Migration Letters
Volume: 21, No: S13 (2024), pp. 695-711
ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)
www.migrationletters.com

Drinking Water Contamination And Its Impacts On Water Quality And Public Health In Layyah, Pakistan

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ABSTRACT
The aim of the current study is to examine the impact of contaminated drinking water on human health and water quality in Layyah, Punjab (Pakistan). This research utilized both primary and secondary data to measure the impact of contaminated water on water quality and public health during 2016-2022. The data was collected from Public Health Authority (Punjab) and through a. structured questionnaire from 152 households by using snowball sampling technique. The current study applied Ordinary Least Square Method and Inverse [1]Distance Weighting (IDW) Analysis through GIS software to observe the relationship among selected variables. The findings of this study show that contaminated water had a significant negative impact on public health which creates such problems as hepatitis, asthma, kidney problems, cardiovascular complications, and waterborne diseases specifically cholera and typhoid. The study is intended to provide a comprehensive guide to address these issues, particularly emphasizing health-related concerns arising from uneven water consumption practices and the presence of pollutants in the local water supply. Further, this study also suggests the strategies to rectify the water crisis, ensuring access to clean and safe drinking water for the residents of this area.

Key Words: *Domestic Water Contamination, Waterborne Diseases, Water Quality Parameters.*

1. INTRODUCTION

Drinking water contamination is a significant global issue, with each country addressing it through unique strategies tailored to their specific challenges. In the United States, the Safe Drinking Water Act regulates pollutants such as lead and PFAS, with the Environmental Protection Agency (EPA) overseeing enforcement and updates to standards (EPA, 2023). Recent efforts focus on emerging contaminants to improve water safety (EPA, 2023). The European Union addresses water quality through the Drinking Water Directive, which sets strict standards for contaminants like nitrates and pesticides (European Commission, 2023). The European Food Safety Authority (EFSA) ensures compliance and monitors risks across member states (EFSA, 2023). India struggles with contamination from pathogens and heavy metals, with the Bureau of Indian Standards (BIS) setting norms and initiatives like the National Rural Drinking Water Program (NRDWP) aiming to improve safety despite

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infrastructure and enforcement challenges (Government of India, 2023). China deals with industrial pollutants and heavy metals through the Water Pollution Prevention and Control Action Plan and updated laws. These efforts include investments in treatment infrastructure and monitoring systems to address contamination (China Ministry of Ecology and Environment, 2023). In Brazil, issues such as untreated sewage and pesticide contamination affect rural and indigenous communities. The National Health Foundation (FUNASA) works on improving sanitation and monitoring water quality (FUNASA, 2023). South Africa faces pollution from mining and inadequate wastewater treatment. The Department of Water and Sanitation (DWS) enforces the National Water Act and works on upgrading treatment facilities and controlling pollution sources (DWS, 2023). Australia manages water quality with the Australian Drinking Water Guidelines, which set standards for contaminants like cyanobacterial toxins (NHMRC, 2023). Local utilities are responsible for maintaining these standards (Australian Government, 2023). Overall, while countries adopt varied approaches to manage drinking water contamination, international cooperation and knowledge sharing are crucial to improving water quality and ensuring safe drinking water globally.

In Pakistan, drinking water contamination poses a severe public health challenge, with various major cities grappling with different aspects of the problem. In Karachi, rapid urbanization and industrial activities contribute to significant contamination issues, including pollutants from untreated sewage and hazardous industrial waste. The Karachi Water and Sewerage Board (KWSB) is responsible for water quality, but frequent lapses in infrastructure and management have led to concerns about the safety of the water supply (KWSB, 2023). In Lahore, contamination from agricultural runoff, industrial discharge, and a high population density exacerbate water quality issues. The Lahore Development Authority (LDA) and Water and Sanitation Agency (WASA) are involved in efforts to improve water safety, but challenges persist due to aging infrastructure and pollution (WASA, 2023). Islamabad, while generally having better water quality compared to other cities, still faces challenges related to the contamination of its groundwater sources from nearby industrial and residential activities. The Capital Development Authority (CDA) manages water supply in Islamabad and works on maintaining higher standards of water quality (CDA, 2023). In Peshawar, the situation is complicated by both natural and anthropogenic factors, with contamination from agricultural practices and inadequate wastewater treatment. The Peshawar Development Authority (PDA) is tasked with addressing these issues, though infrastructure and resource limitations often hinder progress (PDA, 2023). In Quetta, the arid climate and limited water resources make contamination a pressing issue, with concerns about pollutants from agricultural runoff and insufficient water treatment facilities. The Quetta Municipal Corporation (QMC) is involved in efforts to enhance water quality and availability (QMC, 2023). Overall, while various cities in Pakistan are making strides to address drinking water contamination, challenges remain due to infrastructural limitations, rapid urbanization, and industrial pollution. Enhanced regulatory measures, improved infrastructure, and more effective management are crucial for ensuring safe and clean drinking water across the country.

This comprehensive study delves into the critical issue of water sustainability, focusing on Chowk Azam and elucidating the detrimental effects of industrialization, urbanization, and socio-economic activities on water quality. The study underscores the global challenges posed by natural impurities and contaminants, particularly arsenic, emphasizing the need for clean and safe drinking water to prevent diseases, especially among children. In Pakistan, a growing water shortage is exacerbated by industrial and domestic sewage discharge, highlighting the urgency for sustainable wastewater management and responsible water consumption. Socioeconomic factors such as housing structure, family size, financial conditions, and education levels significantly impact groundwater quality in the region. The study identifies education as a crucial factor in fostering responsible water consumption.

