

PRE & POST DRINKING WATER QUALITY ASSESSMENT FROM THE FILTRATION PLANTS OF VARIOUS SECTORS IN DHA PHASE-II, ISLAMABAD, PAKISTAN

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خلاصہ

پاکستان میں، صرف 25 فیصد آبادی کو اعلیٰ معیار کے پینے کے پانی تک رسائی حاصل ہے، جو قابل برداشت حد سے کم ہے۔ زیر غور مطالعہ کا علاقہ DHA فیز II، اسلام آباد پاکستان تھا۔ اس تحقیق کا مقصد پانی کے معیار سے متعلق مختلف پیرامیٹرز اور پائپر تجزیہ کا استعمال کرتے ہوئے پانی کے معیار کی جانچ کے لیے قابل قدر بصیرت حاصل کرنا تھا۔ مطالعہ کا مقصد پانی کے نمونوں پر مختلف نتائج کے ذریعے سیکٹر میں فلٹریشن پلانٹس کی کارکردگی کا جائزہ لینا ہے۔ جسمانی کیمیکل آلودگی، بھاری دھاتیں، اور مائیکرو بائیولوجیکل آلودگی کے لیے کل 22 نمونوں کی جانچ کی گئی۔ تحقیقات میں پانی کے نمونوں کی جانچ مختلف مراحل پر کی گئی، فلٹریشن سے پہلے، دوران اور بعد میں۔ نمونے پانی کی بوتلوں میں جمع کیے گئے تھے جیسا کہ EPA کے ذریعے تفویض کیا گیا تھا، جن کو ڈسٹنڈ پانی سے دھونا، کلی کرنا، سیل کرنا، اور بعد میں EPA لیب میں نقل و حمل کیا گیا، نمونوں کا تجزیہ کیا گیا جو بری جذب ماڈل AA-7000، اور Senso Direct 150 LOVIBOND، سیکٹرو میٹری نتائج پانی کے معیار کے بہتر ہونے کی ضرورت کو واضح کرتے ہیں کیونکہ چھ فلٹریشن پلانٹس سے ہمیں سیسہ، نکل، کیڈمیم اور کرومیم کا زیادہ ارتکاز حاصل ہوتا ہے جو کہ کافی خطرناک تھا، اس کے ساتھ ساتھ مختلف پودوں میں کل سختی، سلفیٹ اور کلورائیڈز کی زیادہ مقدار بھی تھی۔ ہمارے نتائج کے نتیجے میں، یہ سختی سے مشورہ دیا جاتا ہے کہ حکام آلودگی کو روکنے اور مجموعی کارکردگی کو بڑھانے کے لیے فلٹریشن پلانٹس کی نگرانی اور ان کی دیکھ بھال کے لیے فعال اقدامات کریں۔

Abstract

In Pakistan, just 25% of the population has sustained access to high-quality drinking water, which is below tolerable limits. The study area under consideration was DHA Phase II, Islamabad, Pakistan. The research conducted aiming the valuable insights for the water quality testing using different parameters and piper analysis to relate the water quality. The purpose of the study was to examine the efficiency of the filtration plants in the sector by performing different tests on water samples. A total of 22 samples were tested for physicochemical contamination, heavy metals, and microbiological contamination. The investigation examined water samples at various stages, before, during, and after filtration. Samples were collected in water bottles as assigned by EPA that underwent washing with distilled water, rinsing, sealing, and subsequent transportation to the EPA lab. The samples underwent analysis utilizing Atomic Absorption and UV Spectrophotometry. The results underscore the necessity of the enhanced water quality standards as high concentration of lead, nickel, cadmium and chromium was detected along with high concentration of total hardness, sulfates and chlorides in various plants, which is quite alarming. In conclusion to our findings, it is strongly advised that authorities take proactive measures to supervise and maintain filtration plants to prevent contamination and enhance overall performance.

Keywords: Defence Housing Authority, Environmental Protection Agency, Atomic Absorption, Ultra Violet Spectrometry

Introduction

One of the challenges in developing countries is unsafe drinking water. The world is now facing a severe threat to drinking water quality, and specific solutions are being used to address this issue. Water quality is determined in many nations, including Pakistan, by evaluating. Attributes are classified into three types: biological, chemical, and physical. Each of these three sorts of attributes has its own set of water quality criteria. The Environmental Protection Agency of the federal government develops national drinking water standards. These criteria must be met by all municipal water sources (Treacy, 2019).

In Pakistan, just 25% of the population has sustained access to high-quality drinking water, which is below tolerable limits. Waterborne disease prevalence in Pakistan is primarily caused by municipal sewage and industrial waste contaminating drinking water sources (Hashmi *et al.*, 2009).

Some features consider being important to the quality of drinking water. Consequently, the Environmental Protection Agency (EPA) has established two distinct categories for its drinking water standards: primary drinking water standards and secondary drinking water requirements. The primary drinking water standards pertain to regulations, concerning organic and inorganic contaminants, microbial pathogens, and radioactive substances that could pose threats to the safety of drinking water. On the other hand, the secondary drinking water standards addresses the parameters like chlorides, copper, manganese, sulfates, zinc, iron, pH, total dissolved solids, corrosively, foaming agents, color, and odor. These elements primarily influence the taste, odor, color, and overall appearance of water. The designation “SMCL” denotes the maximum permissible concentration of these pollutants in the water supply (Treacy, 2019).

