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IMPACT OF WATERBORNE CONTAMINANTS ON PUBLIC HEALTH IN RURAL AREAS: A STUDY IN FAISALABAD, PAKISTAN

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Abstract

The current study is aimed at assessing the effects of water contamination with different chemicals on human health in rural areas of Faisalabad, Pakistan. For these purposes, groundwater samples were collected from several locations and analyzed for physico-chemical, heavy metal, and microbiological properties. As shown in results, the levels of total dissolved solids and electrical conductivity in most samples were considerably higher than recommended values, which suggests poor water quality. Regarding the concentration of heavy metals in tested water samples, there was also a significant amount of arsenic and lead detected in the areas adjacent to industrial activities, which demonstrates an important anthropogenic impact on water. Besides, there is also evidence for high contamination with various pathogens as all analyzed water samples had levels of coliforms exceeding safety limits and 97.7 percent of samples contained pathogenic Escherichia coli. Health risk assessment shows that children face a greater threat when using contaminated water with hazard quotient values being above safe levels in several areas. Furthermore, the carcinogenic risk associated with arsenic exposure was also higher than recommended values in all studied locations. There is a significant association between microbial contamination of water sources and incidence of typhoid and diarrhea among inhabitants.

Keywords: Water contamination, Groundwater quality, Health risk assessment, Rural public health

1 Introduction

Safe and potable drinking water is a basic requirement for sustaining life, yet water pollution poses a serious challenge to environmental protection and human health globally. This challenge is especially grave in underdeveloped nations, where the burgeoning population and uncontrolled urbanization, coupled with an absence of proper facilities, strain the supply of fresh water(Dr. Amit Krishan et al., 2023). Consumption of polluted drinking water is one of the main reasons for the spread of diseases and exposure to hazardous materials, which in turn result in global disease burden and fatalities. For the residents in rural areas, who have no access to central water treatment facilities, the only available source of water is the ground water, which is vulnerable to pollution(Fawell & Nieuwenhuijsen, 2003). In Pakistan, the problem is exacerbated by extensive farming, waste dumping, and effluent discharge from industries.

The outskirts of Faisalabad offer an important example of areas where industries and agriculture overlap and, thus, become sources of pollution of the water body. The city of Faisalabad is well-known for its textile industry and manufacturing operations, whereby effluent wastewater that contains harmful metals and chemicals is disposed of into the surroundings with little treatment(Ensink et al., 2004). In addition, the widespread application of pesticides and fertilizers in agriculture results in the discharge of nitrates and other chemicals from the landfills into the groundwater supply. Poorly engineered sanitation facilities that are found in the area, such as poorly built septic tanks and open disposal methods, also encourage the contamination of the water sources with various pathogens. Therefore, the rural areas' water supply becomes polluted by a wide variety of pollutants like arsenic, lead, nitrates, and fecal coliforms(Srivastav, 2020).

Such contaminants pose great danger to the health of the local community. Heavy metals such as arsenic and lead have been shown to be toxic and carcinogenic, causing skin problems, brain damage, and even cancers. Increased concentrations of nitrate in water supplies may result in illnesses such as methemoglobinemia, especially in infants. Microbial contaminants are responsible for diseases caused by water supplies, including diarrhea, typhoid, and hepatitis. The negative effects on health are more severe in rural areas since there are few health facilities and lack of awareness regarding proper practices for safe water. In addition, there are no water treatment facilities. Therefore, poor water quality not only causes health hazards but also poses socio-economic implications(Budi et al., 2024).

While there have been increasing concerns about groundwater contamination in recent times, the current state of research within the Pakistani territory has a few limitations. To begin with, most previous studies have concentrated solely on assessing physicochemical characteristics or identifying pollutants without incorporating information regarding microorganisms and health data. Besides, most of the conducted studies have covered only urban or semi-urban areas, failing to consider those residing in rural regions (Batool et al., 2015).. Moreover, the lack of comprehensive research combining environmental testing with epidemiology is notable; thus, proving the correlation between water quality and adverse health effects on residents is impossible(Raza et al., 2017). It should be noted that studies applying quantitative risk assessment models, such as hazard quotient and cancer risk during one's lifetime, are not numerous. As a result, the link between pollutant concentration and risks to human health cannot be clearly established. Therefore, there appears to be a substantial gap in research in the area where several contamination sources exist, especially in Faisalabad region(Clewell et al., 2002).

Under such circumstances, the purpose of this current study is to conduct an exhaustive examination of the effect of water pollution on the health of people residing in the rural areas of Faisalabad using an interdisciplinary and integrative approach. This will involve a comprehensive study of the quality of groundwater based on the assessment of its physiochemical properties, presence of heavy metals, and microbial contamination, among other aspects. Furthermore, efforts will be made to establish the cause of pollution in terms of the effects of industries, agriculture, and poor sanitation, while also establishing the connection between the quality of water and waterborne diseases among the local population. Another important part of this study involves quantifying the risk factors for non-carcinogenic and carcinogenic diseases that arise as a result of water contamination, following guidelines set out by the WHO and US EPA.

Through these objectives, this study is designed to help bridge the current knowledge gap on the relationship between environmental pollution and the health of individuals through an analysis that will be conducted in the rural area. This research is anticipated to contribute to the scientific literature that could assist policymakers and health organizations to develop specific programs and water management policies that would be useful to sustainably solve the issue of water quality in relation to human health problems.