Linking water quality issues in the area to various health problems, the research outlines risks associated with pollutants like chlorine, calcium, magnesium, arsenic, and bacterial contamination. Data collection involves a comprehensive approach, combining primary data from surveys and secondary data from the Public Health Authority in Layyah. Analytical tools such as Arc GIS and SPSS process the data, creating parameters for comparing water quality against both WHO and Pakistan standards. The study concludes by emphasizing the urgent need to address the water crisis in Chowk Azam through strategic interventions considering local socio-economic factors. It proposes a framework for sustainable water use and contributes valuable insights to the broader discourse on water sustainability. This research serves as a crucial resource for policymakers, researchers, and community stakeholders working towards water quality improvement and public health in the area and similar regions facing water sustainability challenges. The statement of the problem highlights the escalating crisis of overconsumption and pollutant influx, resulting in severe challenges to the quality and quantity of drinking water. Socio-economic factors contribute to groundwater depletion and deteriorating water quality, exacerbated by a lack of awareness and responsible water usage practices. Routine activities and sewage injection further compound the problem, leading to elevated levels of pollutants exceeding safe limits. Urgent action is imperative, including comprehensive water treatment measures and stringent pollution control policies, to safeguard public health and ensure the sustainability of drinking water sources in Chowk Azam. The significance of the study lies in addressing the mismanagement of water resources, shedding light on imbalanced consumption patterns in Chowk Azam with far-reaching consequences on public health. The research aims to comprehensively assess water quality and quantity, identifying contaminants and evaluating their impact on human health. By setting local parameters and comparing water quality against international standards, the study initiates discussions on the urgent need for enhanced water resource management practices in this region.

2. METHODS AND MATERIALS

The data processing phase of the research involved several advanced tools to ensure a thorough analysis of the collected information. MS Excel was initially employed for data organization, providing a platform for preliminary data handling and basic analyses. However, a more sophisticated approach was required to fully understand the spatial dimensions of water quality issues in Chowk Azam. This led to the use of GIS software, specifically Arc GIS 10.8, which played a pivotal role in spatial analysis and mapping. A key component of the GIS analysis was the application of IDW analysis. IDW is a geo statistical interpolation method used to estimate values at unsampled locations based on the values from nearby sampled points. The principle behind IDW is that the influence of each point decreases with distance; thus, points closer to the location of interest have a greater impact on the estimated value than those further away. This method was particularly useful in creating spatial representations of water quality data across various locations in Chowk Azam.

In the context of this research, IDW analysis was used to interpolate and visualize critical water quality parameters such as contamination levels, pollutant concentrations, and variations in water quality across the region. The IDW technique allowed for the generation of detailed and accurate maps that illustrated how different water quality parameters were distributed spatially. These maps depicted areas with high levels of contamination and identified regions where water quality deviated significantly from acceptable standards. The application of IDW analysis provided several key benefits to the research. It enabled the creation of continuous surfaces of water quality parameters from discrete data points, offering a clearer view of spatial patterns and trends. By visualizing the severity of water quality issues in different areas, IDW analysis facilitated targeted interventions and resource allocation. For example, areas with higher concentrations of contaminants were easily identifiable, allowing for more focused and effective remediation efforts. Furthermore, IDW analysis helped in understanding the impact of socio-economic factors on water quality. By overlaying socio-economic data with the IDW-generated maps, the research could explore correlations between socio-economic conditions and water quality issues. This integration of spatial and socio-economic data provided a more comprehensive understanding of the factors influencing water quality in the region. In addition to GIS analysis, SPSS version 22 was employed for statistical analysis. SPSS facilitated the generation of descriptive statistics, which summarized the data, and annual comparison line graphs, which tracked changes over time and illustrated trends in water quality and public health. The combination of GIS spatial analysis and statistical techniques allowed for a multi-dimensional investigation of water quality, quantity, and their socio-economic and health impacts in Chowk Azam. This comprehensive approach ensured a robust and insightful analysis, leading to a better understanding of the water quality issues and informing effective strategies for improvement.

3. RESULTS AND DISCUSSION

3.1. Water Contamination and its Devastating Impacts

Chowk Azam, a region grappling with a myriad of challenges, confronts a severe water crisis that jeopardizes both human health and the sustainability of its water resources. Unsustainable practices and escalating levels of pollutants in drinking water have led to a surge in chronic health issues, including cancer, lung diseases, and hepatitis. These health concerns are directly linked to the deteriorating quality of water, exacerbated by factors such as overconsumption and the depletion of groundwater levels. The root causes of water contamination in the area are multifaceted. Socioeconomic activities, such as household cleaning, car washing, and industrial operations, introduce toxic materials and pollutants into the water supply. Additionally, inadequate infrastructure and a lack of awareness among the population perpetuate wasteful practices, further compromising water quality. The introduction of sewage into water sources exacerbates the problem, contributing to elevated levels of chlorine, calcium, magnesium, arsenic, total dissolved solids, and bacterial pollution. The predominant sources of water in the area, namely boreholes and tap water, are significantly impacted by contamination. Boreholes, which rely on groundwater extraction, are susceptible to pollutants seeping into the aquifers due to domestic activities (Lutterodt, 2018). Similarly, tap water distributed through motors faces contamination from various sources, prompting an urgent need for comprehensive water treatment and purification processes (Fernandez-Luqueno, 2013).

In response to these challenges, bottled water has emerged as a perceived safer alternative. However, concerns regarding the economic burden and environmental sustainability due to plastic waste generation persist (Parag, 2009). Some residents opt for water collection from a nearby canal filtration plant, presenting an alternative amid concerns over accessibility and associated costs (Liu, 2012).To address the water crisis in Chowk Azam, concerted efforts are needed at both local and global levels. Improved water treatment processes and stringent pollution control policies are imperative to safeguard public health and preserve water resource sustainability (Abdelrahman, 2011). Furthermore, community education and awareness programs are essential to promote responsible water usage and reduce contamination. By implementing sustainable and comprehensive solutions, the area can mitigate the devastating impacts of water contamination and ensure access to clean and safe drinking water for its residents.