Water pollution is the degradation of water quality caused by wastes from industries, urbanization, and agriculture. The ecology and public health are negatively impacted by the use of such water for beneficial reasons. Water resources have been greatly strained by industrialization and the expansion of metropolitan areas. As a result, waste water is discharged into natural water sources, lowering the quality of ground and surface water (Awan *et al.*, 2002).

Preservatives, color, turbidity, odor, and, most critically, bacteria that damage water quality should be avoided. When water is obtained from surface resources, it must be made safe for drinking purposes; therefore, chlorination is the most essential way of purifying the water by disinfecting the diseases (Hashmi *et al.*, 2009).

Daud *et al.*, (2017) state that the review summarizes the findings of numerous investigations into the drinking water quality status of various regions of Pakistan by accounting for the physical and chemical characteristics of the water as well as the presence of different pathogenic microorganisms. Poor water quality is the primary reason of a high sickness and death ratio, according to Farooqi *et al.*, (2007). The two noteworthy illnesses that are most likely to result in death are diarrhea and gastroenteritis. Surveys indicate that high water contamination is the reason for the estimated decline in water quality. According to estimates, the country's population would rise from 141 million to 221 million by 2025, while the amount of water available per person will decrease from 5,600 m³ to 1,000 m³. Unrestricted discharge of industrial and domestic wastewater into natural water bodies without proper treatment is causing a decline in water quality. Unsafe water is thought to be the cause of 30% of diseases and 40% of deaths in Pakistan, according to Akbar *et al.*, (2013). Water pollution is the cause of sickness in one in five people. Three million Pakistanis are thought to be underprivileged, and 0.1 million of them pass away from watery illnesses each year. The most common cause of death in the nation for infants and children is water-borne diseases like diarrhea, and one in every five citizens has a disease or illness brought on by contaminated water (Hashmi *et al.*, 2009).

A case study was conducted by Haydar *et al.*, (2009) in order to assess the water quality of WASA filtration plants in Punjab areas. At every source (T/W) in the perspective areas, also the physiochemical and biological parameters were within the considerable ranges, thus the water was suitable for the drinking supply purposes. In the recent past Ahmed *et al.*, (2007) concluded a study in Hayatabad area in Peshawar, Pakistan, from the study it was concluded that chemical quality of drinking water samples from the selected areas was not accordance to WHO standards and thus was unfit for drinking and utilization purposes. According to Mohsin *et al.*, (2013) the study conducted in satellite town area in Lahore, Pakistan shows the high concentration of calcium which was approximately around 310mg/l which were above the permissible limits as per standards of PAK-EPA, and in Islamic colony the concentration of chloride was reported above permissible limits while Sodium quantity in Shahdrah was 28-33mg/l which was also quietly lower from WHO standard limit of 200 mg/l and could be harmful for the health of local inhabitants. Other parameters also reflect significant variations to WHO standards (Hashmi *et al.*, 2009).

The study aimed to comprehensively evaluate the physiochemical parameters encompassing pH, total dissolved solids (TDS), total solids (TS), total hardness, sulfate and chloride ions concentration, electrical conductivity (EC), additionally the research focus on determining the concentration of heavy metals in the study area. Because the proximal distance of study area is near to the industrial zone and may be the industrial effluents from the drainage point source may affect the water horizon in the different sectors of the study area. Furthermore, the study aimed to focus on the effectiveness of the filtration plants installed at different sectors of the study area aiming the enhancement of water quality and supply.

Study Area: Geographically, the region is located in the south-eastern outskirts of Islamabad and is part of the Phase II of the Defence Housing Authority (DHA). The primary geological characteristics are lesser Himalayan exposures. Water samples were taken from several wells and drinking water plants shown in Fig 1 which also depicts the map of study region.