2 Literature Review

Waterborne contamination has been identified as one of the most pressing environmental and health problems, especially in developing nations, which lack sufficient amounts of clean drinking water. Based on information from the World Health Organization, a large number of people rely on contaminated water sources for their daily requirements, causing an upsurge in waterborne illnesses. In South Asia, countries such as Pakistan use underground water reserves as their main source of drinking water in rural communities; however, these reserves are becoming more vulnerable to contamination caused by natural factors as well as human intervention. A growing body of research has confirmed the dangers posed by metal contamination, nutrient pollution, and microorganisms in groundwater sources(Sathre et al., 2022).

Groundwater contamination by heavy metals has been widely researched due to their non-biodegradable nature, their toxicity, and the bioaccumulation phenomenon in living organisms. The contamination of groundwater by arsenic (As) has been identified as the biggest environmental health hazard in South Asia, where prolonged exposure leads to conditions such as skin lesions, cardiovascular illnesses, and various types of cancer(Singh et al., 2022). Likewise, exposure to lead (Pb) causes damage to the nervous system, mainly among children, whereas cadmium (Cd) causes kidney dysfunction and osteotoxicity. In Pakistan, various research studies have shown that the concentration of heavy metals is quite high in the groundwater within the country, specifically in the regions of Faisalabad where the sources of pollution include industrial effluents and textile waste(Talib et al., 2019).

Apart from chemical pollution, microbial contamination of drinking water in the rural areas is another serious problem. The detection of fecal coliforms such as *E. coli* is considered a good indication of pathogen presence. Consumption of water contaminated by microbes causes the outbreak of several diseases including diarrhea, cholera, and typhoid. Microbial contamination of groundwater occurs due to improper sanitation facilities in Pakistan, defecation in open areas, and leakages from sewage systems. Several studies performed on the contamination of water in rural areas of Punjab have found high numbers of coliform bacteria, sometimes exceeding safe limits(Khan et al., 2013).

Nutrient pollution, especially nitrate pollution, can also be mentioned as one of the significant concerns related to agricultural activities. As a result of the heavy usage of nitrogen fertilizers, nitrates get mixed in the groundwater because the water flows easily in soil having high permeability. The higher concentration of nitrates in groundwater results in the development of methemoglobinemia disease in infants. In agricultural areas adjacent to Faisalabad, the nitrate level in the groundwater has surpassed the limit due to intense agriculture activity(El Messaoudi et al., 2026).

Although a significant number of studies exist regarding individual pollutants, a major drawback in the current body of research is the absence of any holistic approach to integrate physicochemical, microbiological, and health-based data. Most research conducted in Pakistan has been either related to water quality testing or health effects, but no study has been able to establish a correlation between pollution and its health effect. Additionally, very little use has been made of quantitative health risk assessment techniques like hazard quotient (HQ) and carcinogenic risk (CR). According to USEPA, both these techniques should be adopted for health risk quantification of individual pollutants (Liu et al., 2013).

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Current studies stress the significance of multidisciplinary approaches where environmental monitoring and analysis are combined with health data to get a better understanding of the effects of water contamination. Methods like Principal Component Analysis (PCA) have frequently been used to determine the source of water pollution and assess the impact of various factors on water degradation. Furthermore, other research in the same area of study has underlined the importance of integrating the assessment of water quality with community health status. Still, there is no such study in Pakistan, especially rural industrial-agricultural communities such as Faisalabad(Howard et al., 2003).

To conclude, current literature proves that water contamination with heavy metals, excess nutrients, and microbiological pollutants can cause great harm to people's health and safety. Yet, there is a need for an integrative approach to studying this phenomenon by considering specific locations and assessing their environmental and health conditions in conjunction with one another.

3 Materials and Methods

3.1 Study Area Description

This study was carried out in the rural areas around Faisalabad, a city that serves as the link between industry and agriculture in the Punjab province. The rural sites chosen for this study mainly depend upon groundwater as a source of water supply for household purposes. This area is at risk of pollution because of its vicinity to the textile industry, agricultural pollution, and lack of proper sanitary facilities. The weather conditions prevailing in this area are semi-arid.

3.2 Sampling Strategy and Collection

A total of 40-60 samples of water was obtained from different villages to get sufficient spatial coverage of samples. Sampling sites consisted of hand pumps, tube wells, and open wells where available. Sample collection procedures were based on the set of standard guidelines issued by WHO and APHA. Water samples were collected in clean polyethylene bottles. In case of analysis for heavy metals, immediate acidification of the sample was done with HNO_3 solution to keep its pH less than 2 in order to avoid the precipitation of metals as well as their adsorption on the surface of containers. Microbiological analysis was done using sterile glass bottles which were stored in ice boxes at around 4 °C for transport to the lab.

3.3 Physicochemical Analysis

The physicochemical parameters of water samples were measured using standard analytical methods.

3.3.1 In-situ Measurements

Measurement of pH and electrical conductivity (EC) of water samples was done by a portable multiparameter meter. Estimation of total dissolved solids (TDS) was made by converting the electrical conductivity (EC). Measurement of turbidity was done by a nephelometric turbidity meter.

3.3.2 Laboratory Analysis

Determinations of nitrate (NO_3^-) and phosphate (PO_4^{3-}) levels were carried out through UV-Visible spectrometry while total hardness and alkalinity were analyzed using titrimetric technique. All analytical processes were performed according to the standard procedures set forth by the American Public Health Association (APHA, 2017).

3.4 Heavy Metal Analysis

The levels of heavy metals such as As, Pb, Cd, and Cr were determined using atomic absorption spectroscopy (AAS). Before measuring the heavy metal levels, the water samples were first subjected to digestion using concentrated nitric acid and perchloric acid in order to dissolve all the metals present. Calibration standards were prepared using certified standard solutions. Quality control checks included analyzing blanks, standard reference materials, and replicates to guarantee precision and accuracy. Detection limits and recovery were acceptable.