3.2. Domestic Water Contamination and its Impacts on Water Quality

In Chowk Azam, a town grappling with a severe water crisis, domestic water consumption practices significantly contribute to the surge in waterborne diseases, posing a serious threat to public health (Gibson, 2014). The town, situated in a region already burdened with water scarcity, faces a grim reality where contaminated water sources become breeding grounds for pathogens, leading to the rampant spread of diseases. Realistically, inadequate sanitation and poor hygiene practices are prevalent, allowing waterborne diseases like cholera and typhoid fever to thrive due to the compromised quality of drinking water (Sharma, 2017). The issue extends to everyday activities in the town, where water used in kitchens for food preparation and cooking becomes a potential carrier of pathogens, resulting in a surge of food borne illnesses (Gil, 2014). Personal hygiene practices, often overlooked, contribute to the alarming spread of waterborne diseases such as gastroenteritis, as individuals unknowingly introduce pathogens into their bodies by using contaminated water for daily activities like hand washing and teeth brushing (Suthar, 2009). Bathing and showering, common practices in households, take an unexpected toll on public health as contaminants in the water, although not primarily transmitted through skin contact, can cause skin infections and other health issues. Additionally, accidental ingestion of contaminated water during bathing becomes a concern further exacerbating health risks (Wilkes, 2005). The use of contaminated water for cloth washing introduces pathogens onto clothing and linens, with added detergents contributing to water quality disturbances and potential health risks (Abney, 2021). In the context of inadequate waste management, improper disposal of human waste becomes a critical factor in water source contamination. Sewage infiltrates water supplies, contributing to the transmission of waterborne diseases, further highlighting the interconnectedness of sanitation and public health (Irda Sari, 2018). Wastewater discharge from domestic activities, often overlooked, introduces contaminants like soap, detergents, oils, and grease into water sources, perpetuating water quality challenges (Odigie, 2014). Flushing toilets, a routine activity, becomes a contributor to contamination as it introduces human waste and sewage into wastewater systems, impacting water bodies with harmful bacteria, viruses, and pathogens (Lamichhane, 2013). Chemical use in households, including cleaning agents, disinfectants, and pesticides, leads to the introduction of harmful chemicals into water sources, posing risks to both human health and water quality (Mukhopadhyay, 2022). The improper disposal of pharmaceuticals in Chowk Azam introduces pharmaceutical residues into water bodies, potentially harming human health when water sources are used for drinking (Dar, 2019).

In areas without access to centralized sewage treatment, septic systems become sources of contamination as they leach contaminants like bacteria, nutrients, and chemicals into groundwater, affecting surface water quality (Massoud, 2009). The use of fertilizers, pesticides, and herbicides in gardening and landscaping, a common practice in the community, contributes to the absorption of chemicals into groundwater, further disrupting public health and contributing to environmental challenges (Muratet, 2015). Car washing, a routine activity for many residents, releases pollutants into stormwater systems, impacting groundwater quality when used for drinking (Penzien, 2003). Improper disposal of hazardous waste materials, including batteries, paints, solvents, and electronics, contaminates groundwater and surface water sources, posing serious risks to both the environment and public health (Elbeshbishy, 2019). Sediment, debris, and construction chemicals from home renovations and construction activities wash into stormwater drains, causing sedimentation and pollution of water bodies (Jartun, 2008). Water-saving devices and plumbing system cross-connections, while introduced with good intentions for conservation, impact sewage treatment and water quality here, presenting challenges to both human health and environmental sustainability (Ali, 2020). The extensive use of detergents in various domestic activities, a reality in the community, contributes to water quality degradation, adversely affecting both surface and groundwater quality, and posing potential toxic effects on human health when consumed (Hasan, 2010).Addressing these complex challenges requires urgent and comprehensive measures to improve water quality, promote sustainable domestic water consumption practices, and safeguard public health in the area. In Chowk Azam, detergents, a staple in daily cleaning routines, wield a dual-edged impact on drinking water quality (Develter, 2010). Beyond their intended cleansing role, detergents intertwine with water sources, treatment processes, and public health (Hasan, 2010). Containing surfactants and phosphates, detergents contribute to nutrient pollution when absorbed in groundwater, posing risks to human health (Develter, 2010). The foaming tendencies of detergents disrupt water treatment processes, making it challenging to remove impurities (Petrovska, 2019). Excessive detergent levels overwhelm treatment processes, compromising drinking water quality (Hoko, 2005). Ingesting water with elevated detergent levels raises concerns about gastrointestinal diseases (Sankhla, 2016). Foam accumulation in water alters taste, odor, and appearance, emphasizing challenges in maintaining water quality (Ganidi, 2009). Effective water treatment and responsible detergent use are crucial to mitigate these challenges (Petrovska, 2019).