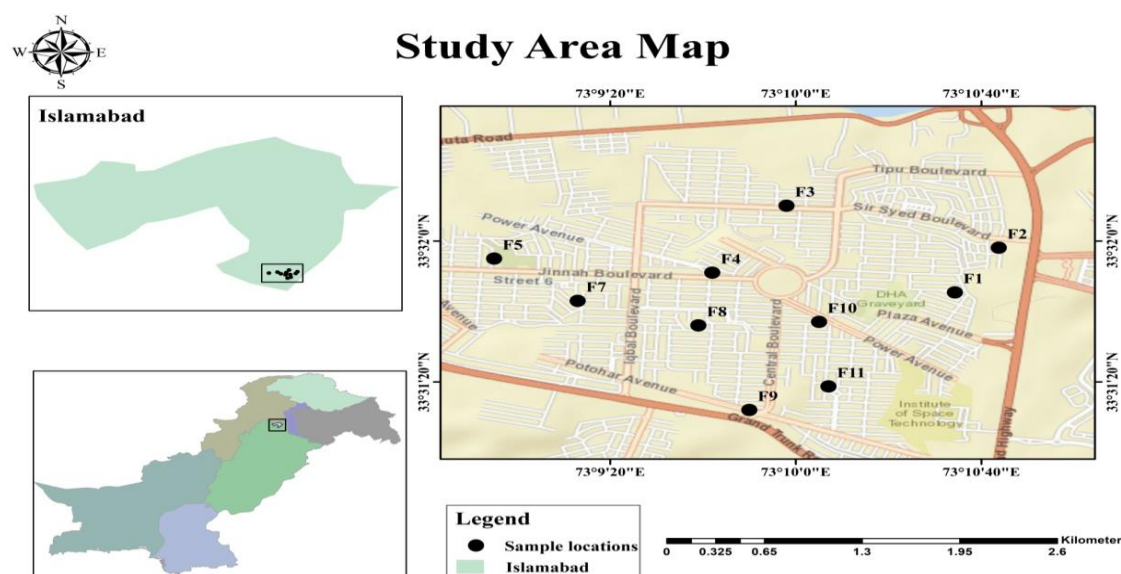


Fig. 1 Map of sample locations from different filtration plants and tube wells.

Methodology

Sample storage

For the study of various parameters in water samples, three different types of bottles were employed. Polyethylene bottles were used to analyze physical and chemical parameters according to Khan *et al.*, (2013), Sterilized glass bottles were used to analyze microbiological contamination Khalid *et al.*, (2018), and plastic bottles were used to analyze heavy metals (Muhammad *et al.*, 2011).

Sample preservation

The pH, Total Dissolved Solids, and Electrical Conductivity were each tested on the spot with portable equipment. In the labs, other parameters were examined. To preserve heavy metals, 3 ml of HNO_3 was added to each sample. For further investigation, the samples were stored in a refrigerator set to 4°C . Using Merck's "water check kit," a qualitative examination of coliform and *E.coli* bacteria contamination was performed. Human faeces will identify *E.coli*, an indicator that the water quality is poor. The set includes a sterile container as well as a blister pack. By opening the container's top, 50 ml of the water sample is put into it until the red line is reached (Hisam *et al.*, 2014).

Sample testing

After being calibrated, the pH of the samples was measured using a portable pH meter. To ensure stability, the sample was placed in a 250 ml beaker and the readings were taken three times for each sample. Because of the potential effects of atmospheric conditions on the samples, this was measured in real time. Using a conductivity probe for converting specific conductivity measurements into TDS values, TDS was measured in water samples. After 20 milliliters of sample water were inserted into the meter, the readings were displayed on a screen. During the analysis, the Senso Direct 150 by LOVIBOND instrument was utilized. Titration against EDTA and EBT indicators was used to assess the samples for total hardness. In a burette, samples were diluted with distilled water and then titrated with EDTA. Three readings were taken to determine the mean value. The number of samples was altered and this method was used on samples 1–7 and 8–11. All filtration plants use the chlorination process to eradicate bacteria. Burette, Erlenmeyer flask, graduated cylinder, funnel, and AgNO_3 solution with potassium dichromate indicator were the equipment used in the chloride test. A LOVIBOND company meter was used to measure the samples for EC. The electrode was dipped into a 250 ml beaker containing 200 ml of the sample, and readings were recorded on the screen. The method of UV visible spectrometry was used to determine the sulfates present in the samples. A flask containing 25ml of the sample under observation was taken. After adding 2 ml of sulfate buffer, thoroughly stirred. After thoroughly mixing in 0.5g of barium chloride, the mixture was left for an hour. Following that, the solution was run through a 420 nm wavelength spectrometer. The best and most popular technique for detecting heavy metals in water is atomic absorption spectroscopy. We used the Perkin Elmer Atomic Absorption Model AA-7000 to find the presence of Cd, Pb, Fe, Mn, Ni, Cr, and Zn. The qualitative analysis of microbial contamination of coliform and *E. coli* bacteria was performed using the Merck "water check kit."

Results and Discussion

The results indicated a range of 7.25-8.38 pH with a mean value of 7.7 as shown in table 1 below, whereas water samples after filtration from filtration plants indicated a range of 6.72-8.35 pH with a mean value of 7.6. Water samples after treatment from filtration plants showed a concentration range of 351-568 mg/l with a mean value of 411.7 mg/l, according to the results of the TDS analysis of water samples. Except for samples from two sectors, water samples taken both before and after filtration showed TDS levels that were within PAK-EPA limits. Prior to filtering, the electrical conductivity of all water samples varied from 461 to 678 ($\mu\text{S}/\text{cm}$), with a mean value of 522.5 ($\mu\text{S}/\text{cm}$) shown in table 1. The electrical conductivity range for the samples obtained after filtering was 472-711 ($\mu\text{S}/\text{cm}$), with a mean value of 536 ($\mu\text{S}/\text{cm}$). Values of electrical conductivity were compared to the national standard limit which is 1000 ($\mu\text{S}/\text{cm}$) shown in table 1. Before and after treatment, electrical conductivity was detected in every water sample taken from filtration facilities, and it was all under the PAK-EPA standard.

