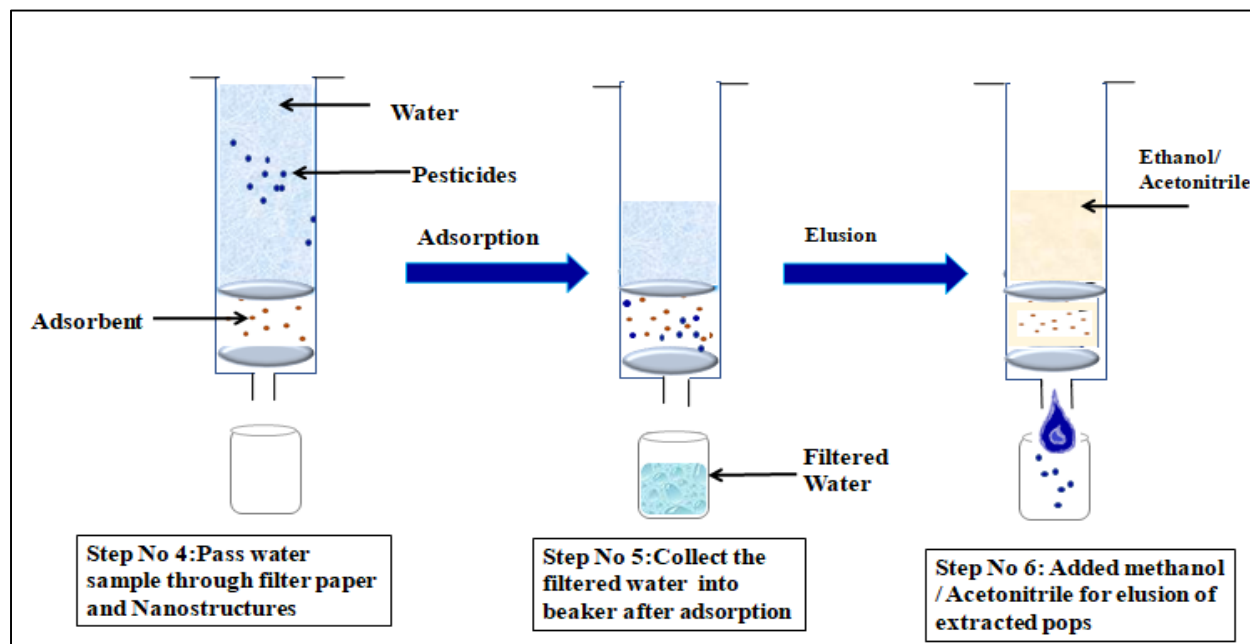


Figure 6: Solid Phase Extraction process for removing Atrazine herbicide from Atrazine pre-concentrations in ppm using nanostructures-based fabricated cartridge.

7. Results and Discussion

7.1 Characterization Techniques for Synthesized Transition Metal Oxide Decorated Chitosan Nanostructures (TMODCNs)

Various Characterization techniques are available in literature, such as UV-visible spectrophotometry, X-ray diffraction (XRD), Fourier transform Infrared Spectroscopy (FTIR), Scanning electron microscopy (SEM), and zeta potential to characterize the synthesized nanomaterial to check the presence of functional groups which shows the chemical and physical attraction between sorbent and pesticides surface [1]. The UV-visible Spectrophotometry was done to check the reliable formation of nanomaterial via scanning and peak formation at a specific wavelength, which was then matched with the literature. To check the shape and structure of nanomaterial (TMODCNs) at 2θ angle at specific points was also characterized to see the functional reliability of fabricated Chitosan and Zinc Oxide nanostructures bound together with cross-linking technique.

7.2 UV-Visible Spectrophotometry

The formation of Transition Metal oxide decorated Chitosan cross-linked nanostructures/core-shell was monitored using UV–visible spectroscopy. The synthesized (TMODC) spectral data was recorded from 300 to 800 nm at a resolution of 1 nm. The UV-visible Spectrophotometry peak of fabricated Transition Metal Oxide Decorated Chitosan nanostructure (TMODCNs) was found in the region of wavelength 370 nm, as shown in figure 7. The results show the synthesized nanomaterial's reliability and functional characteristics for pesticide extraction from water.

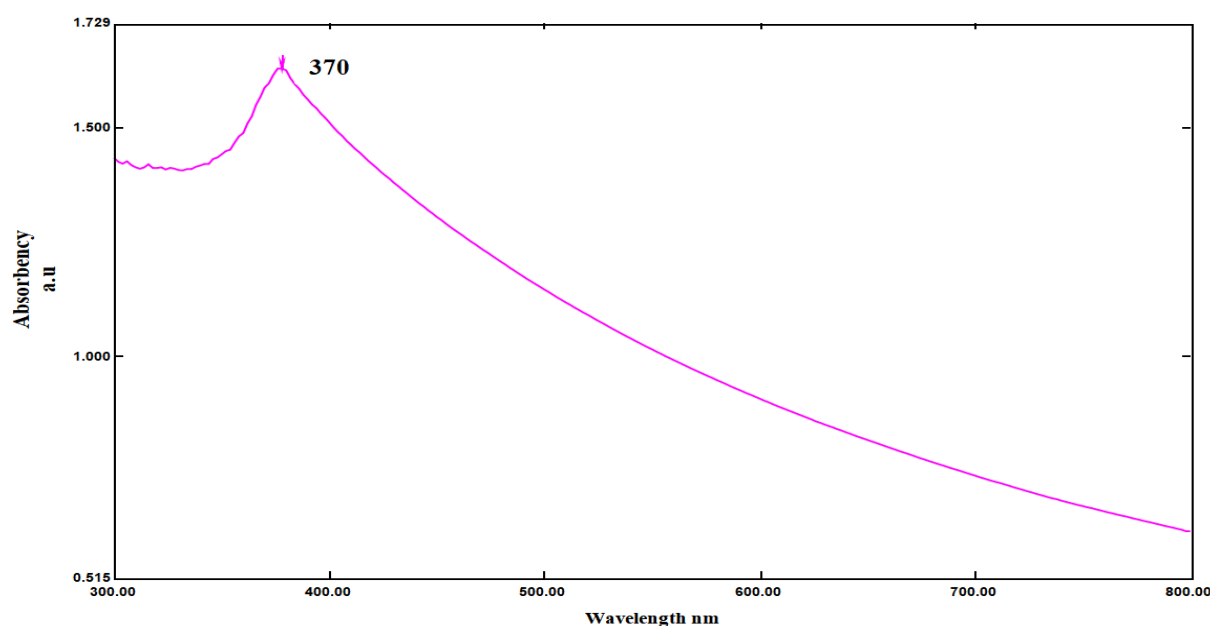


Figure 7: UV-visible spectroscopy of fabricated Transition metal oxide decorated chitosan nanostructures at 370 nm.

In the previous study by Devaraj Bharathi et al., 2019, the UV-visible spectroscopy of prepared Chitosan Zinc Oxide Nanostructures was also found at 370 nm [12]. Furthermore, in another study, the UV-peak formation at 355 shows the characteristic features of Zinc Oxide only and 360 nm scanning peak formation for chitosan and zinc oxide nanomaterial without cross-linking [11].

7.3 X-Ray Diffraction Analysis (XRD)

The X-ray diffraction Analysis for transition metal oxide decorated Chitosan Nanostructures (TMODCNs) was carried out to characterize the shape and angle of synthesized nanomaterial. The main peaks on 2θ values were found at 31.80, 34.35, 35.42, 36.21, 46.34, 47.27, 56.50, 62.70, 66.24, 68.96 which correspond to (1176), (1022), (1023), (1711), (374), (441), (367), (357), (170) respectively as shown in figure 8, structure for crystal plane zinc oxide. The broad peaks of TMODCNs were observed at 31.70, 34.35, 36.21, 56.50, and 62.70, whereas in literature, the stronger and sharper peaks were observed at 31.70, 34.36, 36.21, 56.59, 62.70 and 67.90 diffraction peak [13]. Therefore, the diffraction peaks of transition metal oxide decorated chitosan nanostructures successfully match the literature with 99% similarity.

In another study, the diffraction peaks found at 2θ are 31.80, 34.50, 36.60, 47.40, 56.60, 62.70, and 66.40. 68.10 and 69.10 shows the crystalline structure of zinc oxide and chitosan but synthesized via microwave heating [12]. In our study, the Chitosan biopolymer-based zinc oxide nanomaterial was synthesized via the sol-gel precipitation method, and 99.9 % of the results matched with a study conducted by Mohamed E. I. Badawy et al., 2018.

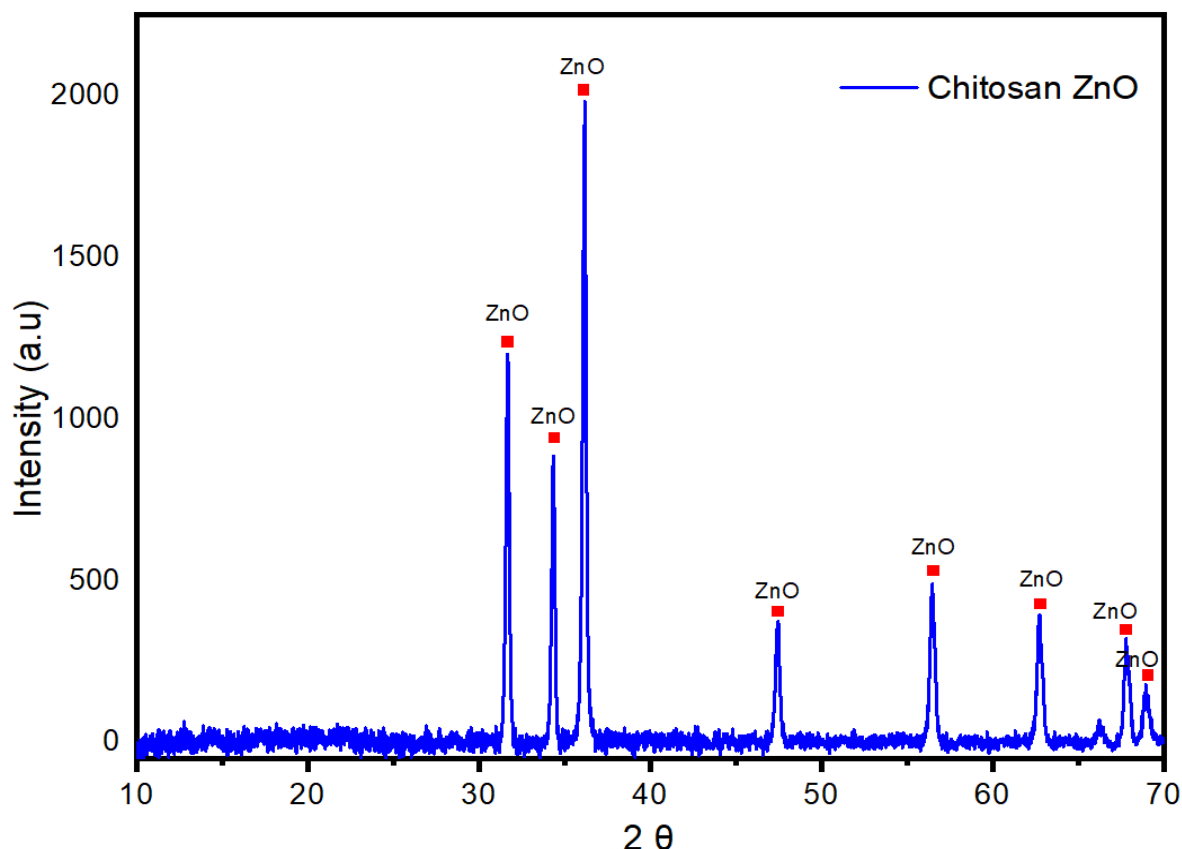


Figure 8: XRD diffraction peaks results of fabricated TMODCNs nanomaterial for the removal of atrazine pesticide from synthetic water.

The FT-IR spectrum of Transition metal oxide decorated Chitosan nanostructures (TMODCNs) exhibits a broad peak at 3401 cm^{-1} absorption band as shown in figure 9, which represents the strong combination between the -NH_2 (amide group) and -OH_2 (Hydroxyl) functional group. The absorption peaks at 2877 cm^{-1} and 2924 cm^{-1} correspond to the CH_2 and CH_3 group stretching of chitosan polymer asymmetrically and the overlapping with the amide (-NH) group. The band at 1657 cm^{-1} is because of the rest of the amide group I (C=O), while a band at 1553 cm^{-1} is observed due to N-H group deformation, whereas the absorption peak at 1407 cm^{-1} represents the C-N axial deformation and -NH_2 band in TMODCNs. In addition, the spectrum of TMODCNs is attributed to bending vibration of (NH_2) and (C-O) stretching at 1067 cm^{-1} absorption band.

Furthermore, the most important core-shell formation was observed at 682 cm^{-1} band due to the O-Zn-O core group's vibration.

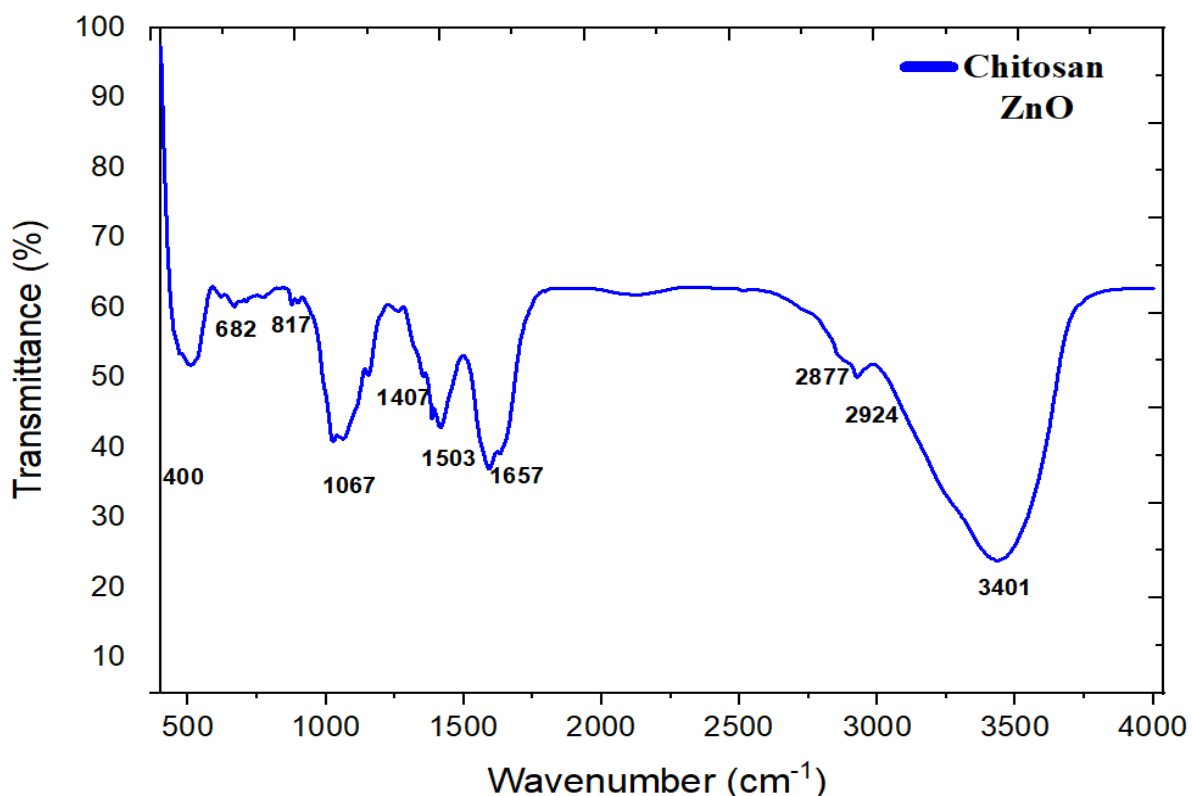


Figure 9: FT-IR results of Transmittance and Wavenumbers (cm) bands of TMODCNs nanomaterial

In literature, the FT-IR absorption band peaks were also exhibited at 3401 cm^{-1} which shows the strong attachment of zinc oxide transition metal with chitosan polymer by combining the -NH_2 group with -OH functional groups [1]. The absorption peak at 2877 to 2944 cm^{-1} is due to the asymmetric stretching of CH_2 and CH_3 Chitosan polymer's groups and overlapping with the NH_2 group of chitosan [14]. The other peaks at around 671 cm^{-1} indicate the presence of amines, phenolic acid, carboxylic group, free hydroxyl, and alcohol groups [14]. The band at 1553 cm^{-1} indicates the deformation of the amide group, and the band at 1657 cm^{-1} is due to the amide group I presence, 1553 cm^{-1} shows the N-H group deformation and 1407 cm^{-1} attributed to the C-N axile-deformation [1].