3.3 Reasons behind the Water Contamination

In Chowk Azam, the interplay between socioeconomic factors and human behavioral patterns profoundly influences the quality of water and the overall health of the community. Socioeconomic status often dictates access to clean water and sanitation facilities, with wealthier areas typically enjoying better infrastructure and waste management systems (Mosimane, 2020). Conversely, marginalized communities like this area face significant challenges due to inadequate infrastructure and limited access to clean water sources, exacerbating the risk of waterborne diseases and contamination (Zhang, 2010). Moreover, economic activities play a pivotal role in water quality dynamics. Industries and agricultural practices, particularly in wealthier areas, can impact water quality through the discharge of pollutants and chemicals into water bodies. While larger industries may adopt more environmentally friendly practices, smaller operations near the area might be less inclined to do so, contributing to contamination risks (Hasan, 2019). On the other hand, human behavioral patterns also significantly shape water quality in the town. Improper waste disposal practices, such as dumping chemicals down drains or littering, introduce pollutants into groundwater, posing serious health risks (Gupta, 2007). Additionally, the use of fertilizers and pesticides in gardens and lawns can lead to chemical runoff, further contaminating water sources and disrupting ecosystems (Meftaul, 2020). Behavioral patterns related to water usage and hygiene practices also impact water quality. Excessive domestic water use and poor hygiene habits increase the risk of contamination, particularly in areas with inadequate sanitation facilities (Edessa, 2017). Lack of awareness and education about water quality issues further exacerbates the problem, as many individuals may not understand the potential health risks associated with contaminated water sources (Adaman, 2009). Addressing these complex challenges requires a multifaceted approach. Equitable access to resources and infrastructure development are crucial for ensuring clean water access for all residents of Chowk Azam. Education and awareness campaigns can help inform the community about the importance of proper waste disposal, water conservation and hygiene practices, empowering individuals to take responsibility for protecting water quality (Seelen, 2019). Additionally, implementing regulations and enforcement mechanisms to control industrial and agricultural pollution is essential for safeguarding water resources in the region. By addressing both socioeconomic factors and human behavior, this town can work towards improving water quality and ensuring the health and well-being of its residents.

a. The Effects of Water Contamination and Overuse

In Chowk Azam, water contamination and overuse have profound implications for public health and the sustainability of groundwater resources.

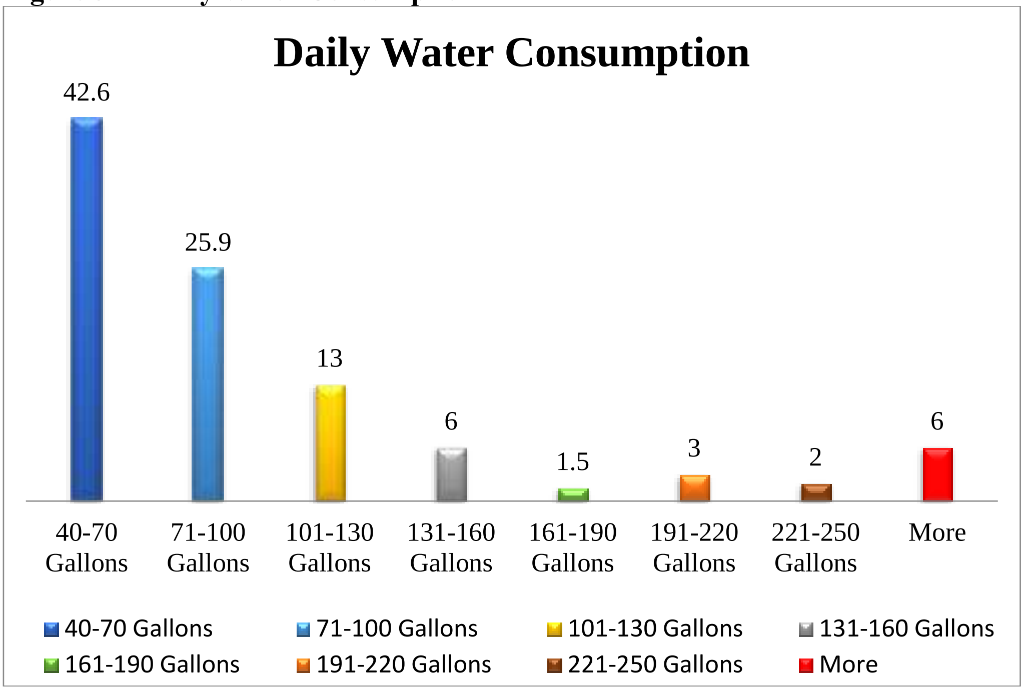
3.4.1. Effects of Water Contamination on Public Health

Waterborne diseases pose a significant threat to public health in Chowk Azam, where inadequate sanitation and poor water quality control contribute to illnesses caused by pathogenic microorganisms (Qiu, 2022). Common waterborne diseases include cholera, typhoid fever, and hepatitis A, with disturbances in drinking water quality increasing the risk of gastrointestinal infections (Alsalme, 2021). Contaminated water sources lead to a variety of health issues, including skin infections, cancer risks, cardiovascular problems, liver diseases, hypertension, and gastrointestinal discomfort (Arnone, 2007; Holm, 2010; Azizullah, 2011; Edzwald, 2011; WHO, 2010). High sodium content in water contributes to hypertension, while chemical contaminants like lead and arsenic elevate cancer risks and liver-related problems (WHO, 2010). Addressing water quality challenges in the area requires a comprehensive strategy, including improving water treatment processes, reducing contamination sources, and implementing broader public health interventions (Omarova, 2021; WHO, 2017). Ensuring safe and clean drinking water is crucial for preventing and mitigating the impact of waterborne diseases on the community's well-being.

3.4.2. Effects of Water Overuse on Groundwater Level

The over-usage of water in Chowk Azam is causing a gradual lowering of the groundwater table, triggering adverse effects on the local ecosystem, infrastructure, and water supply (Zhong, 2009). This leads to increased pumping costs as deeper wells and boreholes require more energy for water extraction (Nas, 2006; Steward, 2013).Moreover, continuous over-extraction raises long-term sustainability concerns, casting doubt on the viability of water resources in the area (Fishman, 2011).