Table 1. Physical parameters of drinking water samples before and after filtration.

Sectors	Pre (Before)			Post (After)		
	pH	Concentration (mg/l)	Concentration ($\mu\text{S}/\text{cm}$)	pH	Concentration (mg/l)	Concentration ($\mu\text{S}/\text{cm}$)
		TDS	EC		TDS	EC
F1	7.3	481	625	7	494	654
F2	8	545	678	8.2	518	711
F3	8.2	359	471	6.8	364	479
F4	7.4	388	497	8	394	515
F5	7.3	405	531	7.5	401	528
F6	8.3	363	477	8	365	481
F7	7.4	678	492	8.2	397	523
F8	8.4	408	538	8.4	402	531
F9	8	365	482	8	391	513
F10	7.4	388	496	7	375	489
F11	8.2	340	461	7.5	351	472
PAK-EPA	6.5-8.5	100-500	1000	6.5-8.5	100-500	1000

Table 2. Chemical parameters of drinking water samples before and after filtration.

Sectors	Pre (Before)					Post (After)				
	Concentration(mg/l)					Concentration(mg/l)				
	Total Hardness	Ca	Mg	Cl ⁻	SO ₄ ²⁻	Total Hardness	Ca	Mg	Cl ⁻	SO ₄ ²⁻
F1	287	88	26	85	17	311	96	22	89	16
F2	267	88	23	67	23	298	128	30	65	19
F3	168	63	18	16	9	180	71	18	14	17
F4	125	48	14	15	10	216	55	13	15	8
F5	266	94	24	44	16	270	91	24	64	15
F6	254	56	17	13	11	196	61	16	12	7
F7	242	53	12	15	12	124	44	13	14	9
F8	255	87	20	83	12	232	99	21	72	7
F9	230	77	16	12	8.	210	36	12	11	13
F10	216	47	9	14	14	168	55	12	13	13
F11	200	68	15	20	7	224	56	17	15	8
PAK-EPA	250	200	100	250	400	250	200	100	250	400

Table 3. Microbial contamination in drinking water samples before and after filtration.

Sample ID	Sectors (DHA-II)	E. coli	
		Before	After
F1	G	Positive	positive
F2	J	Positive	negative
F3	D	Negative	negative
F4	E	Negative	positive
F5	B	Negative	negative
F6	A	Positive	negative
F7	C	Negative	negative
F8	F,St.13	Positive	positive
F9	F,st1	Positive	negative
F10	H, PowerAve	Negative	positive
F11	H, st8	Positive	positive

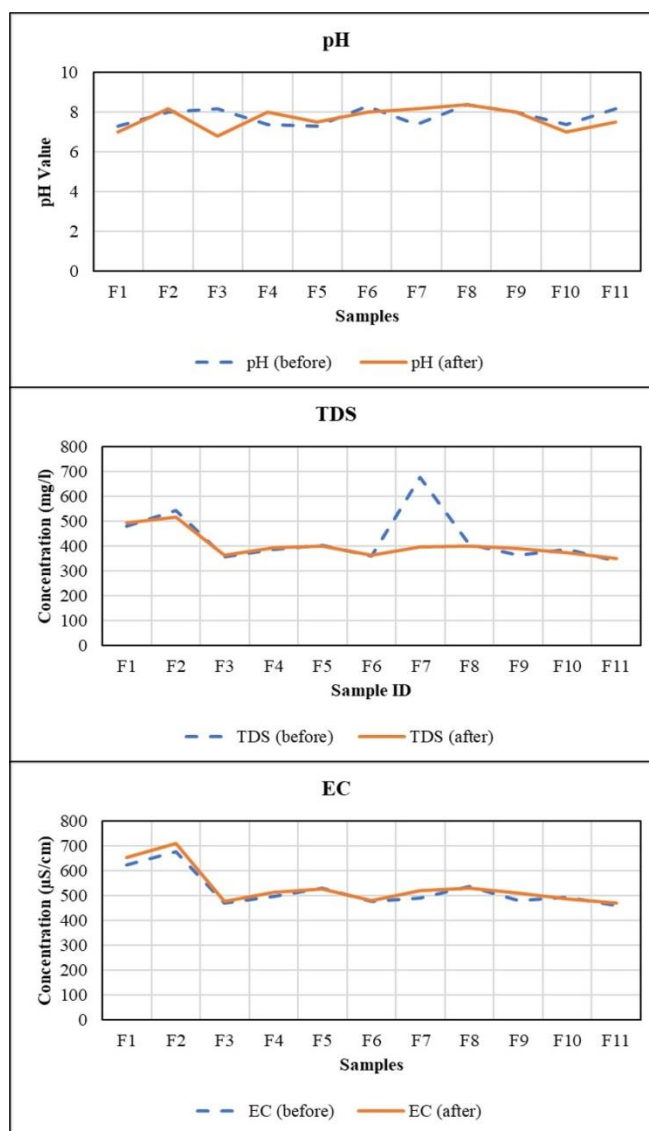


Fig. 2 Graphical representation of the results obtained before and afterfor physical parameters.