The absorption peaks at 1067 cm^{-1} indicate the bending vibration of the -NH group and also the C-O stretching group, while the core-shell formation of chitosan polymers with zinc oxide via cross-linking technique is mainly shown at 682 cm^{-1} absorption band is because of O-Zn-O core groups vibration [1].

This justification shows that the FT-IR results of fabricated Transition Metal oxide decorated Chitosan nanostructures (TMODCNs) were matched with literature successfully. These results indicate the reliable functionality of fabricated nanomaterial for pesticide removal from water.

7.5 Scanning Electron Microscopy (SEM)

The scanning Electron microscopy of TMODCNs was analyzed to examine the surface structure and shape of nanomaterial. The SEM image results in different resolution power and size angle in micrometer were obtained. The optimum particle size of TMODCNs was observed at 50 nm at

four different resolutions. Figure 10 shows the uniform, spherical, and irregular shapes of both Chitosan-Zinc oxide after the cross. The most particles were from 32 nm, 50 nm, 32 nm, 51 nm, 58 nm, 57 nm, 61 nm, and 60 nm at 10,000 X resolution power at 1 μ m scale. In literature, the SEM results of chitosan-coated zinc oxide nanoparticles were found in the average range of 50 nm, which indicates the uniform irregular and spherical structure of chitosan-zinc oxide nanoparticles [15].

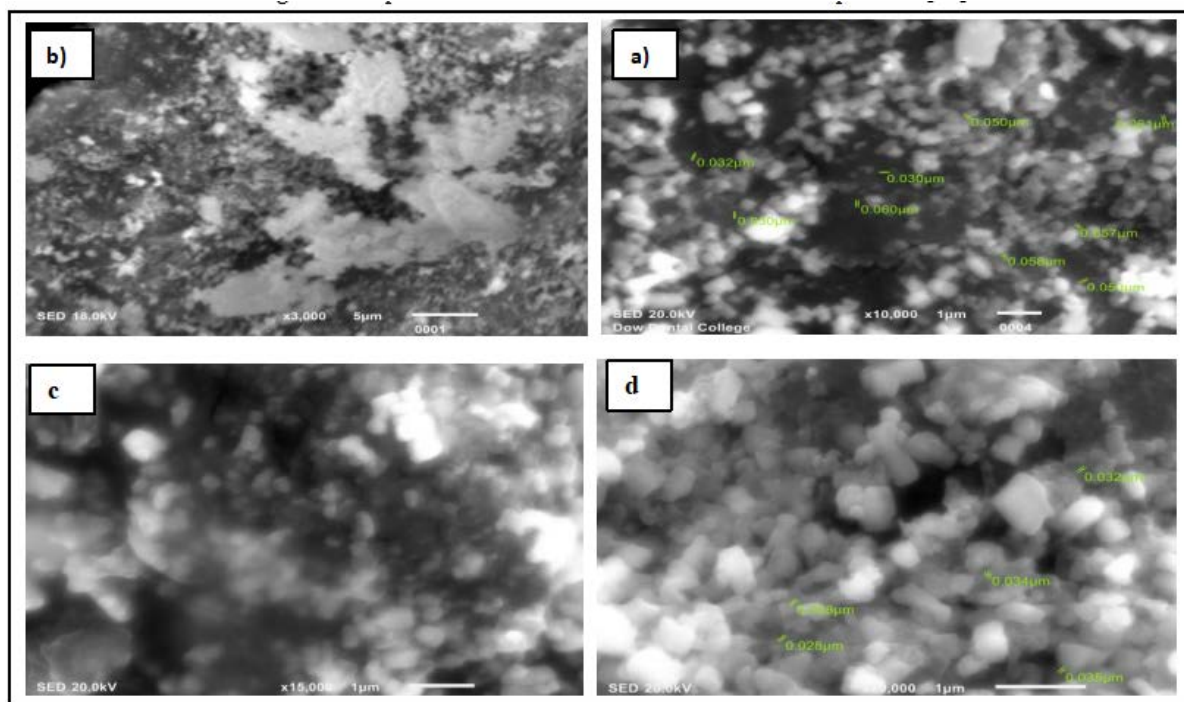


Figure 10: Scanning Electron microscopy images results of fabricated Transition Metal oxide decorated Chitosan nanostructures (TMODCNs) by sol-gel precipitation method in different resolution power. a) TMODCNs particles size at 5 μ m at x3000 resolution power, b) TMODCNs particles size at 1 μ m at x1000 resolution power, c) TMODCNs particles size at 1 μ m at x15000 resolution power, and d) TMODCNs particles size at 1 μ m at x20000 resolution power

7.6 Removal Efficiency of TMODCNs loaded solid phase extraction cartridge material

After the extraction process, the removal efficiency of the fabricated nanomaterial was analyzed using a UV spectrophotometer, as shown in Fig 11. All five concentrations' initial absorbance and final UV-absorbance were applied in the removal efficiency formula to check the difference in Atrazine amount in ppm before and after the experiment, as shown in Figure 12. The removal efficiency of fabricated nanomaterial TMODCNs was achieved at 10 ppm because of the lowest concentration, whereas at 50 ppm, it was reduced due to high concentration. The maximum removal efficiency was 85 % for 10 ppm concentration, as shown in Figure 11, without applying optimized parameters such as pH, time, temperature, dosage, or amount of loaded nanomaterial packed inside the SPE cartridge. These results are found in normal, experimental, or control experiments.

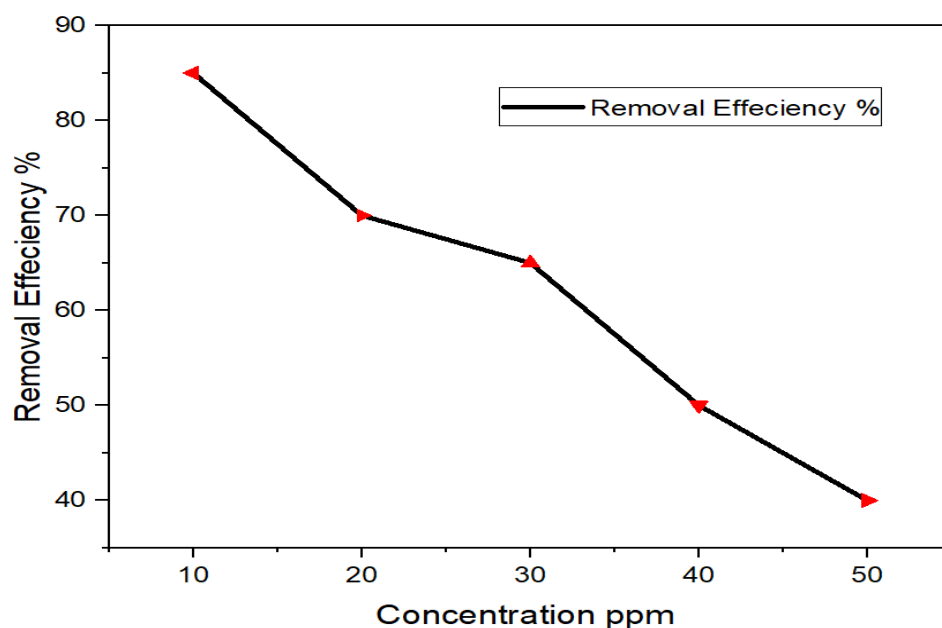


Figure 11: Extraction Efficiency % of TMODCNs nanomaterial for pesticide extraction from water.

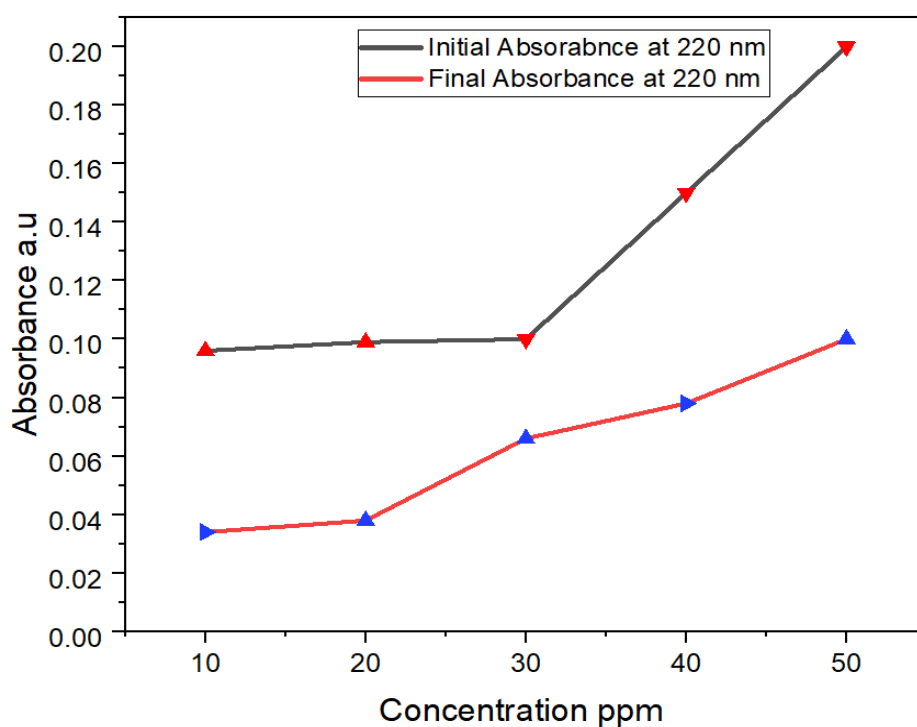


Figure 12: Shows the Initial and Final UV-absorbance of pesticide five pre-concentrations and concentrations after extraction/ removal by passing through an SPE cartridge at pH 7, 25 °C, 25 minutes.

8. Conclusion

In this study, the novel synthesis of biopolymer chitosan with zinc oxide transition metal was achieved to extract the specific targeted pollutant, i.e., atrazine, from water. Using the sol-gel

precipitation method, the nanomaterial Transition Metal oxide fabrication method was used to decorate chitosan nanostructures TMODCNs. The XRD results show the main peaks on 2θ values were found at 31.80, 34.35, 35.42, 36.21, 46.34, 47.27, 56.50, 62.70, 66.24, 68.96, indicating structure for crystal plane zinc oxide with chitosan. The FT-IR spectrum of TMODCNs exhibits a broad peak at 3401 cm^{-1} absorption band, representing the strong combination between the -NH_2 (amide group) and -OH_2 (Hydroxyl) functional group. The SEM results of TMODCNs show the uniform spherical structure and irregular structure of nanoparticles at an average 50 nm particle size. The TMODCNs were packed inside a syringe cartridge to check the removal efficiency of the material. The removal efficiency of loaded material after extraction was achieved at 85% without applying optimum conditions. This shows the attractiveness of the material functionality by using minimum solvent amounts, less material dosage, and environment friendliness.

Acknowledgment:

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Isolation and **quantification** of *Vibrio cholera* and *Vibrio parahaemolyticus* in water samples from seventeen barrages in Pakistan

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Abstract

Cholera is an acute diarrheal illness caused by infection of the intestine with *Vibrio cholera* bacteria. While *Vibrio Parahaemolyticus* is a major cause of bacterial gastroenteritis in Asia. Thus, the purpose of this study is to evaluate the water quality for the existence of these two pathogens, and samples from 17 Pakistani barrages were collected for this purpose. The barrages are the following: Rasul, Sidhanai, Sulemanki, Sukkur, Taunsa, Khánai, Jinnah, Kalabagh, Khanki, Kotri, Marala, Panjnad, Qadirabad, and Trimmu barrage. Targeted bacteria were isolated using TCBS agar. The spread plate method was used to isolate the bacterium. 100 µL of sample water was spread on an agar plate with the help of sterilized spreader. The isolated colonies were enumerated after identification on the basis of their morphological characteristics, i.e., *V. cholera* forms yellow colonies and *V. parabemolyticus* forms green colonies. The results revealed that 10/17 (58.82%) samples were found positive for *V. cholera*, and only 3/17 (17.64%) samples were found positive for *V. parabemolyticus*. The highest contamination for *V. cholera* was found in Khanki barrage with 3.20×10^2 CFU/mL, followed by Guddu and Baloki barrage with 2.20×10^2 CFU/mL and 8.0×10 CFU/mL. The highest presence of *V. parabemolyticus* was detected in the Guddu barrage with 5.0×10 CFU/mL. The mean, median, and mode values were 45, 10, 0, and 4.37, 0, 0 for *V. cholera* and *V. parabemolyticus* respectively. The Pearson's correlation two-tailed test suggested no statistically significant co-relation between *V. cholera* and *V. parabemolyticus* with $p=0.071$ and $r=0.46$.

Keywords: *V. cholera*, *V. parabemolyticus*, water quality, and pathogens

Delineation of quality groundwater zones through an integral approach of Geophysical technique and physio-chemical analysis in central part of Bari Doab, Punjab, Pakistan

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Abstract

Punjab is the land of five rivers comprised of interfluvial system of Doabs. Bari Doab is one of those and especially its central part is prone to groundwater related issues since last decades. The selected study area is a part of Okara dist. and is located at centre of Bari Doab. Geophysical technique and physio-chemical analysis of groundwater samples were carried out as an integrated investigation to infer latest groundwater conditions prevailing in the study area. Electrical resistivity survey (ERS) using 30 vertical electrical soundings (VES) with schlumberger electrodes arrangement was carried out as a geophysical technique allied with drill-logs of boreholes. A total of 3 to 6 geo-electrical subsurface layers are interpreted through VES technique. Calibration is also done for validation of software aided processed VES data with borehole drill-logs. Based on geology and VES data of the study area, five resistivity zones are characterized as very high, high, medium, low and very low resistivity. Subsurface lithology of the study area is interpreted as intermixed layers of sand, silt, clay, gravel and some kankar inclusions. Finally, the spatial distribution of fresh, marginally fit and saline/brackish groundwater zones are delineated and presented in 2D and 3D models. These models decipher that the salinity exists at water table at northern side of the study area and increases with depth covering almost 50% of the study area up to 300m. Other parts of the study area are interpreted to be associated with marginally fit and fresh groundwater zones. Below the water table, low to very low resistivity zones are interpreted as the zones saturated with marginally fit and saline/brackish groundwater respectively. Good/fresh quality groundwater zones are associated with the zones of medium to very high resistivity prevailing the dominance of sand-gravel intermixed layers. However, groundwater yield may be restricted to some extent within very high resistivity zones due to the presence of stiff kankar layers or inclusions. Furthermore, physio-chemical analyses of groundwater samples at 40 well distributed locations were also carried out to depict a broader subsurface groundwater scenario of the study area. The distribution of total dissolved solid (TDS), electrical conductivity (EC) and pH were analyzed by developing their 2D models. Additionally, some of the samples targeting the populated areas were analyzed in lab to get detailed physio-chemical analysis (anions, cations and arsenic content) and categorized as per WHO recommendations.