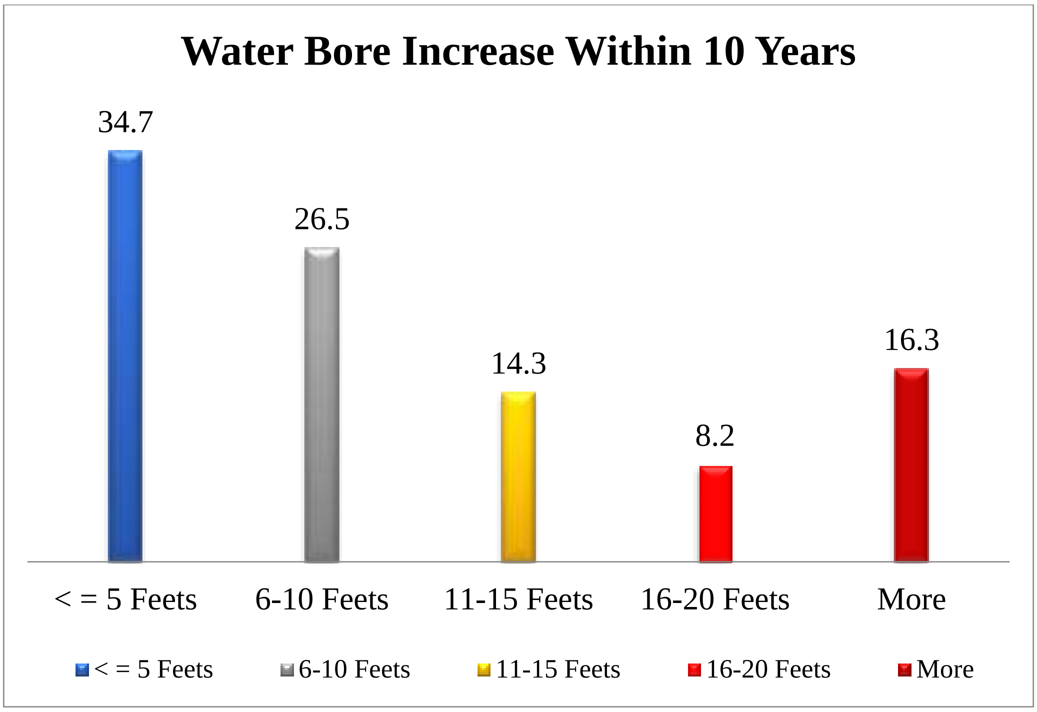
Figure 3.1: Daily Water Consumption



Source: Author, 2023

Sustainable groundwater management practices are imperative, including vigilant monitoring and regulation of extraction, promoting water conservation and exploring alternative water sources (Qureshi, 2010). Balancing water extraction with recharge and fostering conservation are essential steps to minimize the environmental, economic, and social consequences associated with excessive groundwater depletion (Qureshi, 2010). Preserving groundwater resources is crucial for ensuring their availability for both current and future generations.

Figure 3.2: Water Bore Increase



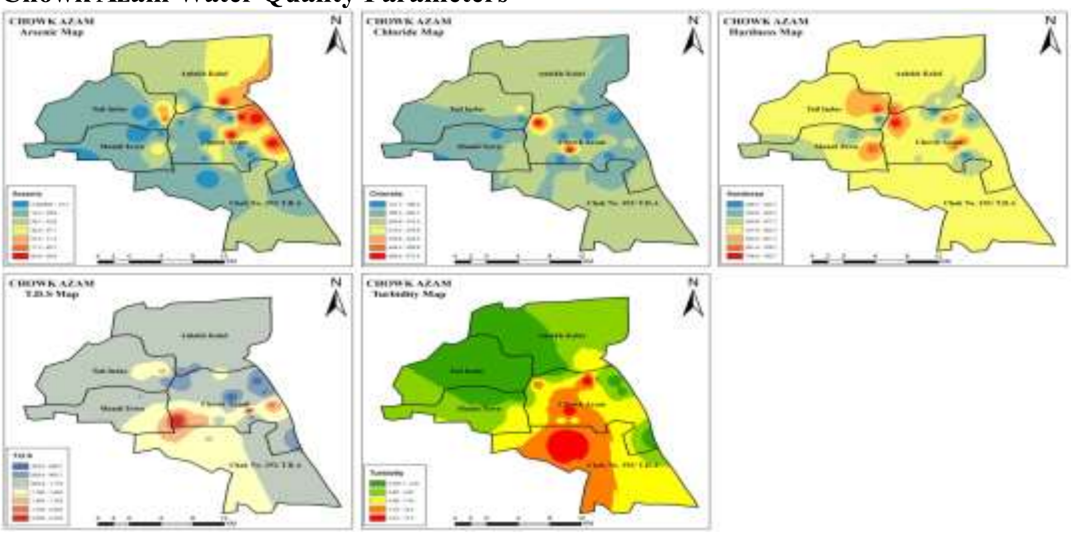
Source: Author, 2023

In short, addressing both water contamination and overuse in the area requires concerted efforts to safeguard public health and ensure the sustainability of groundwater resources. Implementing effective management strategies and promoting responsible water use practices are essential for mitigating the adverse impacts on both human well-being and the environment.

3.5. Assessing the Spatial Distribution and Impacts of Drinking Water Contamination on Water Quality in Chowk Azam

In Chowk Azam, drinking water quality is a pressing issue affecting public health and the environment. This study delves into the spatial distribution of contamination and its impact on water quality parameters. By comprehensively analyzing these factors, we aim to understand and address the challenges posed by water contamination in the town.