3.5 Microbiological Analysis

The level of microbial contamination was measured using total coliforms, fecal coliforms, and *E. coli.* Membrane filtration method was used in which the water samples were passed through membrane filters that have 0.45 µm pore size, and then cultured on selective media. Total coliforms were cultured at 37°C, and fecal coliforms were cultured at 44.5°C. Colony formation was counted after incubation, and the results were recorded as CFU/100 mL.

3.6 Health Data Collection

A questionnaire-based survey was performed on the households from the selected rural communities. The collected data involved the type of water source, methods used for water purification, and the prevalence of waterborne diseases. Diarrhea, typhoid, and hepatitis A and E were the most prevalent illnesses. Whenever possible, medical records of the local healthcare facilities were also checked to ensure the authenticity of the gathered data.

3.7 Human Health Risk Assessment

Health risks associated with contaminated water were evaluated using standard risk assessment models.

3.7.1 Non-Carcinogenic Risk

The hazard quotient (HQ) was calculated using:

$$HQ = \frac{CDI}{RfD}$$

Where:

CDI = Chronic Daily Intake
RfD = Reference Dose

3.7.2 Carcinogenic Risk (CR)

Lifetime cancer risk was estimated using:

$$CR = CDI \times SF$$

Where:
SF = Slope Factor

Risk levels were interpreted according to guidelines provided by the United States Environmental Protection Agency.

3.8 Statistical Analysis

All the data obtained through experiments were statistically analyzed using various computer programs, namely OriginPro and SPSS. The descriptive statistics were computed to provide summary measures like mean and standard deviation for the data. The Pearson correlation coefficient analysis was used to find out the relationships between water pollutants and their related health issues. In addition, a multivariate analysis such as Principal Component Analysis (PCA) was carried out to determine possible sources of pollution.

3.9 Quality Assurance and Quality Control (QA/QC)

In order to provide reliable and accurate results, calibration of all the instruments was done before performing any analyses. The experiments were done in triplicates so as to avoid errors during experimentation. The reagent blanks and duplicates were included during the analysis as part of quality control measures. All experimental work was done using the standard procedures.

4 Results and Discussion

4.1 Physicochemical Characteristics of Drinking Water

Analysis of groundwater samples based on physicochemical parameters shows significant variations in water quality in the analyzed locations. The greatest variations can be observed in such parameters as Total Dissolved Solids (TDS) and Electrical Conductivity (EC), where the median of TDS is around the 1100 mg/L figure, which considerably exceeds the 1000 mg/L limit defined by the WHO as the highest possible level of contaminants in potable water. Moreover, the large interquartile range in both variables implies that despite some locations having relatively clear water, a considerable proportion of the samples are characterized by high mineralization. On the contrary, the distribution of the pH parameter is rather narrow; it stays well within the permissible limit between 6.5 and 8.5, implying a stable buffering system in the aquifer. At the same time, outliers and long upper whiskers in relation to the mentioned parameters imply certain "pollution hot spots" caused by specific anthropogenic factors. Hence, the analysis supports the fact that an enormous percentage of the groundwater is not suitable for drinking because of a high content of minerals.

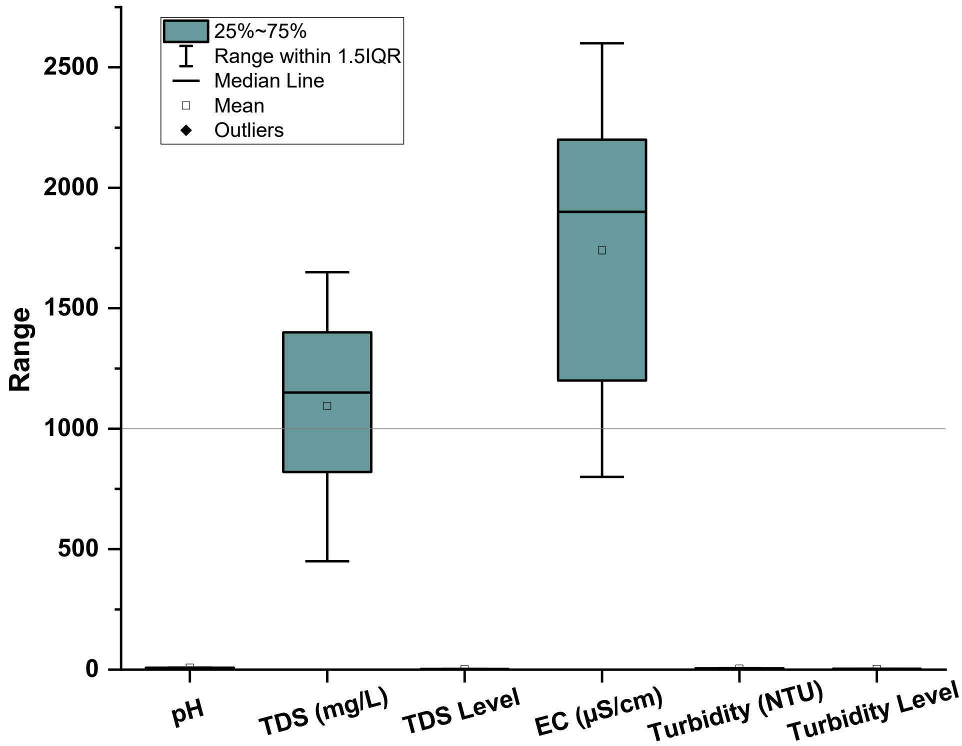

Figure 1: These are box and whisker diagrams showing the physico-chemical properties of the groundwater that were sampled from rural areas in Faisalabad. The horizontal lines inside the boxes represent the medians, whereas the box shows the means. The whiskers reach up to 1.5 × IQR (Inter Quartile Range). The horizontal line at y = 1000 is the WHO standard maximum permissible limit (mg/L) for total dissolved solids.