Keywords: Electrical Resistivity Survey (ERS), Lithology, Alluvium, Doab, Groundwater, Schlumberger, Resistivity Models

Groundwater dynamics of the Dehdan village, Haripur Basin, Pakistan: Integrating science for sustainability

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Abstract

Dehdan village lies downstream of Hattar Industrial Estate (HIE) that dumps industrial effluents into the nearby stream in Haripur Basin, Pakistan. Potable water-quality detected from samples collected from stream water and groundwater is highly contaminated. Six boreholes were drilled to analyze aquifer sediments and to establish a regional water table within the study area. Groundwater samples were also collected from the aquifer sediments for hydrochemical analysis across the drilled wells. Geoelectrical investigation is carried out to improve data coverage and to reduce the cost of borehole drilling. The geoelectrical datasets that consist of 1D and 2D sounding sites suggest the presence of at least three aquifer sediment units. Hydraulic parameters such as hydraulic conductivity derived from the 1D-vertical electrical sounding (VES) data identified moderate to good protective zones for contamination across the region. The dataset reveal a shallow aquifer unit consisting of finer sedimentary layers of silty-clay with alternating gravel beds about 17 m thick and relatively a deep aquifer layer of coarser sediments at about 50 m depth. The 2D-electrical resistivity tomographs (ERTs) each about 300 m long were also acquired across the highly contaminated area of Dehdan stream using the composite Wenner-Schlumberger configuration. The ERT was effective to investigate contaminated highly conductive layer overlain by relatively resistive layers. Resistivity value for the highly conductive zone, about 25 m thick, is less than 11 Ω m. The ERT shows a localized shallow aquifer unit that is recharged by the contaminated stream water especially during rainy seasons. The 3D model based on the ERTs demonstrates that the resistivities within the low-resistivity anomaly remain unchanged and gradually increased downward. It was considered that these spatial changes in resistivities were related to dilution of stream highly contaminated water with shallow aquifer sediments and the contamination migration downward to next aquifer unit across the stream. Physicochemical and heavy metal analyses of twenty-three water samples show that four out of six analysed samples were highly polluted, and the contamination level decreased at greater depths and as distance from the highly contaminated stream increases.

Keywords: Electrical resistivity tomography, Boreholes, Hydrochemical analysis, Vertical electrical sounding, Groundwater

Impacts of Mulching on the yield and economics of different vegetables cultivated under the saline soil conditions at Malwah distributary of Rohri canal, Sindh, Pakistan

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Abstract

Due to the detrimental effects of saline soil, our land was undergoing severe degradation, rendering it unsuitable for cultivating traditional crops. As a result, we faced challenges in sustaining agricultural practices at the Malwah distributary of the Rohri main canal near Qazi Ahmed in district Shaheed Benazirabad of Sindh, Pakistan. This study was conducted to resolve the issue related to water scarcity and improve the livelihood of the farmers community through kitchen gardening that is cultivation of five colored vegetables. This study aims to assess the impact of mulching on the economics of different vegetable varieties cultivated in five farmers' field areas. The mulching was applied using sugarcane, banana waste, and other organic waste material. This organic material served as a protective layer over the soil, aiding in moisture retention and contributing to the improvement of soil structure and fertility. The application of mulch aimed to mitigate the adverse effects of high-water table and salinity on the vegetables. On the other hand, the next plot was kept without mulch, that is exposed to sun, which has evaporates and salts left behind, and moisture became less than wilting point and plants died; thus provides less yield as compared to vegetables with mulching. The kitchen gardening has provided organic vegetable throughout the season for these selected family farmers communities; hence the number of family farmers communities involved in the kitchen gardening has been increased double. It was observed that the mulched areas provide 20 to 30 percent more yield/income than those of non-mulched areas. The results confirmed that mulching is beneficial and provides a better yield requiring less water for cultivation.

Keywords: Kitchen Gardening; Mulching; Family farming; Farmer's Livelihood; Malwah distributary.

1. INTRODUCTION

The word "mulch" likely comes from the German word "molsch," which means soft and decaying. This term was used to describe the practice of gardeners spreading straw and leaves over the ground to serve as mulch. In simple terms, mulch is a material like straw or leaves that is spread over the soil to help retain moisture, suppress weeds, and improve soil health. (Jack et al. 1955). Further, reported that mulching boosts the yield by 50-60 per cent over no mulching under rain-fed situations (Dilip and Sachin 1990).

2. STUDY AREA

The study area is in the command area of Malwah distributary, taluka Qazi Ahmed, district Shaheed Benazir Abad, Sindh. The main crops grown include Peas, Coriander, Cauliflower, Radish, etc. The Malwah distributary's command area is extensive, and water availability varies across different parts. Typically, farmers at the far end (tail) of the distributary struggle with water shortages, resorting to using poor-quality groundwater for irrigation. As an alternative, some land is left unused, leading to salt buildup on the soil's surface due to water rising through the soil. When combined with low rainfall and inadequate drainage, this accelerates soil salinization, resulting in significant losses for farming communities. Over time, once-fertile land becomes unproductive and barren. Finding strategies to address this issue is crucial for preserving farmland for cultivation and sustaining farmers' livelihoods.

3. OBJECTIVES

This study was designed with two objectives: (1) To assess the yield and economics of different vegetables cultivated with and without mulching. In this research we opted for two season rabi and kharif, cultivated different vegetables with mulch and without mulch to compare the results with the yield which is ultimate goal in-terms of the economics. (2) The other objective was to determine the effects of mulching on saline soil. The overall objective was to arrest/reduce soil salinization using water-saving technology or a salt-tolerant variety. Desirable to include Abstract of this research study.

In this study, various vegetables were grown under different soil conditions (saline and moderately saline) with and without mulch, and the outcomes were compared. Mulching, a traditional method, has long been known to enhance agricultural yield and improve soil conditions. We selected five plots within the Malwah distributary area, each representing distinct soil conditions. Similar vegetable varieties were cultivated in each plot, with mulch applied to some and left absent in others. Subsequently, we assessed vegetable yields and monitored irrigation water usage in both mulched and non-mulched plots. This research covers both winter (Rabi) and summer (Kharif) crops.



FIGURE No. 1 MULCHING IN THE KHAREEF IN THE FIELD

3. LITERATURE REVIEW

1. This research was conducted to evaluate the impacts of kitchen gardening on the households and nutrients status of the households in the Sindh province of Pakistan. The major objective of this research is to know the barriers in the adoption of kitchen gardening and their impacts on the nutrient's status of women and children. To achieve the targets then kitchen gardening stations were established with the LANSa project. The survey was conducted for the quantitative data by a verbal interview for each season of kharif and rabi. Model kitchen and community training improved technical knowledge, nutrition awareness, food availability, and health. More research needed for nutritional impact is recommended. (Rauf, et al, 2021).
2. Investigating reclaimed water irrigation for salt-tolerant vegetable production in coastal saline soils is crucial. Although it may accumulate endocrine disruptors, cultivating

Mesembryanthemum crystallinum shows potential for cleaner production. Soil salinity affects pollutant concentrations, and health risks decrease with increased salinity. Overall, reclaimed water irrigation with salt-tolerant vegetables can achieve cleaner production goals with lower pollutant accumulation and environmental burden, offering promise for coastal regions. (Lu, j., et al, 2021).

3. The kitchen gardening soil gets contaminated by the trace element (TE) whose consumption could affect the human health. They are characterized by a great variability in the physicochemical and inclining the anthropization level. In this paper mostly grown vegetables is cultivated to evaluate the soil parameter influence on the cultivated vegetables, soil behavior and various test could be conducted i.e Level of TE, origin of TE contamination etc. (Bidar, et al, 2020)

4. SURVIVING WITH SALINITY:

Salinity has led to high levels land degradation and desertification in some areas and thus contribute to lower crop productivity. (Ali, et al, 2020). Considering the increased water table, low yields, and higher salinity levels in the area where our research is being conducted, we embarked on vegetable cultivation with these challenges in mind. Despite these obstacles, our endeavor proved successful.

Considering the economic perspective, when comparing mulching to non-mulch techniques, it's crucial to focus on yield, productivity, and the long-term benefits for the soil health. Mulch has always significantly enhanced the crop yield. In addition, salt accumulation in the root zone can be controlled the application of soil mulching by reducing the upward movement of salts and evaporation as a better field-management option (Zhao et al., 2014; Chen et al., 2016)

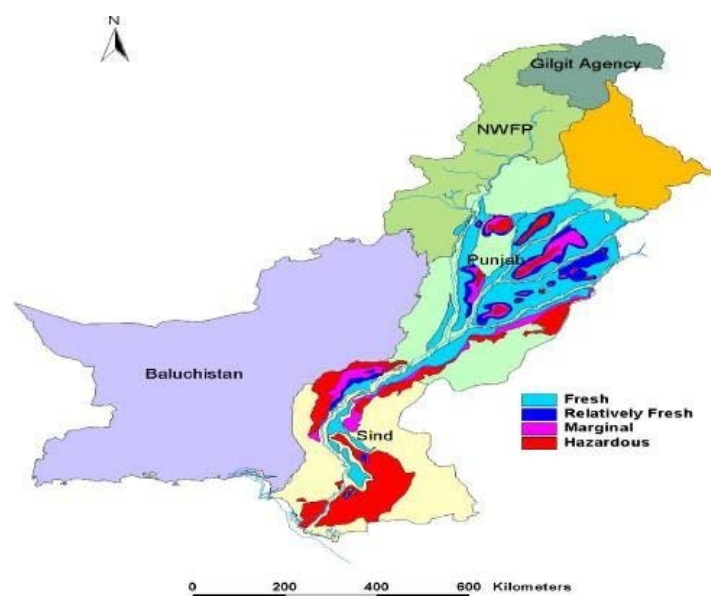


Figure # 2: Composite Ground Water Quality in the Indus Basin of Pakistan

5. METHODOLOGY:

A field experiment was conducted at the Malwah distributory of District Shaheed Benazirabad during 2022 - 2023, located at 26.2891° N, 68.1074° E (Tehsil Kazi Ahmed). The mean maximum temperature during the crop period was recorded 46.37 °C and the minimum temperature was

24.20 °C, respectively average. The mean relative humidity was 62.55%, Before crop sowing, soil analysis (0-30 cm) thrice at the

interval of 30cm regarding various physicochemical properties was done using standard procedures (Klute, 1986; Sparks et al., 1996). Five plots were randomly selected due to which practices was done.

For this study, we selected site (5) for crop cultivation and conducted soil sampling, collecting 15 samples, with 3 from each site, using an auger tool at 0-15 and 15-30 cm intervals, In this EC and pH in 1:5 soil water extract. Irrigation was scheduled according to local farmers. Data on irrigation water usage were collected by recording the time needed for both ridge and flatbed irrigation methods. The water volume applied to the experimental plots was measured and converted to m³/ha for the entire cropping season. Water productivity (WP Kg/m³) was determined by dividing the crop yield (Y; kg/ha) by the amount of water used by the crop (WC, m³/ha) across various treatments, using the equation $WP = Y / WC$. Subsequently, we applied farmyard manure (FYM) for agricultural purposes to enhance crop production. Each plot was then divided into two subsections: one for FYM and the other for non-FYM treatment. Following this, land ploughing and mixing were carried out, with minor leveling using a cultivator. Once clods were broken down, ridges were formed using a ridge maker. Finally, the land was leveled, and initial irrigation was provided before planting, with further irrigation to be scheduled based on the crop's water requirements.

Were,

$$WP = Y/WC$$

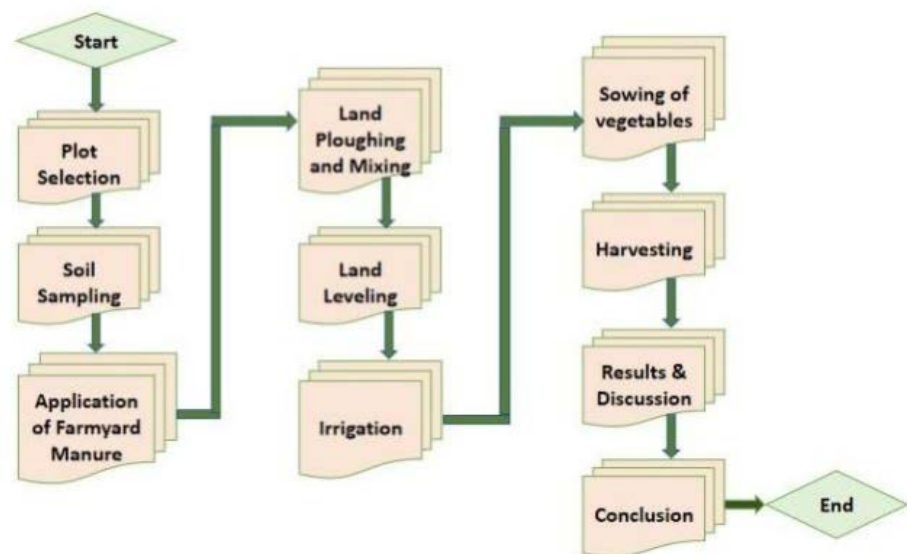
WP= Water Productivity

Y= Yield of crop

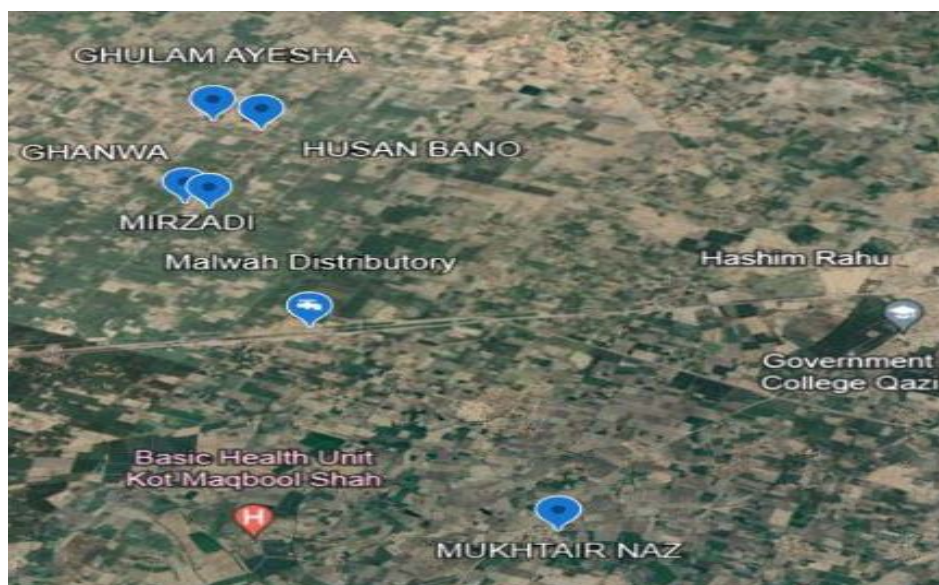
WC= water consumption (requirement)