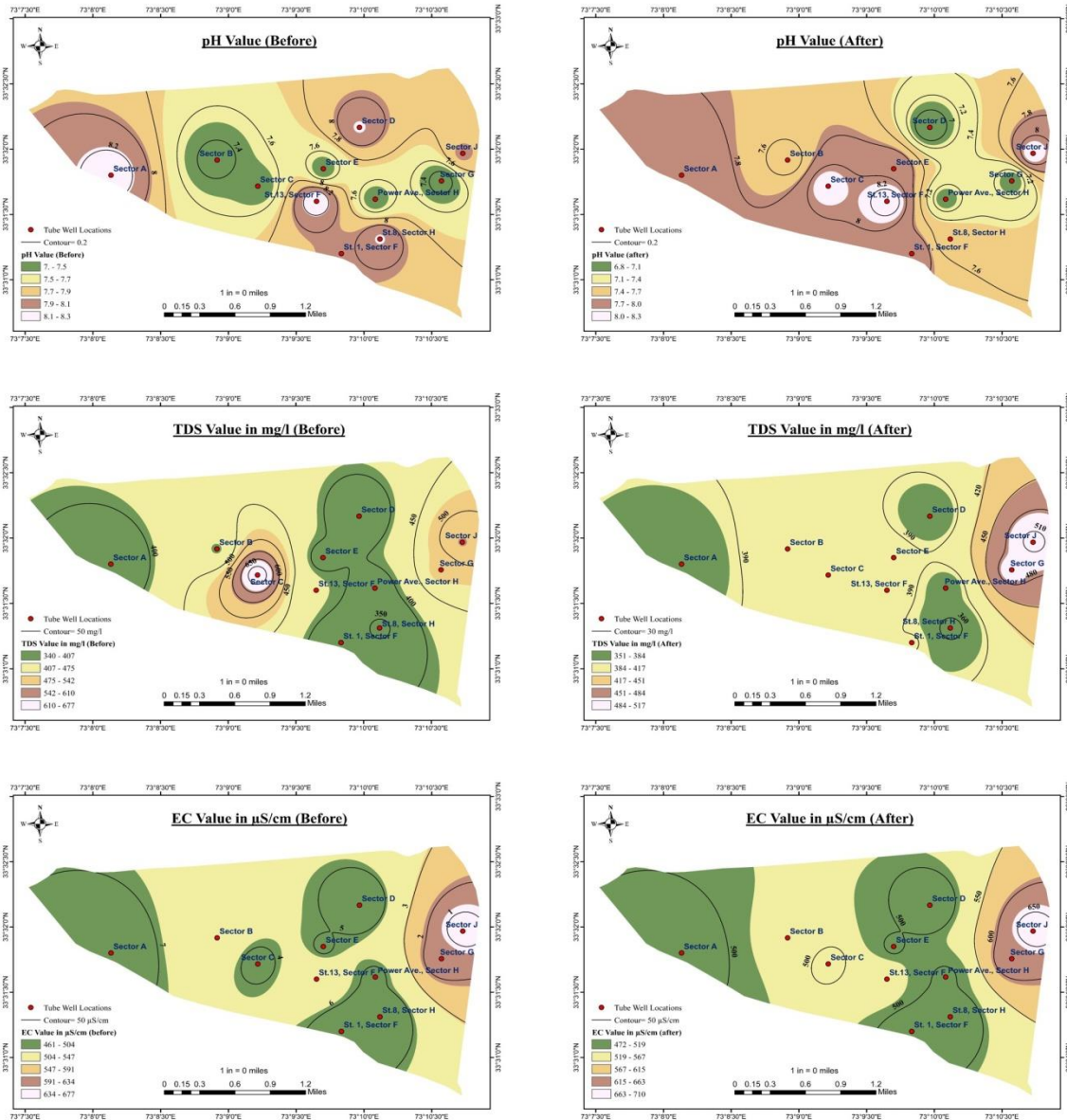


Fig. 3 Interpolation map showing concentration of physical parameters before and after filtration.

Total hardness levels were compared to the PAK-EPA minimum limit of 250 mg/l. The total hardness analysis of samples taken from the water supply to the filtration plant showed concentrations between 125 and 287 mg/l with a mean value of 229.8 mg/l, while samples taken from the filtered water showed concentrations between 124 and 311 mg/l with a mean value of 223.5 mg/l. The calcium concentration was compared to the PAK-EPA standard limit, which is 200 mg/l as shown in table 2. The calcium analysis of the water supply to the filtration facilities of different sectors revealed a concentration of 47-94 mg/l with a mean value of 69.9 mg/l, but water samples obtained after filtration revealed a concentration of 36-128 mg/l with a mean value of 72 mg/l. Magnesium concentrations from water supplies to filtration plants in different sectors ranged from 9.12 to 26.5 mg/l with a mean value of 17.6 mg/l shown in table 2, while concentrations in water samples taken after filtration ranged from 11.8 to 29.7 mg/l with a mean value of 18 mg/l. Magnesium concentration was compared to the PAK-EPA standard limit, which is 100 mg/l. The results of the chloride analysis from the water supply to the filtration plants of various sectors showed a concentration of 11.74-85.26 mg/l with a mean value of 35 mg/l whereas water samples collected after filtration showed a concentration of 11.15-88.52 mg/l with the mean value of 34.86 mg/l shown in table 2. The concentration of chloride was compared with the standard limit of PAK- EPA is 250 mg/l. The results of the sulfate analysis from the water supply to the various sector's filtration facilities showed a concentration of 7.36-16.8 mg/l with a mean value of 12.69 mg/l, while water samples taken after filtration showed a concentration of 7.99-19.21 mg/l with a mean value of 12.22 mg/l. PAK-EPA assigned specific standard limits for the chemical analysis, as mentioned in below table after the concentration the values