4.2 Heavy Metal Contamination and Source Attribution

The pattern of heavy metals in groundwater samples shows that the increase in their concentration levels depends directly on the distance of their location from industrial regions. As indicated in multi-panel representation shown below, the concentrations of Arsenic (As) and Lead (Pb) are quite negligible in rural sampling areas (S1, S2, and S5) while showing a marked increase in sampling locations (S3 and S4) that fall under industrial-proximate regions. More specifically, the concentration levels of arsenic at these locations rise dramatically to nearly 60 µg/L as against the permissible level of 10 µg/L as per WHO regulations. Similarly, the concentration of lead (Pb) at these sampling points rises above the safety limit by going

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past the value of 25 µg/L. In contrast, although cadmium (Cd) also shows an increase in its concentration level at industrial sampling locations, it does not show as alarming an increase as compared to As and Pb.

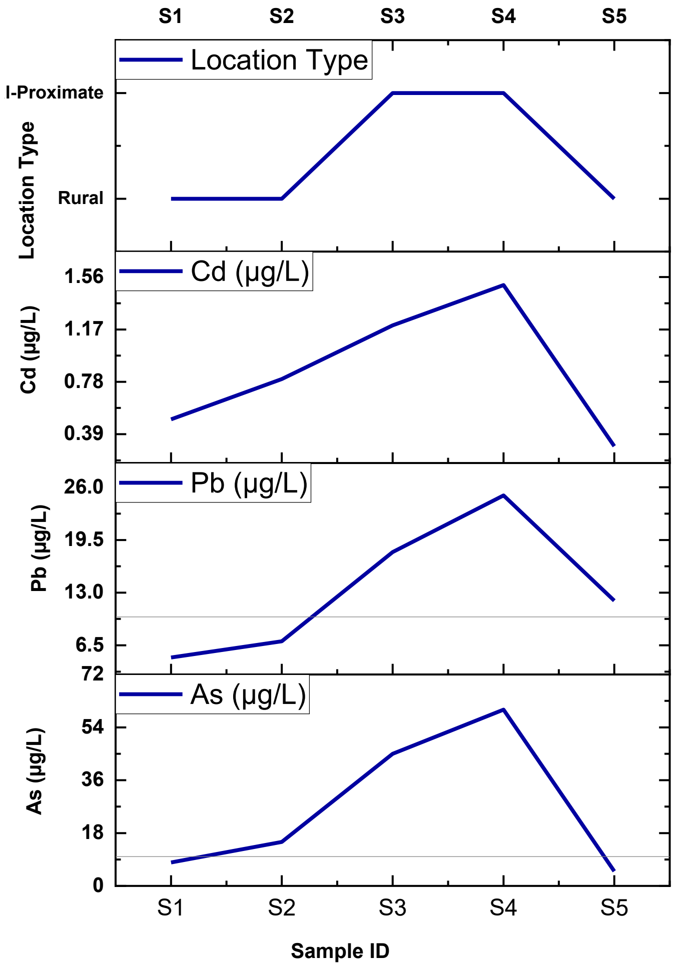

Figure 2: Multi-panel graph depicting the heavy metals (arsenic, lead, and cadmium) concentrations in relation to the land use (Location Type). The gray horizontal lines represent the WHO maximum permissible values of each metal. The simultaneous spikes in samples S3 and S4 point out the major effect of industrial vicinity on the degradation of groundwater quality.

4.3 Microbiological Contamination

Microbiological analysis of water samples obtained from groundwater systems revealed a critically deteriorated water quality from a biological point of view, in terms of a massive pollution found in all sampling points (S1-S5) examined in the study. As can be seen from Figure 3, the samples did not meet the standards of WHO regarding the use of drinking water since the total number of bacteria was higher than 0 CFU/100 mL. It should be noted that there was a considerable variation in the total number of coliforms in the groundwater samples, ranging between 0-310 CFU/100 mL; however, the maximum values were registered in S3 (250 CFU/100 mL) and S4 (310 CFU/100 mL). It is important that in 60% of the samples analyzed, E. coli was detected (S1, S3, and S4). In addition, taking into account the high coliform count in these sampling points, it may be assumed that these waters have recently been exposed to fecal contamination, which makes the groundwater systems vulnerable to contamination from domestic sewage.