Table 1: Cultivated Vegetables of both seasons (Rabi & Kharif)

S. No	Name(s) of farmer	Rabi Vegetables	Kharif Vegetables	Area (Sq ft)
1	Ghanwa d/o Muhammad Yaseen	Spanish, Coriander, carrot, Peas, Radish	Okra, Ridge Gourd, Brinjal, Cluster Bean, Indian Squash	5,445
2	Husan Bano w/o Abdul Haq Dharejo	Spanish, coriander, peas, tomatoes, beet root	Okra, Ridge Gourd, Brinjal, Cluster Bean, Indian Squash	10,890
3	Mukhtair Naz w/o Zulfiquar Dharejo	Spinach, fenugreek, coriander, peas, Radish, Carrot, Onion, Garlic, Cabbage, Tomatoes, Brinjal	Okra, Ridge Gourd, Cluster Bean	21,780
4	Mirzadi w/o Gul Sher Lakho	Spanish, coriander, peas, tomatoes, radish, fenugreek	Okra, Ridge Gourd, Brinjal, Cluster Bean	5,445
5	Ghulam Ayesha w/o Qasim Lakho	Spinach, fenugreek, coriander, peas, Radish, Carrot, Onion, Garlic, Cabbage, Tomatoes, Brinjal	Okra, Ridge Gourd, Brinjal, Cluster Bean, Indian Squash	10,890



6. RESEARCH AREA MAP



MULCHING MATERIAL:

In our research, we have utilized sugarcane waste, wheat straw as a mulching material, taking into account its economic perspective and easily available. This material excels in retaining soil moisture and enriching the soil, thereby establishing a stable foundation for fertilization in future. Organic mulch also reduces erosion by protecting the soil surface (Erenstein 2002). Mulching involves the use of organic materials (e.g. crop residues, straw, grasses, and farmyard manure) or inorganic, synthetic materials, (e.g. polyethylene sheets, and gravels). Organic mulch adds nutrients to soil when decomposed by microbes and helps in carbon sequestration (Chattopadhyaya and Mukherjee, 1990).

6 RESULTS:

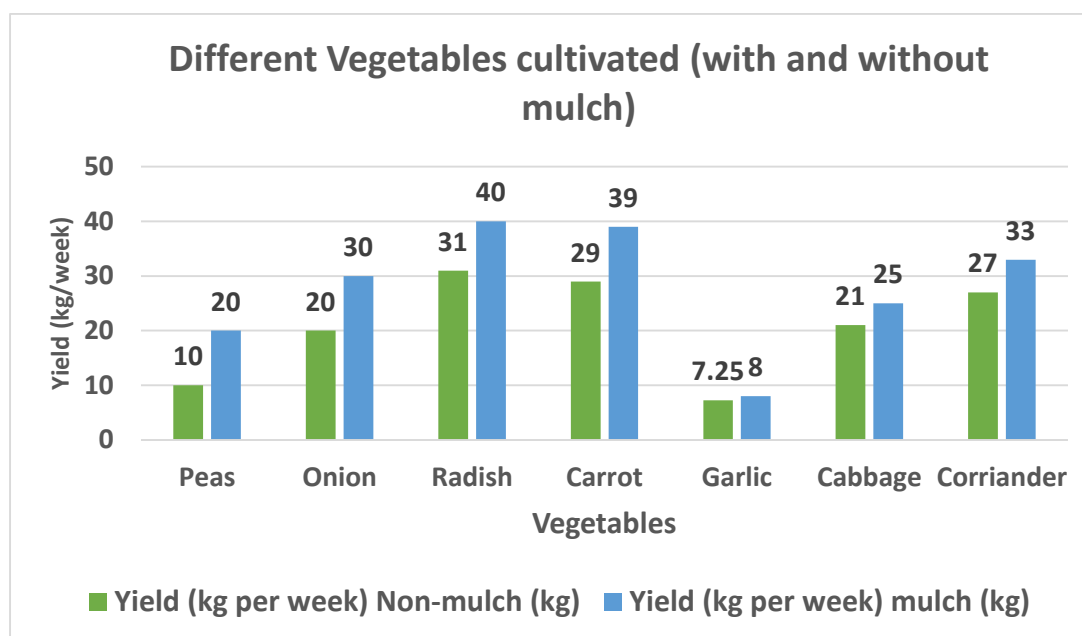
The results are summarized as follows:

- The utilization of mulching in vegetable cultivation has reduced salinity, hence enhanced the yields in comparison with the plot without mulch (Table 2). The yield on the plots with mulching has been increased, but it varies from vegetables to vegetable (Figs. 2). The average percentage increase of yield is varying from 10 to 100 (Fig. 3)

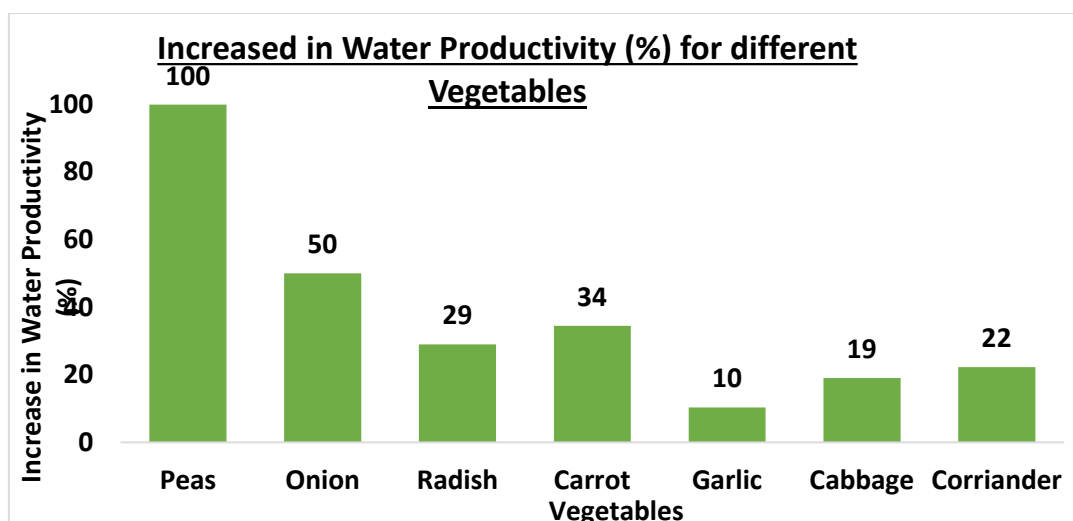
Table 2: Comparison of yield from the plots with and without much

Crop	Yield (kg per week) for:		Increase in Yield (%)
	Non-mulch	Mulch	
Peas	10	20	100
Onion	20	30	50
Radish	31	40	29
Carrot	29	39	34
Garlic	7.25	8	10
Cabbage	21	25	19
Coriander	27	33	22

- The results have confirmed that the mulching is beneficial and provides a better yield requiring less water for the cultivation. Hence, the water is saved/conserved.
- In addition to above, the kitchen gardening has provided organic vegetables throughout the season for the female farming communities. Thus, all the family members including youth (young boys and girls have been engaged in the kitchen gardening.



Graphical Rep 2: Comparison of yield from the plots with and without mulch



Graphical Rep 2: Comparison of yield from the plots with and without much

From an economic perspective, kitchen gardening emerges as the most cost-efficient and accessible method, providing fresh and organic vegetables customized to individual preferences while also fostering biodiversity.

CONCLUSION

- Kitchen gardening, utilizing ridge and mulching irrigation not only conserves water but also boosts yields. The participating farmers were delighted with the outcomes, expressing a preference for ridge cultivation when growing kitchen garden crops in the future.
- To ensure optimal soil health for kitchen gardening, Family farmers intend to be asked for soil tests.

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Monitoring Seasonal Water Surface Fluctuations Using Satellite Radar Altimetry Products for An Ungauged Lake Through Linear Regression Algorithm: A Case Study of The Manchar Lake

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Abstract

Inland water is one of the indispensable resources of the freshwater system. It provides excessive support to the economy of any country due to its sheer importance for agriculture and fishing Industry. However, the lack of availability of physical gauges in the world weakened the monitoring process and requires alternative approaches for improving the monitoring of inland water. Satellite radar altimetry is one of the widely known satellites that measure the level of water through the application of radar technology. It has different passes in multiple locations on the earth. This research monitors the seasonal water level fluctuation in Manchar Lake. The main reason behind observing the water level fluctuation in Manchar Lake is the 2022 super flood due to unprecedented rainfall in its outskirts. It disrupted the lives of the people who were in the close vicinity of Manchar Lake. Therefore, a relationship between rainfall and water level has been created to check the ramification of rainfall in Manchar's water level. Due to unavailability of real data, water level data were obtained from different databases such as DAHITI and HYDROWEB which already had processed the data of Altimetry radar satellites. Similarly, rainfall data were obtained from CHIRPS Pentad: Climate hazards group infrared Precipitation with station data of the whole watershed area of Manchar Lake. After data acquisition, a linear regression model was created between rainfall and water level. It showed a fine relationship in which the correlation was around 0.39 and the intercept was 33.78. Besides, it manifested a weak model which was calculated as 0.140. Despite weak accuracy, the model performed well and predicted a fine output in each input. From these observations, it is concluded that rainfall is not the only factor behind the extreme water level fluctuation in Manchar Lake. There could be other factors such as drain from Baluchistan and Hamal Lake. Therefore, the government must analyze the other factors behind the occurrence of extreme events in Manchar Lake which can support the decision makers to improve the monitoring of extreme events in Manchar Lake.

Keywords: CHIRPS, DAHITI, Lake; Linear regression; Manchar Lake; satellite radar altimetry.

1. INTRODUCTION:

Inland water is an indispensable part of Earth's resources, as it accounts for a significant proportion of the world's fresh water resources. Lakes, in particular, store a considerable amount of this water, and their importance in water resources management cannot be overstated. Without them, people would face multiple challenges, such as a scarcity of drinking water, a soaring food crisis, and the devastation of natural ecosystems. However, due to erratic variations in climate and seasonal cycles, water availability has become the biggest concern of today's era. Therefore, government authorities must monitor spatial and temporal changes in lakes (Muzaffar et al., 2019). However, due to low density of insitu gauges availability, especially in third world countries, it triggers multiple challenges for water authorities to devise a policy for efficient management of variation in Lakes. To resolve this issue, satellite radar altimetry is one of the alternative approach which calculates the water level data of any water body in the absence of Insitu gauges(Zaidi et al., 2021). Different satellite radar altimetry data are available which provides water level data in different temporal resolution. Jason altimetry series provides data with a temporal resolution of 10 days. These datasets are already processed in different databases such as DAHITI and HYDROWEB (Schwatke et al., 2015). Owing to its advantage of global coverage, satellite altimetry calculate the water level of any lake even though in difficult terrain of earth(Ali et al.,

2022). The passes of satellite altimetry which are available in any water body are known as Virtual stations. These virtual stations are considered as an alternative to insitu network(Vignudelli et al., 2011). Different previous studies have demonstrated the utilization of satellite application to manifest the seasonal fluctuation in multiple lakes. Some have checked the volumetric variation and water balance study in Manchar Lake through combination of Satellite altimetry and optical remote sensing approach(Muzaffar et al., 2019). In the same manner, multi-mission satellite approaches were also utilized to monitor the water level variation in different Inland water(Verma et al., 2021).

Another dataset required to monitor seasonal water fluctuations in lakes is rainfall data. Rainfall is one of the main sources of input for different water bodies around the world. Erratic rainfall is the main concern behind extreme events occurring in Manchar Lake. Last year, a rainfall-induced super flood at Manchar Lake created widespread destruction and disrupted the lives of people living nearby the lake. Therefore, it is crucial to analyze the relationship between rainfall and water level.

Different statistical approaches and algorithms have been developed to check the ramifications of rainfall on Manchar Lake water levels. Rainfall data was obtained from CHIRPS Pentad: Climate Hazards Group Infrared Precipitation with Station Data. It provides data with a temporal resolution of five days. The CHIRPS PENTAD data is derived from a blend of data obtained from both ground-based observation stations and satellite images. It utilizes infrared data obtained from geostationary and polar-orbiting satellites and incorporates station observations wherever possible to enhance accuracy. The dataset has undergone rigorous validation procedures against ground observations and has been demonstrated to perform effectively in areas with varying levels of data availability.

Therefore, the main aim of this study is to create a linear regression relationship between Water level and Rainfall of whole Manchar's lake watershed to check the ramification of Rainfall in the seasonal fluctuation of Manchar Lake. Secondly, another purpose of this study is to inform the decision maker about the other factors which also contributes to the seasonal fluctuation in Manchar Lake.

2. STUDY AREA:

Manchar Lake is situated in district Dadu Sindh which is located at the west bank of Indus River. It is one of the largest fresh water lake in Asia and largest in Pakistan. It collects water from different available streams in Kirthar mountain range and finally drain into Indus River. The surface area of Lake varies with respect to time due to seasonal fluctuation. It shrinks up to 200 km² during the dry season and expands in the rainy season up to 500 km². In current super flood in Pakistan, it was observed that Manchar Lake had created numerous disaster in its nearby big cities due to rampant overflowing issue. Along with its surface area, its water level also fluctuates in the range of 0.5-3.75m. Like other lakes, it is also one of the prominent lakes which provide fresh water resources for agricultural and drinking water for nearby localities. It is also one of the biggest livelihood for local fishers communities (Muzaffer et al., 2020),(Ismail et al., 2022). Study area map is shown in figure 1.