were increasing, this is due to the fact the area was closer to the drainage source of a chemical factory located in SE of the study area and the area is closer to the industrial zones while in sector F1, F2 and F6 the concentration of total hardness shown in Fig 2 and Fig 3 respectively was increased even after purification was of the same cause of high dissolved content of magnesium and chloride ions present in water.

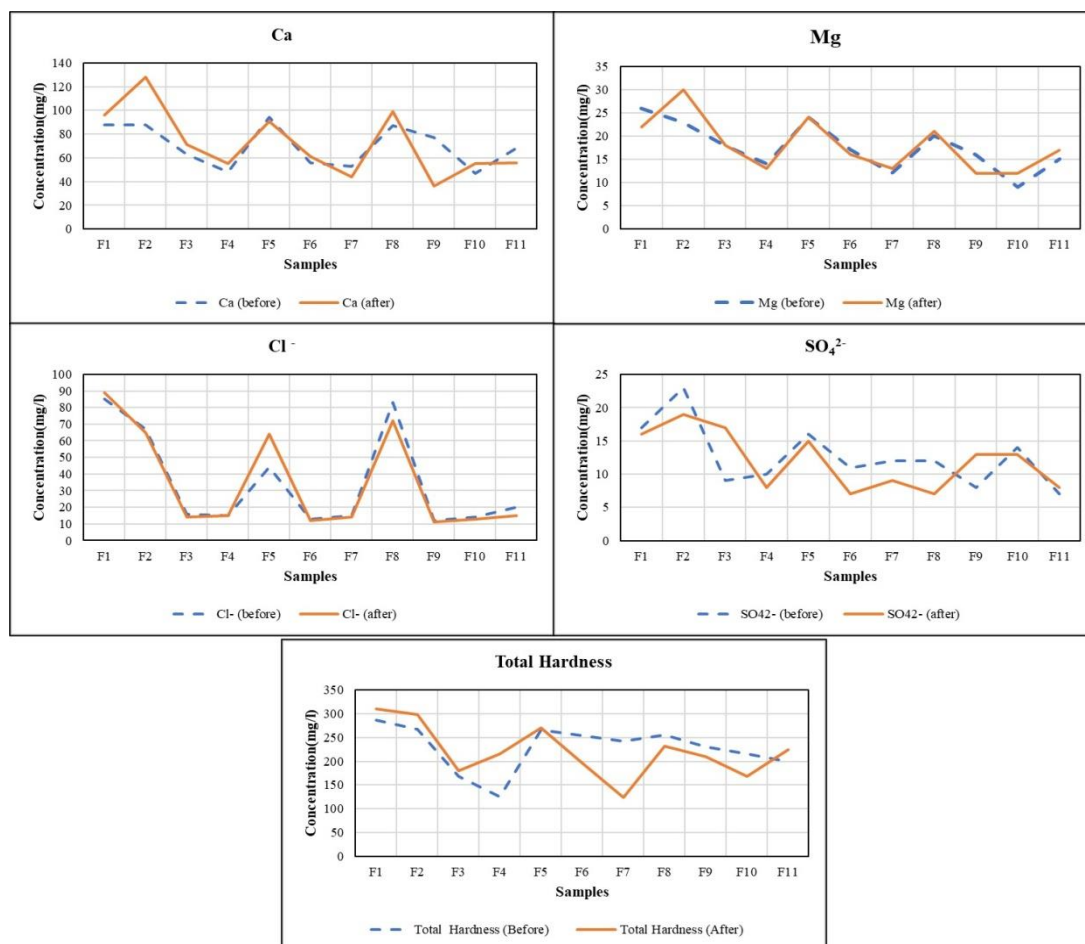


Fig. 4 Graphical representation of the results obtained before and after for chemical parameters.