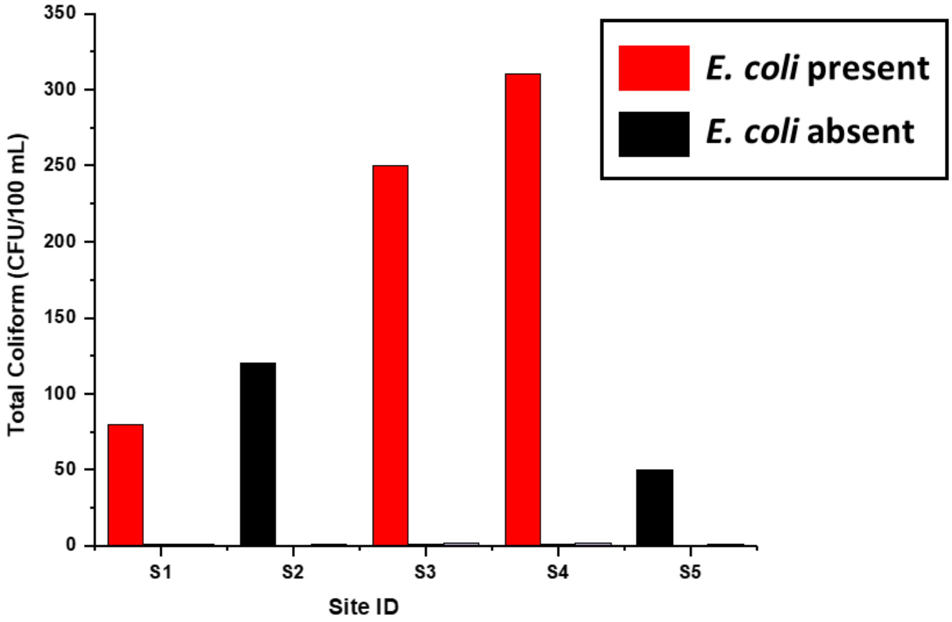

Figure 3: Spatial distribution of microbiological contamination in water samples. The height of bars denotes numbers of total coliform bacteria (CFU/100 mL), whereas red/black colors indicate presence/absence of *E. coli.* None of the samples is below the recommended level (zero coliforms) by WHO, with only 3 of 5 locations showing signs of faecal contamination.

4.4 Correlation Between Water Quality and Public Health Outcomes

There exists a positive correlation between water quality, based on the number of bacteria measured in the *E. coli* colony forming units (CFU)/100 mL, and the incidences of Diarrhea and Typhoid. The places with a high level of bacteria (high loads) are the places with increased occurrences of diseases. For example, S3 is one such place that records the highest number of *E. coli* (close to 100 CFU/100 mL), coinciding with an increase in the occurrence of Diarrhea and Typhoid infections, which stand at almost 35% and 25%, respectively. The place with the worst conditions, i.e., the "red flag" regarding public health safety, is S4, where Diarrhea cases are recorded to be at close to 40%. On the other hand, Site S2 can be used as the control since it has the lowest concentration of *E. coli* bacteria (less than 10 CFU/100mL), which correlates with low cases of disease infection (both for Diarrhea and Typhoid, under 10%). The patterns of the two diseases infection are similar to those shown on the line graph, and the pattern of Diarrhea infections is also consistent with being always higher than that of Typhoid infections; it may be because the disease can be caused not only by *Salmonella typhi* bacteria but also by many other bacteria and viruses.

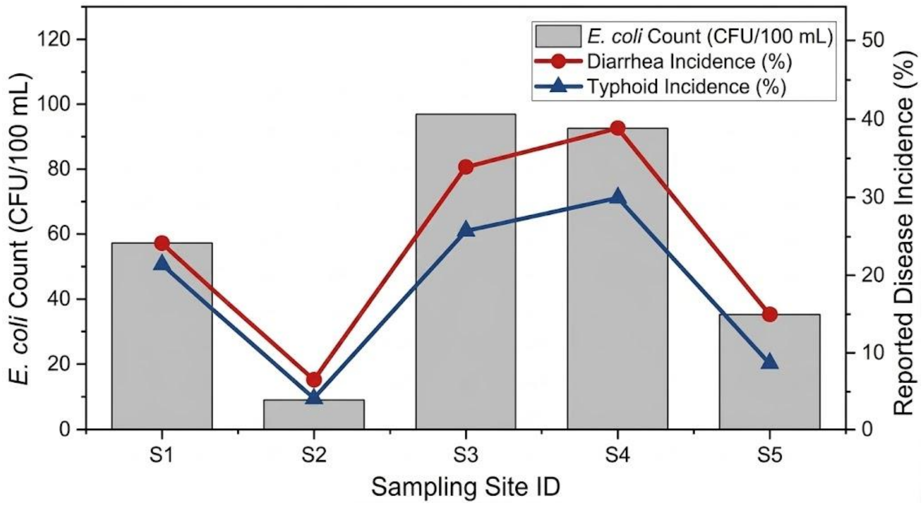

Figure 4: Comparative analysis of fecal indicator bacteria levels and the prevalence of waterborne diseases, demonstrating the impact of water quality on public health outcomes.

4.5 Human Health Risk Assessment

The hazard quotient (HQ) analysis shows a significant and alarming difference in the non-carcinogenic risk levels between adults and children in all the sampled areas. According to the USEPA guidelines, any HQ value above 1.0 suggests possible health effects resulting from prolonged exposure to hazardous substances. From the results, children appear to be highly susceptible to non-carcinogenic risks than adults since the HQ levels are above the threshold in several areas, such as Site A (arsenic), Site B (arsenic), Site B (lead), and Site C (lead). The most dangerous area is Site B (arsenic), with a child's HQ of about 2.8, which is almost three times the maximum permissible level. In contrast, adults exhibit low exceedances with Site B (As) alone exceeding the benchmark (HQ ≈ 1.10), with all other sites staying within the safety zone. The above outcomes indicate that high levels of exposure together with reduced body weight and consumption rates make children the most vulnerable population group in the region under consideration. All things considered, the outcomes reveal the significance of Site B as a key site of heavy metal pollution, especially arsenic pollution, which calls for an urgent intervention program.