Chowk Azam Water Quality Parameters



Source: Author: 2023

3.5.1. Unraveling Turbidity Challenges and Temporal Trends

The investigation into drinking water contamination in Chowk Azam highlights the pressing issue of turbidity, a measure of water's cloudiness or clarity influenced by suspended solids. Elevated turbidity levels, ranging from 7.3 to 17.3 in central areas and UC Chak No. 393 TDA, surpass recommended values, posing health risks due to increased waterborne pathogens (APHA, 2005; MRBDC, 2008). Health challenges such as waterborne diseases and gastroenteritis are prevalent among residents (Mann, 2007). While low turbidity indicates water safety, its impact on microorganism removal awaits comprehensive demonstration (Hrudey and Hrudey, 2004; Health Canada, 2012). Global perspectives underscore the urgency of comprehensive water quality management, with instances of higher turbidity associated with chronic health risks (Mebrahtu, 2011). Moreover, turbidity contributes to mosquito proliferation, exacerbating malaria risks (Paaijmans, 2008). Temporal analysis reveals fluctuating turbidity trends in Chowk Azam, with a notable surge in 2018 attributed to domestic water consumption activities and sewage system issues (Public Health Authority Layyah, 2022). These findings underscore the need for proactive measures, comprehensive water treatment processes, and vigilant monitoring to safeguard community well-being and water resource sustainability.

3.5.2. Total Dissolved Solids (TDS): Spatial Distribution and Temporal Trends

Beyond turbidity, the assessment of water quality in the town includes a thorough examination of Total Dissolved Solids (TDS), a crucial parameter affecting taste, appearance, and plumbing systems. TDS encompasses minerals dissolved in water, with acceptable levels for drinking water set between 80 to 1000 mg/l (PHA, 2012). Chowk Azam faces challenges with elevated TDS levels, particularly in the connecting region of Mandi Town and Chak No. 393 TDA, where some northern areas experience levels ranging from 1730 to 2280, surpassing recommended values (PHA Layyah, 2022). These high TDS levels pose health risks, with associations found between elevated TDS and various health issues such as sudden death, neurological diseases, pregnancy complications, infant mortality, and cancers (WHO, 2005). Furthermore, research indicates links between soft water (low in calcium) and increased risks of childhood fractures, neurological illnesses, preterm birth, low birth weight, and cancers (WHO, 2005). The prevalence of waterborne diseases like diarrhea and cholera in the area underscores the urgent need for comprehensive water management strategies. Temporal analysis reveals fluctuating trends in TDS contamination, with percentages exceeding recommended values in various years, attributed to domestic water consumption activities and disturbances in the underground sewage system. Notably, contamination percentages surged to 30% in 2022, highlighting the ongoing challenges in maintaining safe drinking water quality in Chowk Azam. The comprehensive analysis of TDS in the area's drinking water underscores the necessity for immediate action. Collaborative efforts are essential to mitigate the adverse health effects associated with elevated TDS levels and ensure the well-being of the community.

3.5.3. Unraveling the Impact of Water Hardness: Spatial Distribution and Temporal Trends

This exploration delves into the critical parameter of Total Hardness to understand water quality challenges in Chowk Azam comprehensively. Total Hardness, measured in mg/l of Calcium Carbonate (CACO3), signifies the mineral content crucial for determining water's fitness for consumption. The IDW hardness map reveals areas grappling with heightened levels, particularly in the area, Aulakh Kalan, Tail Indus, Mandi Town, and Eastern areas, where hardness exceeds the recommended value of 500 mg/l.Elevated water hardness in Chowk Azam is associated with various health issues, including cardiovascular diseases, growth retardation, reproductive issues, and kidney problems. Studies link hard water consumption to blood pressure problems, skin issues, diarrhea, typhoid, E. coli infections, cancer, heart problems, liver problems, hypertension, stomach problems, breathing difficulties, and gastrointestinal problems. Analyzing temporal trends reveals fluctuations in water hardness levels, with contamination percentages reaching 8.75% in 2017 and escalating to 20% in 2022 due to uneven domestic water utilization and disturbances in the underground sewage system (PHA Layyah & THQ Chowk Azam, 2022). The exploration into water hardness underscores the urgency for intervention and collaborative efforts to address the root causes. Strategies for water quality improvement and education on water consumption practices are vital to ensure the well-being of the community and counter the challenges posed by hard water in the town.

3.5.4. Impact of Chloride Contamination on Drinking Water Quality: Spatial Distribution and Temporal Trends

This segment focuses on chlorides, a significant aspect influencing water potability, in the area. Chlorides, measured in mg/l, serve as indicators of water quality, with acceptable levels set below 250 mg/l. Elevated levels can impart a salty taste to water and may indicate potential wastewater contamination. While chlorides themselves pose no direct threat to health, sodium chloride, commonly found in table salt, has been linked to kidney and heart diseases at higher concentrations. The IDW Chloride map reveals specific areas in Chowk Azam grappling with heightened chloride levels, with Northern and Central locations facing levels exceeding 250 mg/l. The presence of chlorides is associated with breathing problems and cancer in the area, adding to the community's health challenges. Analyzing temporal trends from 2015 to 2022 exposes fluctuations in chloride levels, with contamination percentages reaching 8.2% in 2019 (Progress Reports PHA Layyah, 2022). However, improvements were observed in subsequent years, with chloride levels reaching 0% in 2022 due to interventions like the pavement of the urban sewage system, signaling positive strides in water quality. Understanding the dynamics of chloride contamination in this area's drinking water is pivotal for devising effective mitigation strategies. Collaboration between local authorities, communities, and health agencies is imperative to implement sustainable measures, ensuring a healthier, safer water supply for residents.