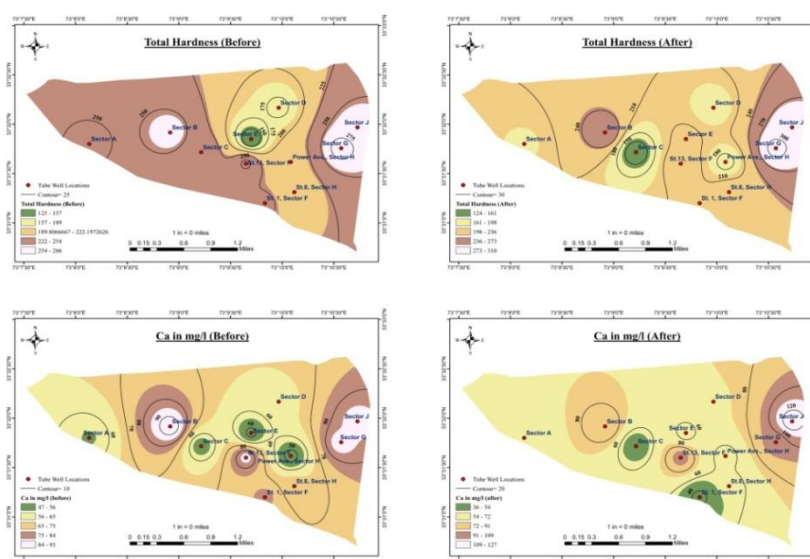


Fig. 5 (a) Interpolation map showing concentration of total hardness and Ca²⁺ ions before and after filtration.

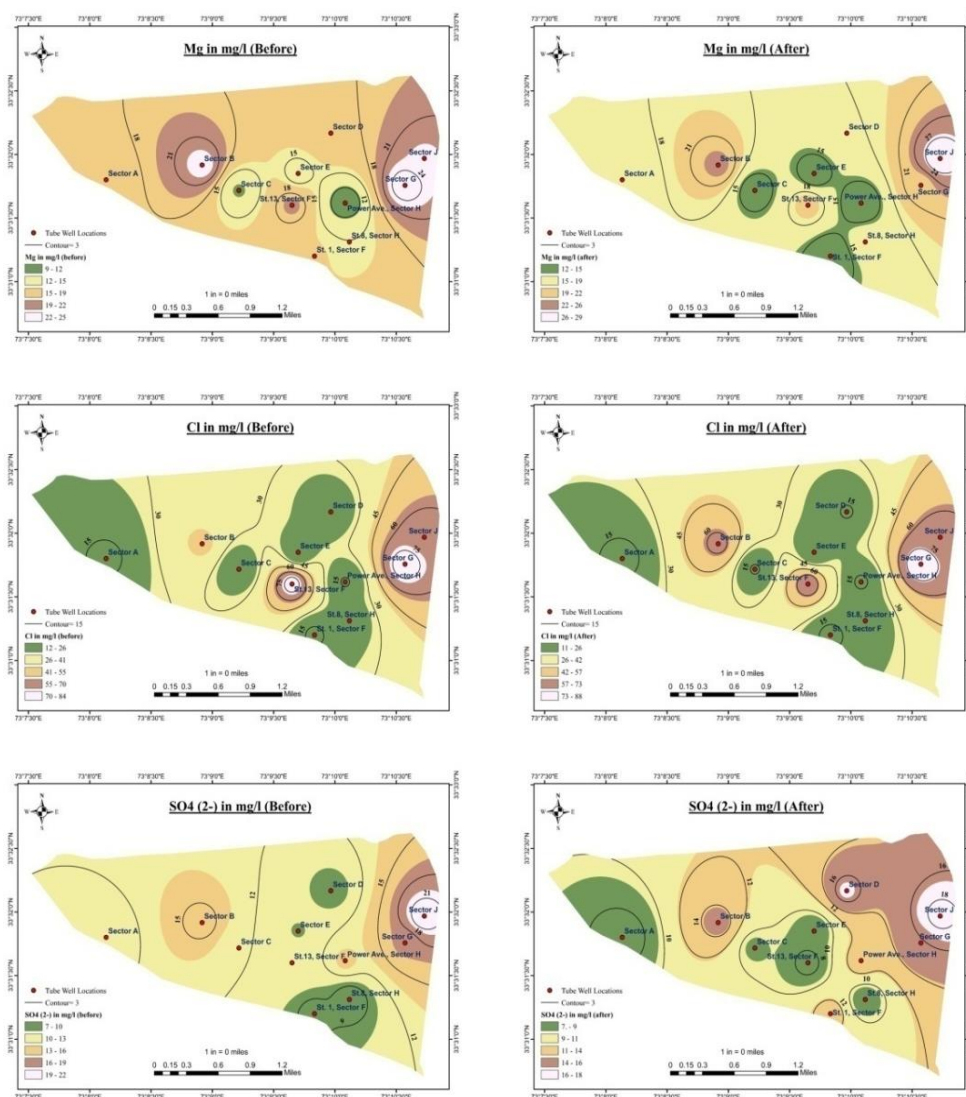


Fig. 5 (b) Interpolation map showing concentration of Mg²⁺, Cl⁻ and SO₄²⁻ ions before and after filtration.

Piper Analysis

The Piper diagram, a graphical representation for hydro-chemical analysis of water, comprises two triangles and one diamond, each representing different components. These overlapping triangles allow for the visualization of cations, anions, and the total dissolved solids (TDS) concentrations in water samples. The positioning of water samples on the Piper diagram revealed their hydro-chemical facies, characterized by predominant concentrations of Ca, Mg²⁺, Cl⁻, and SO₄²⁻ ions.