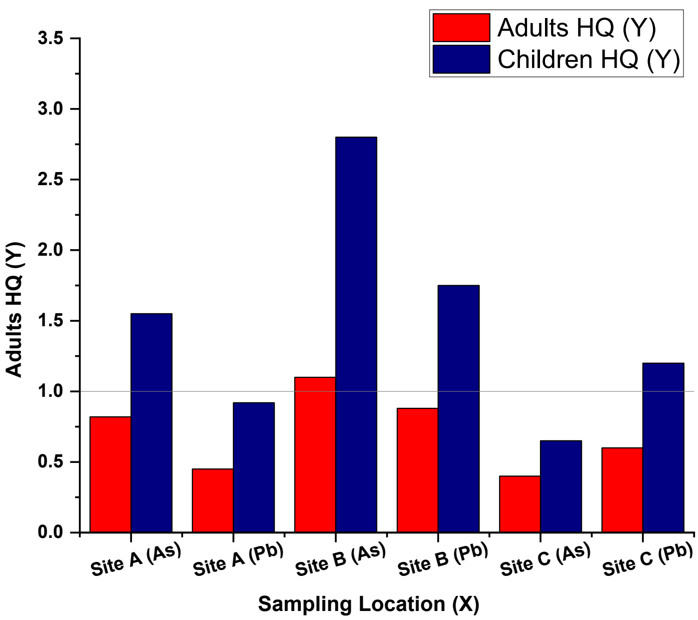

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Figure 5: Comparative health risks (non-cancer, Hazard Quotient, HQ) of As and Pb exposure for adults and children based on samples collected from various locations. The dotted horizontal line indicates the USEPA's acceptable limit of hazard quotient (HQ = 1.0). Any value that is greater than this signifies possible health problems due to prolonged exposure. These findings show a pattern of higher HQ levels in children than in adults, especially concerning arsenic exposure in Site B.

4.5.2 Carcinogenic Risk

The carcinogenic risk (CR) assessment of arsenic exposure suggests that the concentrations at all sampling points are above the USEPA acceptable risk level of 10^{-4} (1 in 10,000). This implies that there could be a possible long-term cancer risk among the exposed community. The carcinogenic risks have been plotted using a logarithmic scale, illustrating the clear deviation from the acceptable risk level between 10^{-6} and 10^{-4}. In general, Site B is considered the worst-case scenario since the carcinogenic risk of children is estimated at 4.5×10^{-3}, which is more than 45 times higher than the upper acceptable risk level. In addition, children have relatively higher carcinogenic risks than adults across all sampling sites because they consume higher amounts compared to their body weights. At the least contaminated site (Site C), both children and adults still have CRs exceeding the acceptable risk level. Hence, it can be inferred that the study region is under high carcinogenic risk of arsenic.

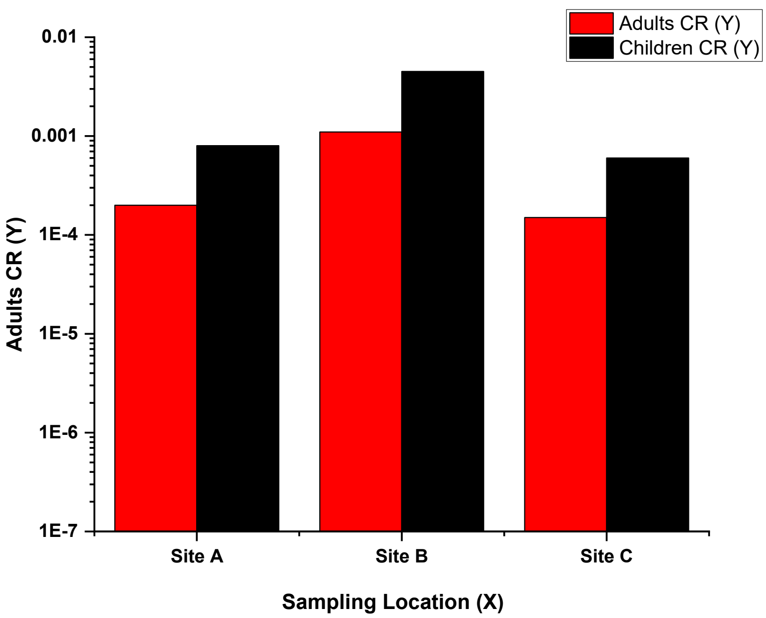

Figure 6: This shows the carcinogenic risk (CR) from exposure to arsenic based on samples obtained from three locations (Location A, Location B, and Location C). The y-axis uses the log10 scale to allow for the large variation among the risk values. Based on the findings, both the adults and children are being subjected to carcinogenic risks beyond the threshold of 1×10^{-4} set by the USEPA. More so, the carcinogenic risk is higher for the children at Location B.

4.6 Mechanistic Insights into Contamination Pathways

The schematic diagram above demonstrates the primary ways in which human activities compromise groundwater quality through transportation. The schematic indicates that the saturated region (the aquifer) becomes contaminated by human activities through the following three ways of contamination, depending on the land-use areas. For instance, in the case of industrial zones, contaminants include effluents discharged directly into the ground, resulting in heavy metal pollutants like lead (Pb) and cadmium (Cd). Such pollutants are not

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biodegradable and remain in the environment for long. Secondly, in agriculture zones, fertilizers and other chemicals result in leaching of substances like nitrates and phosphates.

This causes the pollutants to move down through the unsaturated region to contaminate the groundwater. Finally, in the domestic area where there are poor sanitation facilities like unlined pit latrines, the contaminants include biological pollutants from the feces. Unlike the heavy metals, microbes can survive in the subsurface region, thus multiplying. As indicated above, all the pathways of contamination eventually converge at the point of water abstraction like drinking water wells. This creates a scenario where one is exposed to a combination of all these pollutants that may cause more health problems than the single ones.