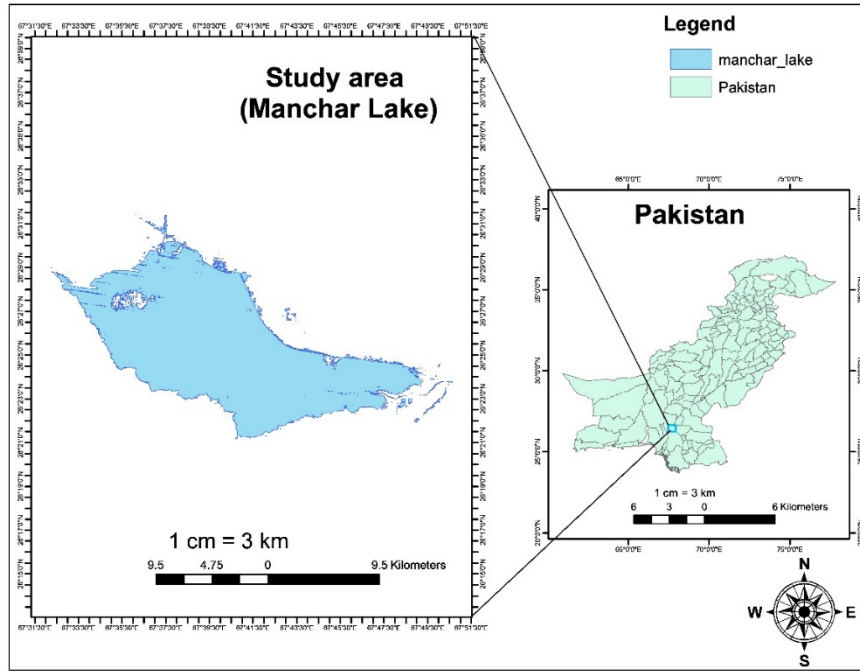


Figure 1: Description of study area

3. DATASETS:

3.1 Water level data:

Due to unavailability of Insitu gauges, it is very difficult to acquire water level data of different water bodies in the world. Similarly, there is no proof of any availability of physical gauge for Manchar Lake. Dearth of physical data provided an opportunity for researches to derive an alternative for ungauged water body (Muzaffer et al., 2020). Therefore, in order to alleviate data scarce issues, satellite radar altimetry is currently being utilized in the world for water level monitoring in the water bodies. It has an advantage of global coverage which assist researchers to obtain data without any official constrain and at the same time, it provides data in free of cost which is again beneficial for third world countries. In Pakistan, sentinel 3 data has been utilized in Indus river which were validated in good agreement with gauge data in previous studies (Zaidi et al., 2021). In this study, water level data was obtained from two different databases: DAHITI and HydroWeb. DAHITI is database for Hydrological Time series of Inland water which exploit different radar satellite to derive water level of Inland water system. In the same way, HydroWeb is also the database which utilized multi-mission radar altimetry system to compute water level of different water bodies. Both databases entails the processing of Jason Altimetry radar series and sentinel 6 which calculates the water level data with a temporal resolution of 10 days.

3.2 Rainfall dataset

Unprecedented precipitation in 2022 has triggered serious ramifications in the form of Flood in Pakistan especially the region of Sindh. In Sindh, extreme rainfall created devastative situation in the region of Dadu due to sudden variation in Water level of Manchar Lake. It has wreaked havoc in the outskirts of Manchar lake, even drowned the big cities like Khairpur Nathan shah. It was the main problem which encouraged the researches to expedite their work on monitoring of Manchar Lake. Due to unavailability of rainfall data, it was obtained from satellite dataset named as CHIRPS Pentad v2.0: Climate Hazards Group InfraRed Precipitation with Station Data. It is high resolution data created by the Climate hazard group in University of California. It provides a

precipitation data with temporal resolution of five day. Elucidation of these datasets are shown in Fig 3.

3.3 Manchar Lake watershed:

In order to develop a strong relationship between parameters, data of whole watershed of Manchar Lake is extremely necessary. Therefore, the watershed of Manchar lake was automatically delineated from Global Watershed by defining an outlet of Lake.

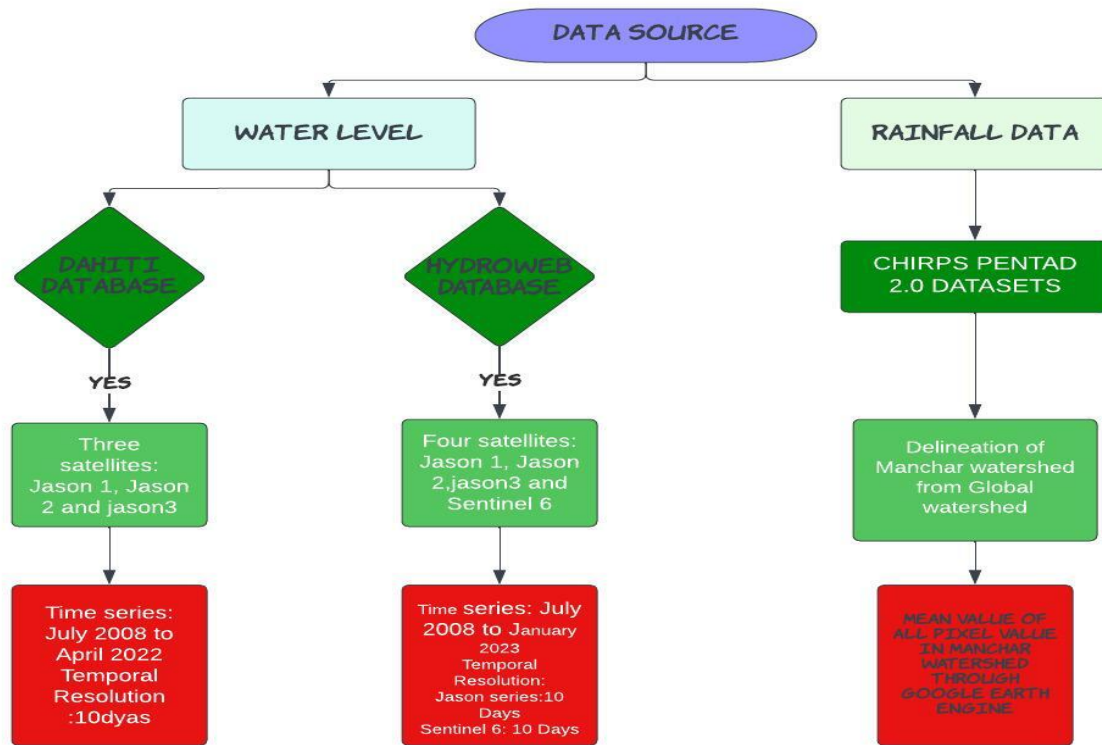


Figure 2: Description of Data set utilized in this study

4. Methodology and Data processing:

4.1 Adjustment of required data:

Two datasets were utilized for this research work. One is water level data which was obtained through DAHITI and Hydroweb data base. Another one is Rainfall dataset which was obtained from CHIRPS Pentad v2.0. As Rainfall data of whole watershed of manchar lake was required, therefore, mean of all pixel values within watershed of Manchar lake was calculated through Google Earth Engine. Water level data was available with a temporal resolution of 10 days whereas Rainfall data was available with five day interval. Therefore, in order to create a relationship between these two parameters accurately, data of both parameters converted into Monthly data through mean approach.

4.2 Statistical relationship:

Whenever studying the relationship between parameters, it is indispensable to show the relationship through statistical concepts. One of the concept is correlation which determines the linear relationship between two parameters. The correlation between two variable can be negative,

positive and zero. It ranges from -1 to +1. +1 shows the perfect correlation between two parameters. Besides, intercept was also calculated to analyze the variation in water level if there is no rainfall. Trend between both parameters were shown with different visualization technique which is shown in next chapter.

4.3 Linear Regression model between Rainfall and Waterlevel:

Linear regression model between both variables were created in Jupyter notebook with a Python language. Before creating a model, exploratory data analysis (EDA) was created to clean the outliers and missing data in both parameters. After the procedure of EDA, data was Split into training and test data. 80% data was reserved for train the model while 20% was reserved to check the accuracy of model. After the creation of model, its accuracy was checked which assisted the researches to validate the prediction of model. Aftermath the creation of model, different rainfall input were given to model which calculated the water level data. The methodological framework is further explained in figure 3.

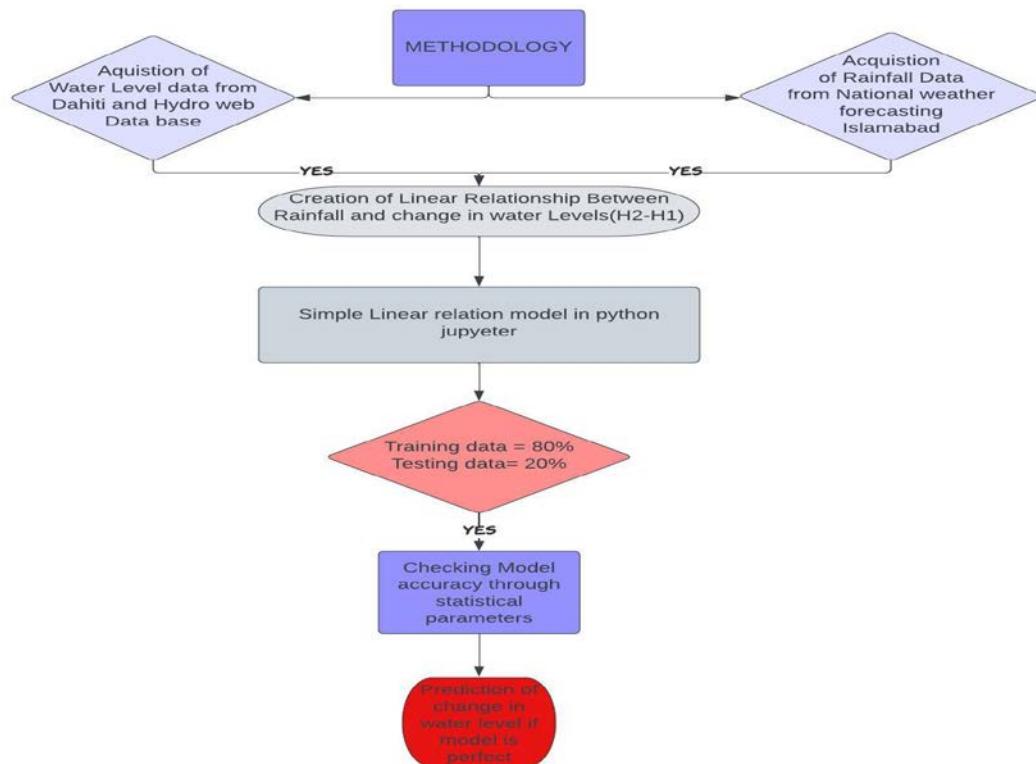


Figure 3: Methodological frame work of this study

5. Results and Discussion:

First, the given data were distributed in different ways. Rainfall data was given with a temporal resolution of five days and water level data with a temporal resolution of 10 days. In order to convert the data with same interval, monthly temporal resolution was taken. Rainfall and water level data were converted into monthly data through statistical approach of Mean. After this process, outliers were removed from this dataset. It helped to improve the correlation between

these two parameters. Correlation was calculated between two parameters which was 0.392 and intercept value was 33.78m. It showed a fine relationship between both parameters which suggests that Rainfall trigger the variation in Manchar Lake at some extent but not the only factor behind gradual change in water level of Manchar Lake. Line graph was created to show the trend of change in water level with respect to Rainfall. With peak value of Rainfall, water level also reached to peak level as shown in figure 4.

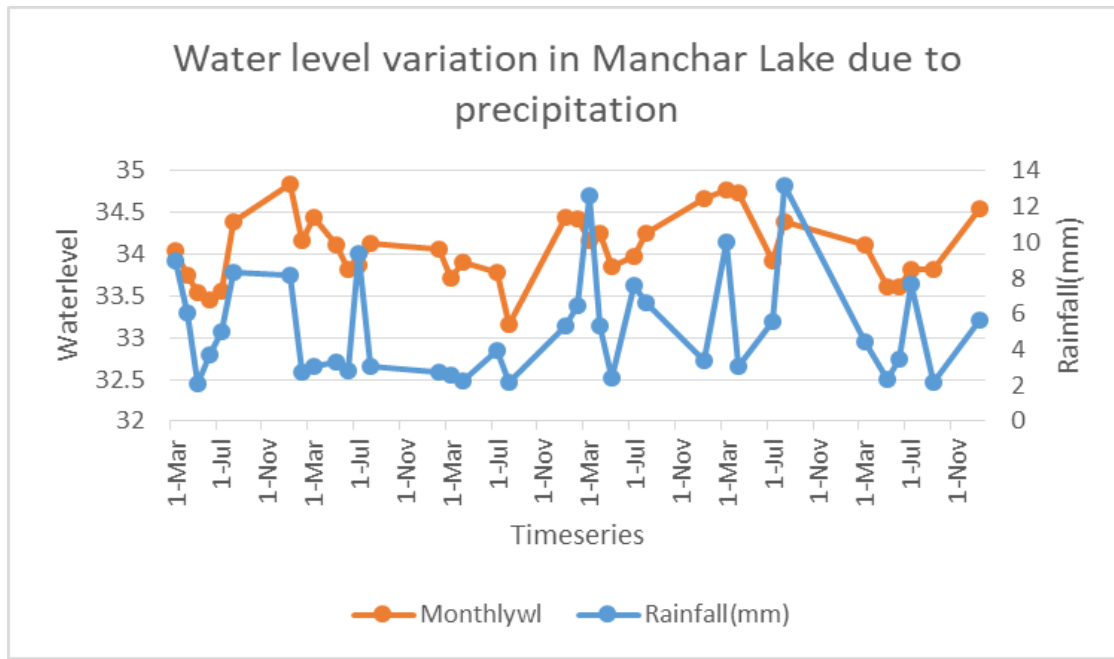


Figure 4: Graphical representation of precipitation with water level

Moreover, for better visualization, heat map was also calculated through sea born visualization in Python which also showed the correlation between Rainfall and Water level as shown in Figure 5.

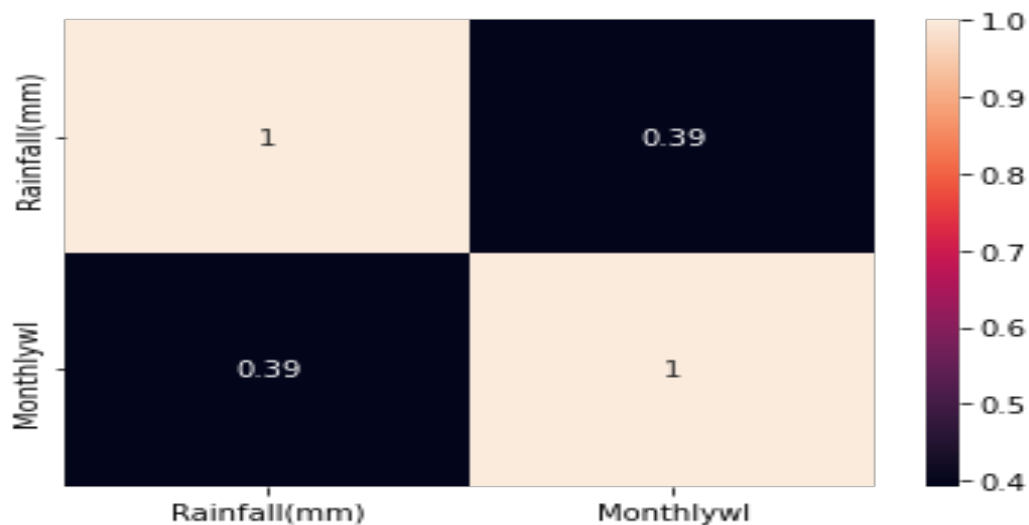


Figure 5: Heatmap showing correlation between rainfall and water level

After checking the statistical relationship between parameters, Linear Regression model was created to predict the Water level variation due to Rainfall. Its methodology is discussed in previous chapter. Model was successfully created; however, its accuracy was low which is 0.140 as low accuracy. Due to such a low accuracy, its predictions were not considered as validated. Therefore, its prediction is not considered as final prediction. Although, in order to check the model performance, five-year Random Rainfall data was given to model which predicted an insightful information. It is shown in following table 1. From above analysis, it is understood that Rainfall is not the only factor behind the unprecedented changes in water level variation in Manchar Lake. Besides, Limited data was also one of the Limitation which affected the accuracy of Model. These limitations give an idea that there must be some other factors responsible for variation in Water level of Manchar Lake.