3.5.5. Unmasking the Threat of Arsenic Contamination: Spatial Distribution and Temporal Trends

This segment delves into arsenic contamination in Chowk Azam's drinking water, a pervasive issue with significant health implications. Arsenic, considered a pollutant when exceeding 50 parts per billion (ppb), poses health risks including skin issues, gastrointestinal problems, cardiovascular disorders, and cancer. Children are particularly vulnerable to its effects. The area grapples with arsenic contamination, impacting residents' health due to socioeconomic activities contributing to elevated levels. The IDW Arsenic map highlights areas with alarming arsenic levels, with eastern regions facing the highest contamination. Temporal trends from 2015 to 2022 reveal fluctuating arsenic levels, with contamination percentages peaking at 1.7% in 2017 (PHA Layyah, 2022). Challenges persisted into subsequent years but showed promise in 2022 with 0% arsenic contamination, indicating potential progress in mitigation efforts. Addressing arsenic contamination demands collaboration among local authorities, communities, and health agencies. Strategies involving regular monitoring, public awareness, and infrastructure improvements are crucial for ensuring a safer water supply for the area's residents.

3.5.6. Unveiling the Menace of Bacterial Pollution: Spatial Distribution and Temporal Trends

This segment delves into the escalating threat of bacterial contamination in Chowk Azam's drinking water, spotlighting total coliforms, E. coli, and their impact on human health. Bacterial pollution presents a significant challenge, demanding a zero-tolerance standard, yet the area grapples with various types of bacterial contamination, including total coli forms and E. coli, which are indicative of fecal matter contamination. Socioeconomic activities significantly contribute to heightened bacterial pollution, leading to severe health issues such as gastroenteritis, dysentery, and viral hepatitis, with children particularly vulnerable to these health risks. Mapping reveals alarming concentrations in eastern regions, particularly Aulakh Kalan, where bacterial pollution levels exceed acceptable limits, necessitating immediate action and intervention. Temporal trends from 2015 to 2022 show fluctuating levels of bacterial contamination, with challenges peaking in 2018 due to domestic water consumption and sewage system issues. While progress was noted in 2020, with a reduction in contamination levels, the stagnation observed in 2021 and 2022 underscores the urgent need for concerted efforts to curb pollution and ensure water safety in the area. Collaborative initiatives, rigorous water quality monitoring, sewage system improvements and community awareness campaigns are vital components of addressing bacterial pollution and safeguarding public health in the town.

3.6. Ensuring Clean Drinking Water in Chowk Azam: A Comprehensive Annual Analysis against WHO and Pakistan Standards

The provision of clean drinking water is a fundamental right, and yet, many regions face significant challenges in maintaining water quality. Chowk Azam, strategically located at the heart of Pakistan, grapples with a severe water quality crisis. This article delves into an annual analysis of water quality from 2016 to 2022, comparing the standards set by the World Health Organization (WHO) and the Pakistan Standard Quality Control Authority. The WHO, recognizing the critical importance of clean drinking water, has established stringent guidelines based on scientific research and epidemiological findings. These guidelines serve as a beacon for nations worldwide. However, countries, including Pakistan, also develop their own water quality standards to cater to unique economic, technical, social, and political considerations. Water, a precious gift from nature, is facing unprecedented threats to its quality and quantity. Domestic water consumption activities play a pivotal role in disturbing the sustainability and purity of water sources. The area is no exception, experiencing disruptions in its water quality due to these activities, rendering the water unfit for consumption.

The area, often regarded as a transportation hub due to its central location in Pakistan, has witnessed a gradual decline in water quality over the years. The lack of access to safe drinking water has given rise to prevalent diseases such as hepatitis A and gastroenteritis in the city. The contamination culprits include arsenic, bacterial pollution, and Total Dissolved Solids (TDS), stemming from the uneven utilization of water sources and domestic activities. Reports of water quality concerns in the area date back to before 2016, with the uneven utilization of water through domestic activities identified as a major cause of contamination. To monitor water quality, numerous samples were collected through the Public Health Authority Layyah. The overall assessment of drinking water in Chowk Azam was disheartening, indicating a pressing need for intervention.

Water Quality Contamination of Chowk Azam in 2016-22

Sr.	Parameters	WHO Standards	Pakistan Standards	% in 2016	% in 2017	% in 2018	% in 2019	% in 2020	% in 2021	% in 2022
1	Turbidity	5 NTU	5 NTU	-	-	6.9	8	6.17	5	7
2	TDS	< 1000	< 1000	12	13.83	11.8	19.15	18.55	20	30
3	Calcium	200	200	-	-	0.74	0.5	-	-	-
4	Magnesium	150	150	-	-	0.74	0.5	-	-	-
5	Total Hardness	< 500	< 500	-	8.75	6.15	8.2	7.7	8.67	20
6	Chloride	250	< 250	-	6	6.9	8.2	9.5	10	-
7	Arsenic	10	≤50	4.75	1.7	1	1.5	1.35	2.34	-

8	Bacterial Pollution	Must be zero in 100 ml sample	Must be zero in 100 ml sample	7	10.14	11.6	12	6.33	7	7

Source: Public Health Authority Layyah 2022

Drinking Water Quality (2016-2022)

From 2016 to 2022, the assessment of drinking water quality in Chowk Azam according to Public Health Authority (PHA) Layyah's progress report consistently revealed alarming contamination levels, raising significant concerns about the safety of the water for human consumption. In 2016, the analysis indicated that 7% of water samples were tainted by Coli structures, E. coli, and bacteria. Additionally, 12% of the water sources had excessive Total Dissolved Solids (TDS), and 4.75% of tests showed arsenic concentrations exceeding permissible values. In 2017, contamination levels worsened, with 10.14% of water samples showing contamination by Coli structures, E. coli, and other microorganisms. TDS concentrations surpassed acceptable limits in 13.83% of tests. The year also saw reports of excessive hardness, chloride levels, and arsenic concentrations in the water.