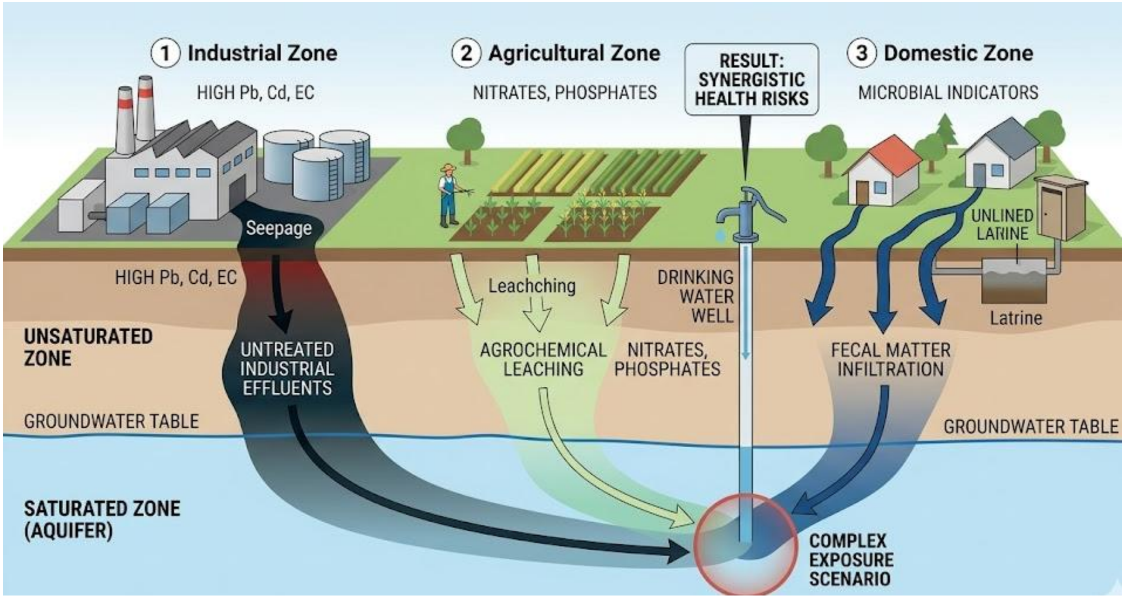

Figure 7: Conceptual Model of Groundwater Contamination Pathways Highlighting the Synergistic Health Risks Arising from Industrial Seepage, Agrochemical Leaching, and Microbial Infiltration into a Shared Aquifer.

4.7 Implications for Public Health and Sustainability

From the quantification analysis of the contamination factor (Cf), it is evident that the contamination of the different land use zones exceeds the threshold limit values, thus proving the existence of a complex exposure scenario in the conceptual model. The industrial land use zone is characterized by the presence of heavy metal contaminants. For instance, the contamination factor of lead (Pb) is 8.5 while that of cadmium (Cd) is 4.2, which surpasses the WHO threshold limit value, indicating extreme contamination. The contamination in the agricultural land use zone is due to nutrient pollution. The concentration of nitrates and phosphates exceeds the permissible limit values because of leaching by fertilizers and agrochemicals in the groundwater. The contamination level is maximum in the domestic land use site, where the level of total coliform bacteria is high with a Cf value of 12.4. The high Cf value suggests that there might be microbial contamination, and the most possible reason for this scenario is the infiltration of feces in groundwater due to improper sanitary facilities like unlined latrines. More importantly, the results reveal that there could be more than one source of contamination in each land use zone, despite the dominance of one type of contaminant. In cases where any contaminant does not dominate in terms of concentration, the levels of contaminants are quite high or near the threshold level set by the WHO.

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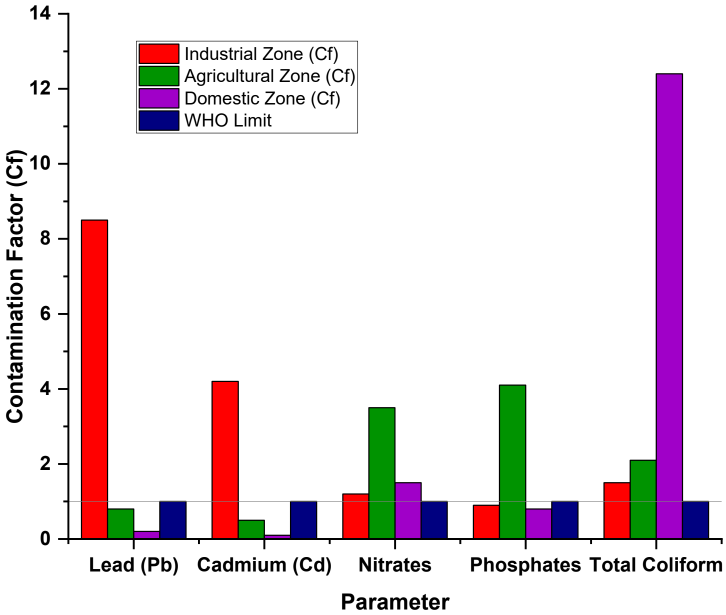

Figure 8: Comparison of contaminant factors (Cf) for the presence of heavy metals, nutrients, and microbial pollutants in industrial, agricultural, and residential areas. The horizontal reference line drawn at Cf = 1.0 indicates the maximum allowable limit by the WHO standards and shows that there is a violation of safety standards to a large extent.