Table 16: statistical relation between rainfall and water level

RAINFALL (MM)	WATER LEVEL (M)
25	35.06
50	36.28
150	41.11
0	33.85
200	43.57

6. Conclusion and Recommendations:

One of the biggest finding of this paper is the weak correlation between Rainfall and Water level; which conveyed an idea that there is no such considerable impact of Rainfall on Water level variation in Manchar Lake. Apart from it, low accuracy of model has shown that limitation of data could create a strong effect in data driven decision making. From these finding, it was anticipated that other factors in watershed of Manchar Lake along with rainfall are the main reason behind the water level fluctuation in Manchar Lake. The main purpose of this research is to check the ramification of Rainfall in the variation of water level in Manchar due to devastation triggered by 2022 Rainfall induced super flood. However, as per the finding of this study, it was concluded that there are other factors besides rainfall are responsible for water level variation in Manchar Lake. From this research paper, decision makers must get an idea that they must check or monitor the other factor in Manchar Lake water shed area to control the further devastation for the community. It will encourage other researchers also to acquire more data for rainfall and other factors to monitor the changes in Manchar Lake. Therefore, government organizations must devise a strategy to monitor the Manchar Lake for the amelioration of management of Manchar Lake.

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Abstract

This research paper presents a comprehensive geospatial analysis aimed at delineating groundwater recharge potential zones in the Pishin-Lora Basin, located in the Baluchistan province of Pakistan. The study integrates multiple factors influencing groundwater recharge, including slope, lineament density, drainage density, soil characteristics, rainfall distribution, and land use/land cover (LULC), through a sophisticated overlay analysis. Weightages assigned to each layer were derived from existing literature and expert knowledge, ensuring a holistic representation of the basin's hydrogeological dynamics. The resulting groundwater recharge potential zone map reveals distinct spatial patterns within the basin. Approximately 0.6% of the total area falls within the very low potential zone, while 3.9% is classified as low potential. The majority of the basin, constituting 39.5%, is characterized as having a medium recharge potential. Furthermore, 40.3% and 15.6% of the area exhibit high and very high groundwater recharge potential, respectively. These findings offer valuable insights for sustainable water resource management and infrastructure planning in the region. To validate the accuracy of the model, the locations of existing recharge structures were overlaid onto the recharge potential map. This analysis aims to assess the alignment of previously constructed recharge facilities with identified potential zones. Such an evaluation provides a practical framework for decision-makers, aiding in the identification of optimal locations for future groundwater recharge infrastructure. This research contributes to the scientific understanding of groundwater dynamics in arid regions, particularly in the context of climate change and increasing water scarcity. The methodology employed can serve as a valuable template for similar studies in other geographically diverse regions, fostering a more informed and strategic approach to groundwater resource management on a global scale.

Keywords: Groundwater, GIS and remote sensing, Groundwater recharge, Overlay analysis, Sustainable Groundwater management.

Introduction

Groundwater is the major source of water supply for population dependent on Pishin-Lora basin. However, in recent year the water table is depleting at an alarming rate. According to a report published by Pakistan Council of Research in Water Resources (PCRWR), “The decline in groundwater table is attributed to extensive groundwater abstraction and inefficient use of the pumped water. The excessive groundwater abstraction has resulted in lowering of water table up to 5 m per annum in some valleys, causing groundwater mining especially in Quetta, Pishin, Mastung and Mangochar, the status of water table of tube wells in the Quetta Valley presents further grim situation of groundwater. This has resulted because of irrational and highly inefficient use of water for irrigation where water losses are immense. This situation cannot be allowed in view of the ever-increasing gap between water demand and supply”(Ashraf & Sheikh, 2017).

In view of the above statement, it is imperative for the water management authorities to plan and construct more artificial recharge structures to cope up with the increasing groundwater abstraction rate. However, for the construction of artificial recharge structures it is critically important to identify the most potential zones for groundwater recharge in order to increase the efficacy of artificial recharge facilities. (Aftab et al., 2018)

This study aims at mapping the groundwater potential zones for Pishin-Lora basin, the zones would be categorized as Very good zone, good, average, poor and very poor zone.

This study aims to incorporate multi criteria decision making approach (MCDM) to decide ranking of zones. The outcome of the results would be based on the integration of six factors which contribute in groundwater recharge. Namely, drainage density, slope, elevation models, lithology of the area, rainfall, land use and land cover and lineaments.

These factors would be integrated and overlapped using GIS and analytical hierarchy process (AHP) by assigning weights to each criteria and obtaining ranking for each zone.

The results obtained from this study will also be useful for exploring potential groundwater wells.(Steenbergen & Bakhsh, 2015)

Study Area

Figure No.1 shows the study area Pishin-Lora basin boundaries. The study area for the research "Identification of Groundwater Recharge Potential Zones of Pishin-Lora Basin using GIS and Remote Sensing Tools" is the Pishin-Lora Basin located in the southwestern part of Pakistan. This region is home to a diverse population of people who rely heavily on the groundwater resources of the area for their daily needs. The Pishin-Lora Basin covers an area of approximately 15,000 square kilometers and is characterized by a complex geology, diverse climatic conditions, and a varied topography.

The people living in the Pishin-Lora Basin depend on the groundwater resources for drinking, irrigation, and industrial purposes. The groundwater in the area is also a critical source of water for the local agriculture, which is the main source of livelihood for many of the residents in the region. The area is also home to several rivers and streams that flow through it, contributing to the recharge of the groundwater aquifers.

However, the increasing demand for water and the impacts of climate change have led to a decline in the groundwater levels in the Pishin-Lora Basin. The reduction in the recharge of the aquifers has also contributed to the decline, leading to concerns about the long-term sustainability of the groundwater resources in the area. This has had a significant impact on the lives of the people living in the Pishin-Lora Basin, and there is an urgent need to understand the groundwater recharge potential of the area and identify the most suitable areas for recharge.

This research aims to address this issue by using GIS and remote sensing tools to identify the groundwater recharge potential zones in the Pishin-Lora Basin. The study will provide valuable information for water resource management and planning in the region and contribute to the sustainable use of groundwater resources in the Pishin-Lora Basin. The results of the study will have a direct impact on the daily lives of the people living in the Pishin-Lora Basin, providing them with a secure and sustainable source of water for their future needs.

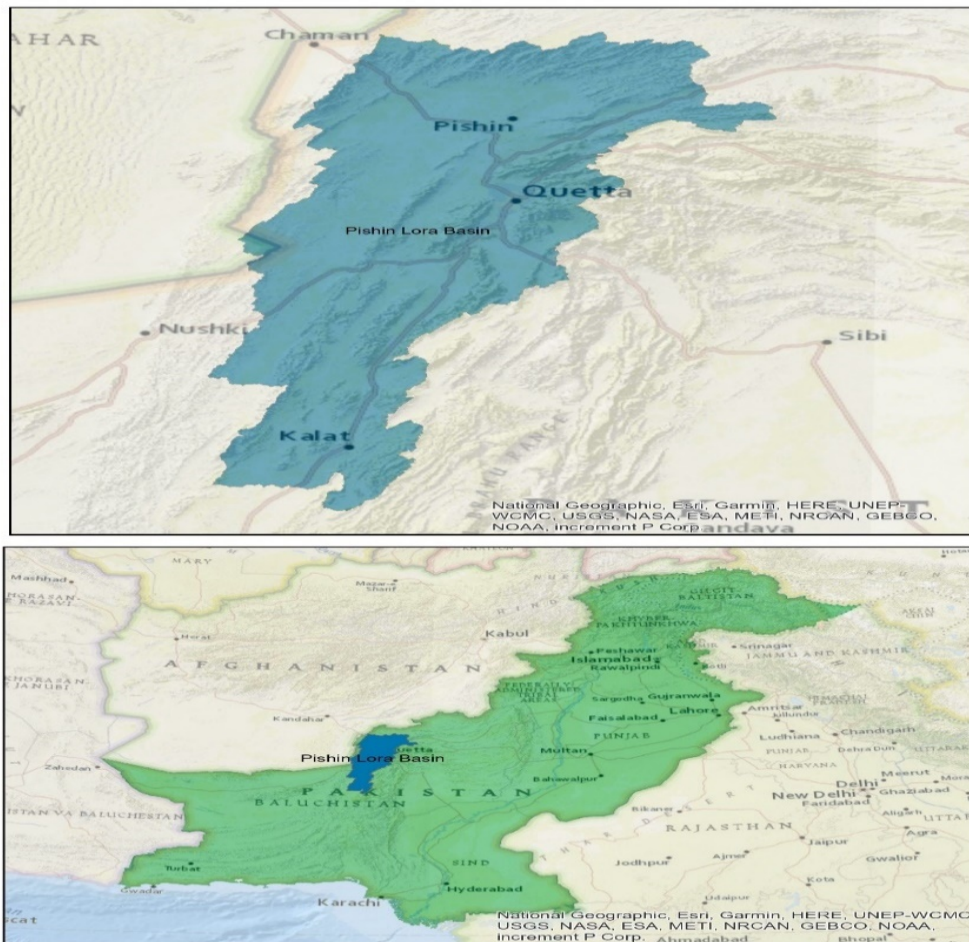


Figure 1: Study area map

Methodology

Data Collection: Collect relevant data on the geology, hydrology, climate, land use, and soil properties of the Pishin-Lora Basin. This data can be collected through remote sensing techniques and secondary sources, including geological maps obtained from the Geological Survey of Pakistan (GSP) and shape files already available for the study area. LANDSAT 8 satellite images will be obtained from the USGS website for the preparation of land use land cover maps, and the digital elevation model (DEM) SRTM data will also be obtained online for the study area.

Data Processing and Preparation of Thematic Maps: Process the collected data using GIS techniques to create spatial databases for the study area. Prepare various thematic maps, including slope maps from the DEM data, stream density maps from the streams layer, and soil maps from the maps to be acquired from GSP by digitizing the maps.

Multi-Criteria Decision Making (MCDM) Analysis: Integrate the six factors responsible for groundwater recharge into the Analytical Hierarchy Process (AHP) approach to assign weights to each criterion. The layers of each factor will be displayed in GIS and integrated together to produce an integrated map of groundwater potential zones.

Results and Conclusion: Evaluate the potential zones for groundwater recharge using the overlay and AHP analysis. Present the results of the study and draw conclusions on the groundwater

recharge potential zones in the Pishin-Lora Basin. Provide recommendations for future studies and water resource management practices in the region.

Figure 2: Flowchart for GWRPZ map

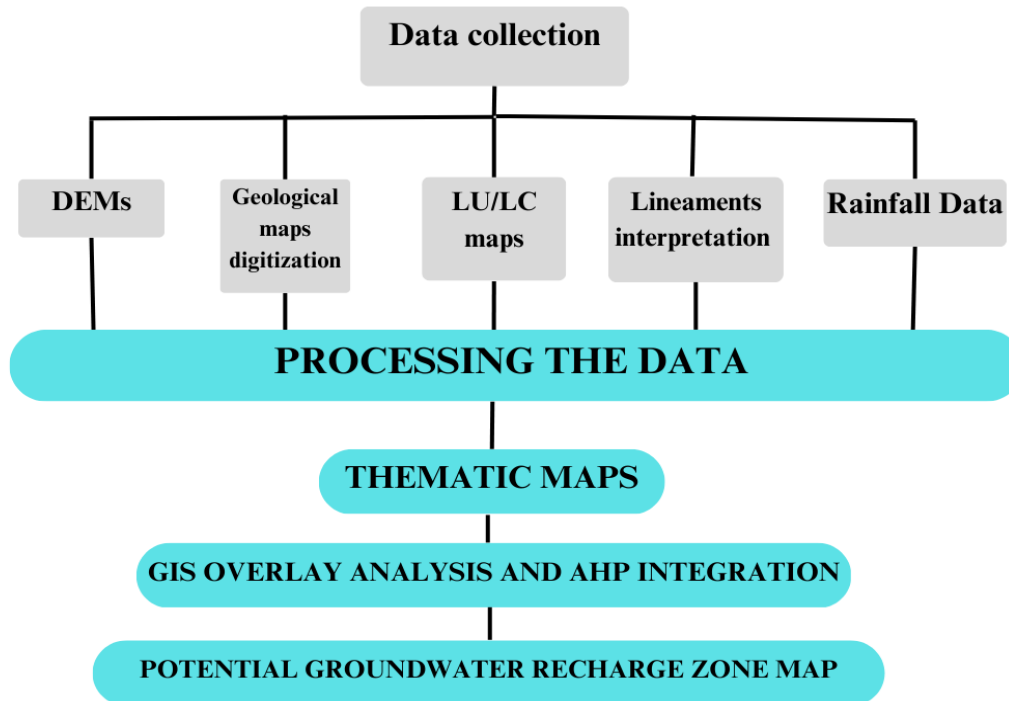


Table 1: Weightage calculation

Factors	LD	Lithology	Slope	LULC	Rainfall	DD	weight
Lineament density	6	5	4	3	2	1	0.41
Lithology	3	2.5	2	1.5	1	0.5	0.2
Slope	2	1.666666667	1.333333333	1	0.666667	0.333333	0.14
LULC	1.5	1.25	1	0.75	0.5	0.25	0.11
Rainfall	1.2	1	0.8	0.6	0.4	0.2	0.08
Drainage Density	1	0.833333333	0.666666667	0.5	0.333333	0.166667	0.06
							1

Table 2: Assigned and normalized individual features of six factors of groundwater recharge potential zone mapping.

Factors	Weight	Rank	Overall
Lineament Density			
Very Low	41	1	41
Low		2	82
Moderate		3	123
High		4	164
Very High		5	205
Lithology			
Conglomerate	20	1	20
Gravel Sand silt and clay		4	80
Limestone		2	40
Sandstone and shale		3	60
Slope			
Nearly Level	14	4	56
Gentle		3	42
Moderate		2	28
Steep		1	14
LULC			
Water bodies	11	7	77

Trees		6	66
Flooded vegetation		5	55
Crops		4	44
Built area		1	11
Baren land		3	33
Rangeland		2	22
Rainfall			
Low	8	1	8
Moderate		2	16
High		3	24
Drainage Density			
Very low	6	5	30
Low		4	24
Medium		3	18
High		2	12
Very high		1	6

Results and Discussion

Our investigation into groundwater recharge potential zones in the Pishin-Lora basin of Baluchistan province, Pakistan, using GIS and remote sensing techniques, provided vital insights into how recharge varies across the area. We analyzed six key factors—lineament density, lithology, slope, land use and land cover (LULC), rainfall, and drainage density—to gain a thorough understanding of groundwater recharge dynamics.