By 2018, bacterial pollution had further increased, with 11.6% of samples exceeding acceptable limits. This year highlighted the urgent need for coordinated efforts and increased attention to address water quality issues. In 2019, bacterial contamination reached 12% of the water samples. The year also saw elevated levels of TDS, turbidity, and other contaminants, emphasizing the need for comprehensive measures to improve water quality. The situation continued to deteriorate in 2020, with bacteria, E. coli, and other Coli forms present in 16.33% of water samples. The year also experienced higher TDS concentrations, excessive turbidity, and elevated chloride levels, which raised significant concerns. In 2021, 5% of water samples exceeded acceptable turbidity levels, and a substantial 20% revealed elevated TDS concentrations. Additionally, increased levels of hardness, chlorides, arsenic, and bacterial pollution further added to the water quality concerns. By 2022, the situation had reached a critical point, with 17% of samples contaminated with bacteria and Coli forms. The bacterial pollution levels surpassed WHO-set limits, indicating heightened microbiological risks. Moreover, 30% of samples exhibited higher TDS than recommended standards, and 20% displayed excessive hardness.

These persistently elevated contamination levels underscore the urgent need for sustained monitoring, collaborative efforts, and targeted interventions to secure a safe and reliable drinking water supply for the residents of Chowk Azam. The percentages each year emphasize the ongoing challenges faced by the community and the necessity for decisive actions to mitigate water quality issues. Addressing these persistent challenges requires concerted efforts from local authorities, environmental agencies, and the community. A comprehensive strategy involving regular monitoring, targeted interventions and community education is essential to ensure that the residents of the area have access to safe and clean drinking water. The findings underscore the urgency of sustained initiatives to alleviate the longstanding water quality concerns in this community.

4. CONCLUSIONS AND POLICY RECOMMENDATIONS

This comprehensive research highlights the urgent global issue of water contamination, with a specific focus on the multifaceted challenges encountered in the area around Chowk Azam, Pakistan. It underscores the severe repercussions of inadequate access to clean drinking water, critically impacting human health, particularly in developing regions such as this one. The study thoroughly examines the diverse causes of water pollution affecting the region, including domestic practices, socioeconomic factors, excessive water usage, improper detergent application, and insufficient sewage treatment. Each of these factors plays a significant role in the deterioration of water quality. For instance, domestic activities, such as unregulated disposal of household waste and lack of proper sanitation facilities, significantly contribute to the contamination of water sources. Socioeconomic

factors, including housing conditions, family size, financial status, and education levels, further exacerbate these issues. Poorly constructed housing and inadequate financial resources often lead to insufficient infrastructure for water and sewage management, while lower education levels may result in a lack of awareness about safe water practices.
The health risks associated with consuming contaminated water are a major concern. The research identifies several pollutants, including chlorine, calcium, magnesium, arsenic, total dissolved solids (TDS), and bacteria, which are prevalent in the water supply of the region. The presence of these contaminants is linked to a range of serious health issues, from gastrointestinal diseases to chronic conditions such as kidney damage and cancer. For example, high levels of arsenic in drinking water are known to be carcinogenic, while excessive calcium and magnesium can contribute to the formation of kidney stones. The study highlights how these pollutants pose substantial threats not only to individual health but also to public health at large, exacerbating existing health disparities and burdening the local healthcare system.
The research methodology is robust and detailed, incorporating both primary and secondary data to provide a comprehensive analysis of the water quality issues in the area. Primary data was collected through a carefully designed survey administered via Google Forms. This survey explored various aspects of daily life, including socio-economic conditions, family structure, housing quality, financial status, educational background, daily water consumption practices, and related health impacts. This extensive data collection aimed to understand how these factors interrelate and affect water quality. Secondary data was sourced from authoritative reports provided by the Public Health Authority Layyah and THQ reports from the region. These reports supplemented the primary data with historical context and additional insights into local water quality trends and public health statistics.
Data analysis was conducted using advanced tools to ensure accurate and meaningful results. MS Excel was utilized for initial data organization and basic statistical analysis. For spatial analysis and mapping, Arc GIS 10.8 was employed, with a particular focus on IDW analysis. IDW is a geo statistical technique that estimates water quality parameters at unsampled locations based on data from nearby sampled points, weighted by their distance from the target location. This method allowed for the creation of detailed maps illustrating the distribution and severity of various water quality parameters across the study area. These visualizations helped identify regions with higher contamination levels and provided insights into spatial patterns of water quality issues.
Further statistical analysis was performed using SPSS version 22, which facilitated the generation of descriptive statistics and annual comparison line graphs. These tools were instrumental in tracking changes over time and assessing trends in water quality and public health. The combination of GIS spatial analysis and statistical techniques provided a comprehensive view of the water quality issues and their socio-economic impacts.
In conclusion, this research offers valuable insights into the complex interplay between water quality, socioeconomic factors, and public health in the region surrounding Chowk Azam. It underscores the need for effective and sustainable solutions to address water contamination and improve water management practices. The findings advocate for modern, water-efficient technologies and strategies to enhance water quality and ensure safe drinking water. By addressing both immediate and long-term challenges, the research aims to promote a healthier and more sustainable future for the communities affected by water contamination. The study highlights the importance of concerted efforts at both local and global levels to tackle water crises and safeguard public health.

Declarations

1. Ethical Approval

Ethics approval was not required for this study.

2. Funding Source

The author did not receive support from any organization for this study.

3. Competing Interest/Conflicts of Interest

The author declare no competing interests.

4. Availability of Data and Material

The data and material that support the findings of this study are available from the author upon reasonable request.

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