5 Conclusion

The findings indicate that ground water in the rural parts of Faisalabad, Pakistan is highly contaminated with heavy metals (arsenic and lead) and fecal coliforms, thus posing a serious public health hazard. The physiochemical factors, including total dissolved solids, often exceeded the WHO limits, whereas the concentration of arsenic was six times higher than the permissible limit in industrial areas. Microbial examination confirmed the presence of total coliforms and *E. coli* bacteria in all water samples, which indicates extensive fecal pollution because of poor sanitary conditions. There was a clear relationship between microbial contamination and waterborne diseases, such as typhoid fever and diarrhea, and the most polluted regions exhibited the highest incidence of illnesses. The health risk assessment indicated that children were more susceptible to illness compared to adults, with hazard quotient values being almost thrice the maximum limit and a lifetime cancer risk for arsenic almost 45 times higher than the maximum level. These results provide clear evidence of an unhealthy situation, especially among children. Immediate action is needed, and it includes regulation of industries, upgrading of sanitation facilities, point-of-use treatment of water, and awareness campaigns. Otherwise, more harm than good will be done by this situation since it keeps perpetuating the cycle of ill-health among children and poverty in society.

References

Batool, Z., Anjum, F., Faiz, S., Akram, M., & Ibrahim, M. (2015). Household Perspectives towards Integrated Management of Drinking Water in Faisalabad District, Punjab, Pakistan. *Mediterranean Journal of Social Sciences*. https://doi.org/10.5901/mjss.2015.v6n5s2p503

Budi, H. S., Catalan Opulencia, M. J., Afra, A., Abdelbasset, W. K., Abdullaev, D., Majdi, A., Taherian, M., Ekrami, H. A., & Mohammadi, M. J. (2024). Source, toxicity and carcinogenic health risk assessment of heavy metals. *Reviews on Environmental Health*, *39*(1), 77–90. https://doi.org/10.1515/reveh-2022-0096

Clewell, H. J., Andersen, M. E., & Barton, H. A. (2002). A consistent approach for the application of pharmacokinetic modeling in cancer and noncancer risk assessment. *Environmental Health Perspectives*, *110*(1), 85–93. https://doi.org/10.1289/ehp.0211085

Dr. Amit Krishan, Dr. Shweta Yadav, & Ankita Srivastava. (2023). Water Pollution's Global Threat to Public Health : A Mini-Review. *International Journal of Scientific Research in Science, Engineering and Technology*, 321–334. https://doi.org/10.32628/IJSRSET2310643

El Messaoudi, N., Miyah, Y., Georgin, J., Franco, D. S. P., Yılmazoğlu, M., Kouka, T., & Messali, M. (2026). Sustainable casein-derived materials for water purification: opportunities, challenges, progress, and perspectives. *Reactive and Functional Polymers*, *220*, 106612. https://doi.org/10.1016/j.reactfunctpolym.2025.106612

Ensink, J. H. J., Simmons, R. W., & Hoek, W. van der. (2004). Wastewater use in Pakistan: the cases of Haroonabad and Faisalabad. In *Wastewater use in irrigated agriculture: confronting the livelihood and environmental realities* (pp. 91–99). CABI Publishing. https://doi.org/10.1079/9780851998237.0091

Fawell, J., & Nieuwenhuijsen, M. J. (2003). Contaminants in drinking water. *British Medical Bulletin*, *68*(1), 199–208. https://doi.org/10.1093/bmb/ldg027

Howard, G., Pedley, S., Barrett, M., Nalubega, M., & Johal, K. (2003). Risk factors contributing to microbiological contamination of shallow groundwater in Kampala, Uganda. *Water Research*, *37*(14), 3421–3429. https://doi.org/10.1016/S0043-1354(03)00235-5

Khan, S., Shahnaz, M., Jehan, N., Rehman, S., Shah, M. T., & Din, I. (2013). Drinking water quality and human health risk in Charsadda district, Pakistan. *Journal of Cleaner Production*, *60*, 93–101. https://doi.org/10.1016/j.jclepro.2012.02.016

Liu, X., Song, Q., Tang, Y., Li, W., Xu, J., Wu, J., Wang, F., & Brookes, P. C. (2013). Human health risk assessment of heavy metals in soil–vegetable system: A multi-medium analysis. *Science of The Total Environment*, *463–464*, 530–540. https://doi.org/10.1016/j.scitotenv.2013.06.064

Raza, M., Hussain, F., Lee, J.-Y., Shakoor, M. B., & Kwon, K. D. (2017). Groundwater status in Pakistan: A review of contamination, health risks, and potential needs. *Critical Reviews in Environmental Science and Technology*, *47*(18), 1713–1762. https://doi.org/10.1080/10643389.2017.1400852

Sathre, R., Antharam, S. M., & Catena, M. (2022). Water Security in South Asian Cities: A Review of Challenges and Opportunities. *CivilEng*, *3*(4), 873–894. https://doi.org/10.3390/civileng3040050

Singh, A., Sharma, A., K. Verma, R., L. Chopade, R., P. Pandit, P., Nagar, V., Aseri, V., K. Choudhary, S., Awasthi, G., K. Awasthi, K., & S. Sankhla, M. (2022). Heavy Metal Contamination of Water and Their Toxic Effect on Living Organisms. In *The Toxicity of Environmental Pollutants*. IntechOpen. https://doi.org/10.5772/intechopen.105075

Srivastav, A. L. (2020). Chemical fertilizers and pesticides: role in groundwater contamination. In *Agrochemicals Detection, Treatment and Remediation* (pp. 143–159). Elsevier. https://doi.org/10.1016/B978-0-08-103017-2.00006-4

Talib, M. A., Tang, Z., Shahab, A., Siddique, J., Faheem, M., & Fatima, M. (2019). Hydrogeochemical Characterization and Suitability Assessment of Groundwater: A Case Study in Central Sindh, Pakistan. *International Journal of Environmental Research and Public Health*, *16*(5), 886. https://doi.org/10.3390/ijerph16050886