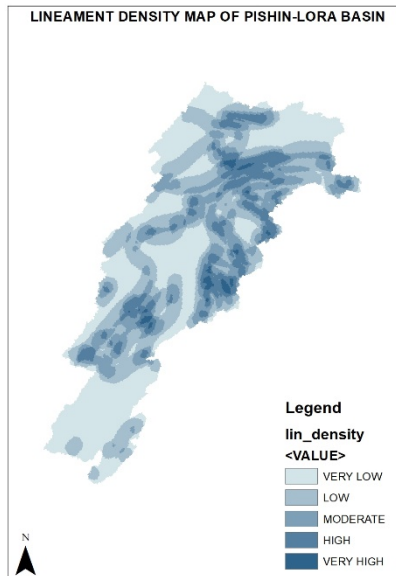


Figure: 3

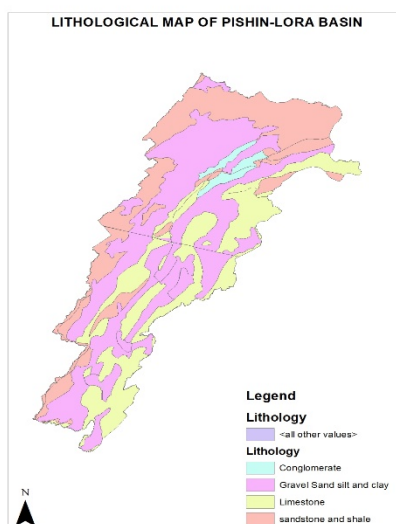
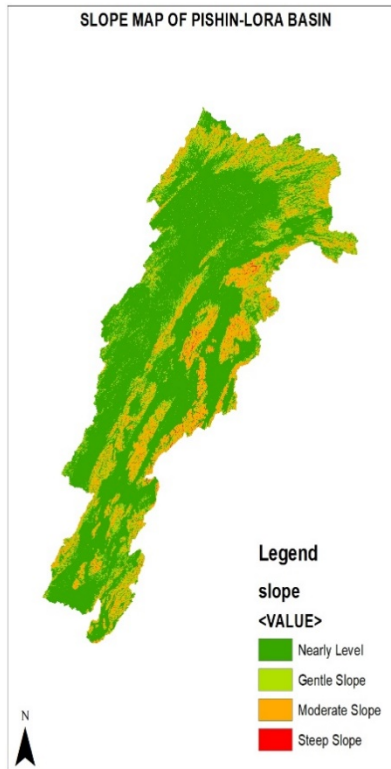


Figure: 4

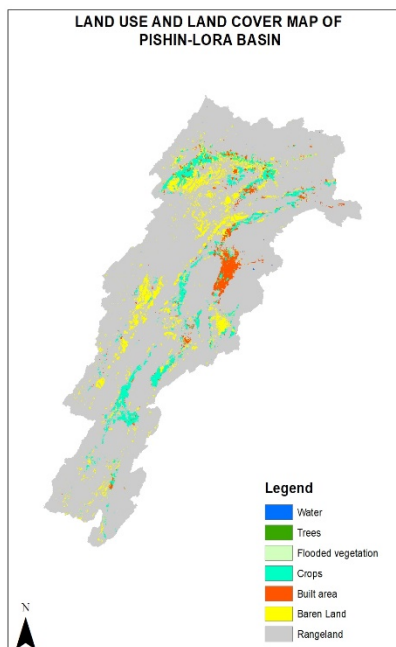
Lineament Density: Figure No.3 illustrates Lineament density map which depicts the distribution of fractures and faults in the subsurface. In the Pishin-Lora basin, these linear features serve as pathways for groundwater movement and infiltration. Areas with higher lineament density indicate greater potential for groundwater recharge, as fractures facilitate the flow of water into the aquifer system. Understanding the distribution of lineaments helps identify regions where groundwater replenishment may be more pronounced.

Lithology: Figure No.4 illustrates Lithology map of Pishin-Lora Basin which shows the geological composition of the basin, highlighting variations in rock types and formations. Porous lithologies, such as sandstones and alluvial deposits, have high groundwater storage capacity and promote infiltration. Conversely, impermeable lithologies like shale and hard rocks inhibit water movement, limiting recharge potential. By assessing lithological variations, we can identify areas conducive to groundwater recharge and those where infiltration may be restricted.



Slope: Figure No.5 illustrates Slope map of the basin which characterizes the topographic relief of the basin, indicating the steepness of terrain across different areas. Gentle slopes facilitate groundwater recharge by allowing water to percolate into the subsurface, while steep slopes promote surface runoff, reducing infiltration. In the Pishin-Lora basin, understanding slope gradients helps pinpoint locations where recharge potential is higher due to favorable topographic conditions.

Figure:5



Land Use and Land Cover (LULC): Figure No.6 shows the LULC map of the basin which depicts the distribution of vegetation, agricultural land, urban areas, and other land cover types within the basin. Natural land covers, such as forests and grasslands, promote infiltration and groundwater recharge, while urbanization and impervious surfaces inhibit infiltration, leading to reduced recharge rates. By analyzing LULC patterns, we can identify areas where human activities may impact recharge dynamics and prioritize conservation efforts accordingly.

Figure: 6

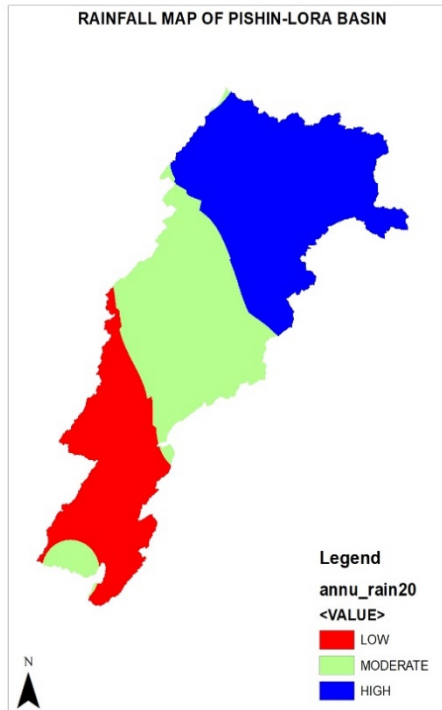


Figure: 7

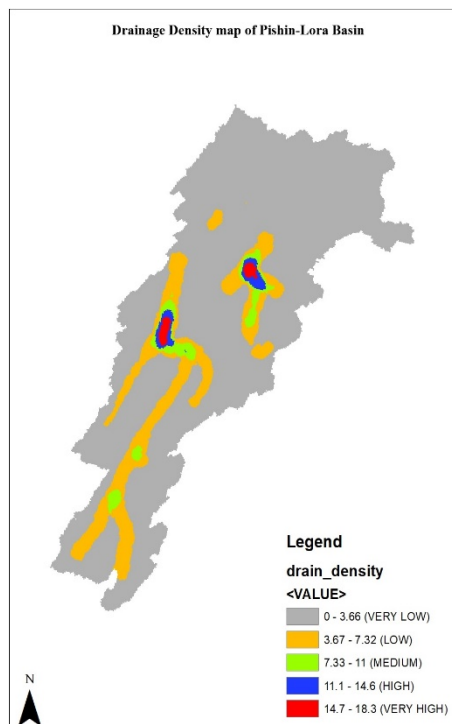


Figure: 8

Rainfall: Figure No. 7 illustrates the Rainfall map of the basin which shows the spatial distribution of precipitation across the basin. Higher rainfall intensities correlate with increased groundwater recharge potential, as more water infiltrates into the ground. In the Pishin-Lora basin, regions experiencing greater rainfall are likely to exhibit higher recharge rates, making rainfall distribution a crucial factor in assessing groundwater recharge potential.

Drainage Density: Figure No.8 shows the Drainage density map of the basin which depicts the density of stream networks and surface water flow paths within the basin. Higher drainage densities indicate areas with increased surface runoff, which may limit groundwater recharge opportunities. By analyzing drainage density patterns, we can evaluate the influence of surface water dynamics on recharge processes and identify areas where recharge potential may be compromised.

In conclusion, our study highlighted the complex interplay of various factors influencing groundwater recharge potential in the Pishin-Lora basin. Understanding these dynamics is crucial for effective water resource management in the region, ensuring sustainable groundwater availability for future generations.

Spatial Distribution of Groundwater Recharge Potential Zones:

The above-described key factors were integrated into an overlay analysis by assigning each factor ranking and weightage, which was based on existing literature and expert opinions, we got groundwater recharge potential zone map of Pishin-Lora basin. Figure No. 9 shows the spatial distribution of groundwater recharge potential zones which delineates areas with varying degrees of recharge potential, ranging from very low to very high.

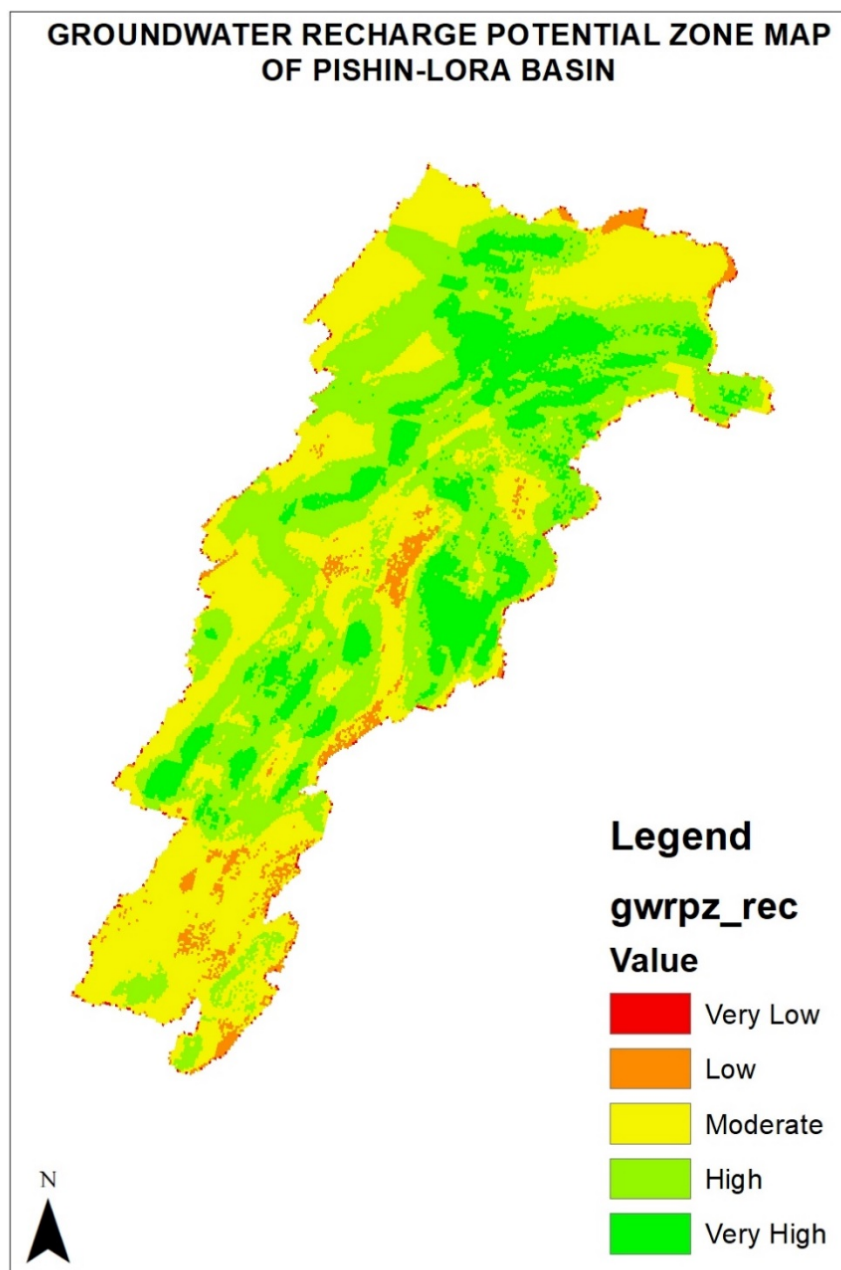


Figure: 9

Very Low Recharge Potential Zone (0.625% - 119.3 sq km): This zone mainly occurs in regions with steep slopes and impermeable rocks, making it difficult for water to infiltrate the ground.

Rugged terrains and human activities like urbanization worsen the situation. Although covering a small area, these zones are critical for groundwater replenishment and require targeted conservation efforts.

Low Recharge Potential Zone (3.89% - 741.2 sq km): Areas in this zone have moderately unfavorable conditions for groundwater replenishment, with moderately steep slopes and variable rock compositions. Human activities such as agriculture and infrastructure development further reduce infiltration. Although larger in extent, the factors affecting recharge vary, highlighting the need for tailored interventions.

Moderate Recharge Potential Zone (39.54% - 7551.1 sq km): This is the largest zone, featuring diverse conditions including gentle slopes, porous rocks, and natural vegetation cover. These areas significantly contribute to groundwater replenishment, emphasizing the importance of sustainable land management practices.

High Recharge Potential Zone (40.31% - 7699.1 sq km): Zones with optimal conditions for groundwater replenishment feature gentle to moderate slopes, porous rocks, and natural land covers. Favorable rainfall further enhances recharge rates, making these areas critical for sustaining groundwater availability.

Very High Recharge Potential Zone (15.631% - 2984.82 sq km): These zones offer exceptional conditions for groundwater replenishment, characterized by gentle slopes, porous rocks, and dense vegetation. Despite covering a smaller area, they play a crucial role in maintaining groundwater levels and supporting ecosystems, necessitating strict conservation measures.

Conclusion: Understanding where groundwater can be recharged in the Pishin-Lora basin is very important for making smart decisions about water. By focusing on saving water and managing land well, leaders can make sure there's enough groundwater for the future, not just in this area but also in neighboring places. This means protecting special areas where water can soak into the ground. Doing this helps us be ready for changes in the environment and more people needing water, keeping our groundwater safe for years to come.

Acknowledgements: We would like to express our gratitude to the Higher Education Commission in Islamabad for their generous financial support through the Local Challenges Fund Project No. 20-LCF-63. This project, titled "Metering the Aquifer Using a Smart Monitoring and Data-driven Approach to Assist in Devising an Adaptive Groundwater Management Strategy in Balochistan," has been instrumental in facilitating our research efforts.

Additionally, we extend our appreciation to Mehran University of Engineering & Technology in Jamshoro, Pakistan, for providing funding during the literature data collection and writing phases of this paper. Their support has been invaluable in bringing this research to fruition.

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8TH IWC POLICY RECOMMENDATIONS

POLICY RECOMMENDATIONS

Valuing water for sustainability is crucial as the world grapples with the escalating pressures of climate change and population growth. Water, an essential resource for life, agriculture, industry, and ecosystems, is under increasing threat from pollution, over-extraction, and erratic weather patterns. Recognizing the true value of water is fundamental to promoting sustainable use and ensuring equitable access. Effective water management policies must prioritize conservation, innovative technologies for water efficiency, and the protection of natural water sources. By valuing water appropriately, we can foster resilience in communities, support sustainable economic development, and safeguard the health of our environment for future generations.

Some of the policy recommendations in pursuance of the sub-themes of 8th International Conferences are as below:

WATER SANITATION AND HYGIENE (WASH)

Developing effective Water, Sanitation, and Hygiene (WASH) policies is crucial for improving public health and quality of life. Key areas to be addressed are:

Fair monitoring of drinking water supplies and, where possible, the use of low-cost, quick and sustainable drinking water purification methods are required to ensure safe drinking water. In addition, longitudinal research involving metals, microbials, and physicochemical parameters could be proposed in the future in order to obtain a deeper understanding of the quality of drinking water in current settings. Even though laws such as PEPA 1997 are important in the country, their enforcement is extremely poor and the level of compliance is therefore low, especially in the industrial and housing sectors.

Relevant policies are in place, such as the National Environment Policy, the National Water Policy, the National Drinking Water Policy, etc., there is no consistent strategy for enforcing them so far. To execute these policies, a simple and realistic plan needs to be established. The provision of water and sanitation facilities in Pakistan is, in addition to the above, insufficient and needs to be addressed.

Developing comprehensive guidelines and standards for water quality, sanitation, and hygiene practices and their compliance.

Upgrading water supply systems and sanitation facilities.

Inter-sectoral and Integrated approach is required between various actors.

Establishment of robust monitor systems and evidence-based policy decisions for the effectiveness.

WATER-FOOD-ENERGY NEXUS

The water-food-energy nexus refers to the interconnectedness and interdependencies between water, food, and energy systems. Developing effective policies to address this nexus requires a holistic approach that considers the complex interactions between these sectors. Here are some policy recommendations:

Integrated Resource Management: Encourage integrated resource management approaches that consider water, food, and energy systems simultaneously rather than treating them in isolation. This could involve creating cross-sectoral planning bodies or agencies to coordinate policies and actions.

Water Efficiency and Conservation: Implement policies to promote water efficiency and conservation across all sectors, including agriculture, energy production, and municipal use. This might include incentives for adopting water-saving technologies, promoting water reuse, and improving irrigation practices.

Sustainable Agriculture Practices: Support policies that promote sustainable agriculture practices, such as precision irrigation, agroforestry, and organic farming methods. These practices can help reduce water usage, minimize soil erosion, and enhance resilience to climate change.

Renewable Energy Development: Promote the development of renewable energy sources, such as solar, wind, and hydroelectric power, which have lower water requirements compared to fossil fuel-based energy generation. This can help reduce competition for water resources between the energy and agriculture sectors.

Investment in Infrastructure: Invest in infrastructure projects that enhance water, food, and energy security, such as upgrading water supply and distribution systems, expanding irrigation infrastructure, and improving energy efficiency in agricultural and industrial processes.

Research and Innovation: Support research and innovation in technologies and practices that can improve water, food, and energy systems' efficiency and sustainability. This might include funding for research on drought-resistant crops, water desalination technologies, and renewable energy storage solutions.

Stakeholder Engagement and Education: Foster collaboration and dialogue among stakeholders, including governments, businesses, farmers, and communities, to develop and implement effective policies. Additionally, invest in public education and awareness campaigns to promote understanding of the water-food-energy nexus and the importance of sustainable resource management.

Policy Coherence and Integration: Ensure policy coherence and integration across different levels of government and sectors to avoid conflicts and maximize synergies. This could involve mainstreaming considerations of the water-food-energy nexus into national development plans, strategies, and regulatory frameworks.

Resilience and Adaptation: Develop policies and strategies to enhance resilience and adaptation to climate change's impacts on water, food, and energy systems. This might include climate-smart agriculture practices, water conservation measures, and diversification of energy sources.

International Cooperation: Foster international cooperation and collaboration to address transboundary challenges related to the water-food-energy nexus, such as shared water resources management and cross-border trade in food and energy. This could involve bilateral and multilateral agreements, joint research initiatives, and capacity-building efforts.

By implementing these policy recommendations, governments and stakeholders can work towards achieving a more sustainable and resilient water-food-energy nexus that meets the needs of present and future generations.

CLIMATE CHANGE

Conservation and Reforestation: Implement policies to protect and restore ecosystems, including reforestation efforts, conservation of natural habitats, and sustainable land management practices to enhance carbon sequestration and biodiversity.

Climate Resilience and Adaptation: Develop and implement strategies to enhance resilience to climate change impacts, including investing in infrastructure that can withstand extreme weather events, improving water management systems, and integrating climate considerations into urban planning and development.

Education and Awareness: Promote climate literacy and public awareness campaigns to educate individuals and communities about the causes and impacts of climate change, as well as the actions they can take to mitigate and adapt to its effects.

Water Scarcity: Pakistan heavily relies on water from the Indus River system for agriculture, industry, and domestic use. Climate change is altering precipitation patterns, leading to decreased water availability and increasing the risk of droughts and water scarcity in many parts of the country. This scarcity exacerbates existing tensions over water resources and can impact agricultural productivity. Hence a holistic and integrated approach is needed to address the key variable of Climate Change i.e. “WATER”.

Glacial Melt: Pakistan is home to some of the world's largest glaciers, which serve as a crucial source of freshwater for rivers and agriculture. However, rising temperatures are causing these glaciers to melt at an accelerated rate, leading to increased river flows in the short term but threatening water supplies in the long term as glacier volumes decline. There is strong need to carry out comprehensive studies on Glacier Melt and work out the strategies in accordance with the Paris Accord of Climate change in respect of the high temperature.

Agricultural Impact: Pakistan's economy is heavily dependent on agriculture, which is highly sensitive to climate variability. Changes in temperature and precipitation patterns can affect crop yields, leading to reduced agricultural productivity and food insecurity for vulnerable populations. There is a strong need to re-define the 16 agro-climatic zones of the country.

Ecosystem Degradation: Climate change is causing shifts in ecosystems and biodiversity in Pakistan, including changes in vegetation patterns, loss of habitat, and disruption of ecosystems' functions. This can have implications for ecosystem services, such as water purification, pollination, and carbon sequestration. Develop and enforce comprehensive environmental protection laws that prioritize ecosystem conservation and restoration.

AGRICULTURE

Water Management: Implement efficient water management practices to address water scarcity issues, such as investing in drip irrigation, rainwater harvesting, and modernizing irrigation systems to reduce water wastage.

Crop Diversification: Encourage farmers to diversify their crops beyond traditional staples like wheat and rice. This can help mitigate risks associated with climate change, pests, and diseases, while also enhancing food security and farmer incomes.

Technology Adoption: Promote the adoption of modern agricultural technologies, including precision agriculture, genetically modified crops (GM), and digital farming solutions. This can improve productivity, reduce input costs, and enhance the resilience of the agricultural sector.

Access to Finance: Facilitate access to credit and financial services for smallholder farmers, especially women and marginalized communities. This can enable them to invest in modern inputs, machinery, and infrastructure, thereby boosting productivity and income levels.

Extension Services: Strengthen agricultural extension services to provide farmers with timely information, training, and technical support. This can improve agricultural practices, increase yields, and promote sustainable farming methods.

Market Access: Improve market infrastructure, transportation networks, and access to markets for farmers, particularly in remote and rural areas. Facilitate the establishment of farmer cooperatives and linkages with agribusinesses to ensure fair prices and market opportunities.

Climate Resilience: Develop and promote climate-resilient farming practices, including the adoption of drought-resistant crops, agroforestry, and soil conservation techniques. Invest in research and development to address climate change challenges facing the agricultural sector.

Policy Coordination: Enhance coordination among relevant government departments, agricultural institutions, research organizations, and stakeholders to ensure coherent policies, effective implementation, and monitoring of agricultural initiatives.

Capacity Building: Invest in human capital development by providing training, education, and skill-building programs for farmers, extension workers, and agricultural professionals. This can enhance productivity, innovation, and sustainability in the sector.

Legal and Regulatory Reforms: Review and update agricultural policies, laws, and regulations to create an enabling environment for investment, innovation, and sustainable development in the agricultural sector. Ensure transparency, accountability, and inclusiveness in policy-making processes.

GROUND WATER

Policy recommendations for groundwater management vary depending on the specific context, but here are some general recommendations that are often considered:

Monitoring and Assessment: Implement comprehensive monitoring and assessment programs to continuously monitor groundwater levels, quality, and usage patterns. This data can inform decision-making and identify areas of concern.

Regulation and Enforcement: Develop and enforce regulations to prevent over-extraction, contamination, and depletion of groundwater resources. This may include setting limits on extraction rates, establishing buffer zones around sensitive areas, and implementing penalties for non-compliance.

Stakeholder Engagement: Involve all stakeholders, including local communities, industries, farmers, and government agencies, in the decision-making process. Consultation and collaboration can lead to more effective and sustainable management strategies.

Water Conservation Measures: Promote water conservation measures to reduce demand on groundwater resources. This could include incentives for water-efficient technologies, public awareness campaigns, and regulations on water use in agriculture and industry.

Groundwater Recharge: Implement strategies to replenish groundwater supplies through artificial recharge methods such as rainwater harvesting, groundwater banking, and managed aquifer recharge. This can help offset the effects of over-extraction and natural depletion.

Land-Use Planning: Integrate groundwater considerations into land-use planning processes to minimize impacts on aquifers. Zoning regulations, land-use restrictions, and incentives for sustainable development practices can help protect groundwater resources.

Investment in Infrastructure: Invest in infrastructure for groundwater management, including monitoring networks, water treatment facilities, and alternative water sources such as desalination plants or recycled water systems. Adequate infrastructure is essential for sustainable water management.

Education and Capacity Building: Provide education and training programs for water managers, policymakers, and the public on the importance of groundwater conservation and sustainable management practices. Building awareness and capacity can foster a culture of responsible water stewardship.

Research and Innovation: Support research and innovation in groundwater management technologies and practices. This could include research into groundwater modeling, new extraction techniques, and sustainable irrigation methods to improve efficiency and reduce environmental impacts.

Integration with Surface Water Management: Recognize the interconnectedness of groundwater and surface water systems and develop integrated management approaches that consider both resources holistically. Coordinated management can help optimize water use and mitigate conflicts between different users.

INTEGRATION OF RAINWATER HARVESTING IN URBAN PLANNING

Incorporate rainwater harvesting provisions into building regulations and urban planning frameworks in Pakistan. This includes mandatory rainwater harvesting systems for new developments, particularly in public and private buildings, to significantly reduce urban flooding. Additionally, pilot projects should be implemented in urban spaces to demonstrate the effectiveness and feasibility of various rainwater harvesting techniques, such as rooftop harvesting, aquifer recharge, and green belt landscaping.

ESTABLISHMENT OF A WATER TECHNOLOGY PARK

Create a comprehensive Water Technology Park to serve as a hub for innovation, research, and commercialization of water-related technologies. This park should provide modern research facilities, testing grounds, and incubation services for startups and early-stage companies. By fostering collaboration among academia, industry, and government, the park will promote the development of indigenous technologies, reducing reliance on imported solutions and driving local innovation in water management.

MESSAGES FROM THE PARTNERS



Prof. Dr. Athar Hussain
Head Center for Climate Research and Development (CCRD),
COMSATS University Islamabad

Climate Intervention: Recent Progress in Pakistan

Climate intervention is defined as the changes made in the environment that tends to minimize the harmful effects of climate change. Examples include the plantation of trees that leads to reduction in amount of Carbon Dioxide in the Atmosphere. A grown-up tree absorbs around 20 Kg of Carbon Dioxide per year from the Atmosphere.

In another class of climate intervention called solar geoengineering, aerosols are injected into the stratosphere (20-25 Km up in the Atmosphere) to reflect a small fraction of incoming solar radiation. This will reduce the rising trend of the temperature at earth. It does not address the cause of global warming, namely, the reduction in Carbon Dioxide in the Atmosphere.

A research group at COMSATS University Islamabad is studying the impacts of solar geoengineering on climate of Pakistan. Since there is slight reduction in temperature, so the extreme weather events related to high temperatures are somewhat suppressed in Pakistan under the assumption of solar geoengineering.

Additionally, the precipitation is also somewhat further decreased, under solar geoengineering, over Pakistan, relative to climate change, in coming decades. Precipitation is a source of fresh water, which is the theme of this conference. The conference has provided a vital platform to integrate the multi-disciplinary information across Pakistan.



Dr. Salar Ali
Head, Department of Environmental Science
University of Baltistan, Skardu

The eighth International Water Conference (IWC) provides a crucial platform for global stakeholders to converge and address pressing issues related to water management, sustainability, and conservation. As we navigate through the complexities of water governance and management, it becomes increasingly apparent that collaborative efforts and innovative solutions are imperative to ensure water availability and quality for current generations.

In my view, the success of the conference depends on the promotion of interdisciplinary dialogue, the exploitation of technological advances and the integration of traditional knowledge systems to develop holistic approaches to water management. In addition, prioritizing inclusivity and equity in decision-making processes is key to addressing the needs of marginalized communities and vulnerable ecosystems.

As we embark on this collective journey, I am optimistic that the insights shared, and discussions held during the conference will catalyze actionable strategies and partnerships to safeguard our precious water resources.

I am grateful for the opportunity to contribute to such an important discourse and look forward to the outcome of the Eighth International Water Conference.

Thank you for your continued dedication to promoting dialogue and collaboration in the field of water resources.



Dr. Muhammad Rizwan
Assistant Professor
U.S. Pakistan Center for Advanced Studies in Water
Mehran University of Engineering and Technology
Jamshoro, Sindh

Dear Esteemed Colleagues and Participants,

As we conclude the 8th International Water Conference in Islamabad, held on March 6-7, 2024, I am honored to reflect on our profound discussions. Serving as a session chair has been immensely rewarding, and I am grateful for the opportunity to engage with such distinguished experts, policymakers, and innovators.

The theme, "Valuing Water for Sustainability," was vividly explored through key themes:

- **Tech for Tap: Leveraging Innovation to Secure Pakistan's Water Future**
We examined innovative technologies transforming water conservation and quality assurance.
- **Rainwater Harvesting to Manage Urban Flooding**
Strategies for mitigating urban flooding and enhancing water availability were shared, emphasizing the importance of integrating rainwater management into urban planning.
- **Climate Change Adaptability, Water Governance & GLOF**
Discussions focused on adaptive strategies, governance frameworks, and managing Glacial Lake Outburst Floods (GLOF), contributing to resilience against climate-induced water challenges.
- **Water Sanitation and Hygiene (WASH)**
The latest developments, challenges, and solutions in WASH were addressed, aiming to improve health outcomes and quality of life.
- **Water Productivity: Water, Energy, Food Nexus & Hydro Diplomacy**
We explored the interconnectedness of water, energy, and food production, and the role of hydro diplomacy in transboundary water management.

Thank you for your invaluable contributions and active participation. Together, we can secure a sustainable water future for Pakistan and the world.



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I am honored to present this message in recognition of the pivotal 8th International Water Conference titled "Valuing Water for Sustainability." This conference has brought together experts, academics, policymakers, and stakeholders from around the world to address one of the most pressing challenges of our time—water sustainability.

The conference has provided a platform for the exchange of innovative ideas and practical solutions essential for tackling Pakistan's water issues. The discussions have underscored the importance of collaborative efforts in valuing and conserving our precious water resources. The creation of a unified Topic Bank for water research projects is a testament to the collective dedication of the participants to identify and address major study areas and themes related to our water challenges.

Furthermore, the proposal to establish a networking platform for water stakeholders is a significant step forward. By connecting all parties involved in the water sector, this platform will foster the sharing of concepts, insights, and best practices, promoting cooperation and synergy in our fight against water-related problems. The emphasis on specific funding streams for water research, highlighted by the panelists, is crucial. Government funding organizations and venture capital firms are encouraged to support research and development projects, aiming to create regional solutions that will benefit our communities.

Lastly, the creation of a Water Technology Park represents a visionary step towards building a comprehensive ecosystem for water-related solutions. This park will serve as a hub for innovation, research, and commercialization, bringing together academics, entrepreneurs, and industry experts. By providing access to modern research facilities, incubation support, and fostering collaboration between government, business, and academia, the Water Technology Park will be instrumental in advancing our water sector.

I extend my heartfelt gratitude to the Institute of Public Policy, RIU and PCRWR for their unwavering support and dedication to organizing this conference. Their efforts have been instrumental in bringing together a diverse group of experts to address our water challenges. Together, we are paving the way for a sustainable water future for Pakistan.