Prior to treatment, the water samples demonstrated a cation concentration characterized by a predominant calcium type, with approximately 65-76% Ca and 24-35% Mg. Following treatment, the water samples maintained a similar percentage distribution of calcium and magnesium, regardless with slight deviations as magnesium ranged from 25-38%, while calcium ranged from 62-75%. In terms of anion concentration, the water samples exhibited a chloride type composition on the Piper diagram before treatment. This composition consisted of 10-47% SO₄²⁻ and 53-95% Cl⁻ ions. Conversely, after treatment, there were minor variations in the anion concentration. The range shifted slightly to 8-51% SO₄²⁻ and 49-92% Cl⁻ ions as shown in Fig 6. Therefore, the treatment process resulted in marginal adjustments in the cation and anion concentrations of the water samples, maintaining the overall dominance of calcium and magnesium in the cationic composition and chloride as the primary anion.

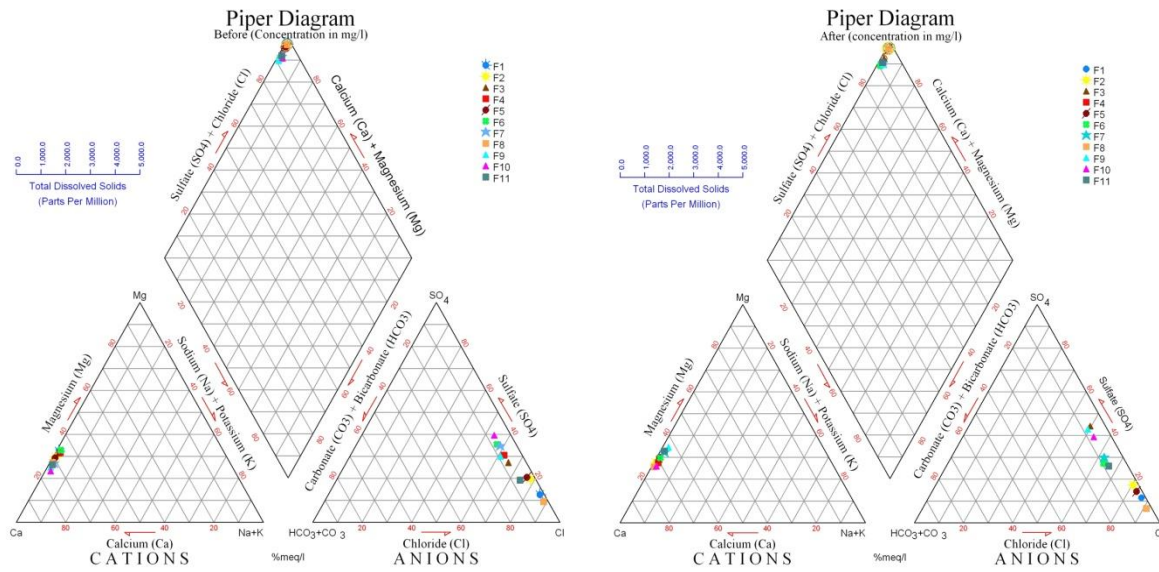


Fig. 6 Piper analysis for the distribution of anions and cations for the chemical analysis.

Water samples were analyzed for various contaminants, and the findings were mentioned in Fig 7 as Cadmium levels in the water samples fell within the range of 0 to 0.100 mg/l, with the highest concentration of 0.100 mg/l detected in sector F1. However, all cadmium samples exceeded the regulatory limit set by PAK-EPA, which is 0.003 mg/l. The iron concentrations in the water samples ranged from 0.005 to 0.100 mg/l, and the highest value of 0.093 mg/l was observed in sample S6. Fortunately, all iron samples remained within the permissible range according to PAK-EPA's standard of 0.3 mg/l. Lead concentrations in the water samples varied from 0.001 to 0.034 mg/l, with the highest reading of 0.012 mg/l in sample F10 (Sector H). It is worth noting that all water samples from sectors F1, F2, F4, and F5 complied with the PAK-EPA permitted limit of 0.010 mg/l. Sample F5 (sector B) exhibited the highest nickel concentration at 0.012 mgL⁻¹ as shown in Fig 8a However, nickel concentrations in samples F4, F6, and F9 surpassed the PAK-EPA threshold of 0.020 mg/l. Chromium concentrations were analyzed in comparison to the PAK-EPA standard limit of 0.050 mg/l. The results showed a range from 0 to 0.1043 mg/l, with the highest concentration recorded as 0.030 mg/l. Notably, samples from F3, F8, and F9 exceeded the PAK-EPA standard for chromium. Manganese (Mn) levels were assessed against the PAK-EPA normal limit of 0.500 mg/l shown in Fig 7 and 8b respectively. The investigation revealed concentrations ranging from 0.001 to 0.105 mg/l, with the highest concentration observed as 0.022 mg/l. Lastly, the PAK-EPA standard for zinc concentration in drinking water is 5 mg/l. The zinc investigation results indicated concentrations ranging from 0.0078 to 0.277 mg/l, with the highest value recorded as 0.039 mg/l mentioned in Fig 7. It is evident from the analysis that certain sectors exhibited concentrations of certain contaminants above the permissible limits set by PAK-EPA, raising concerns about the water quality in those areas.

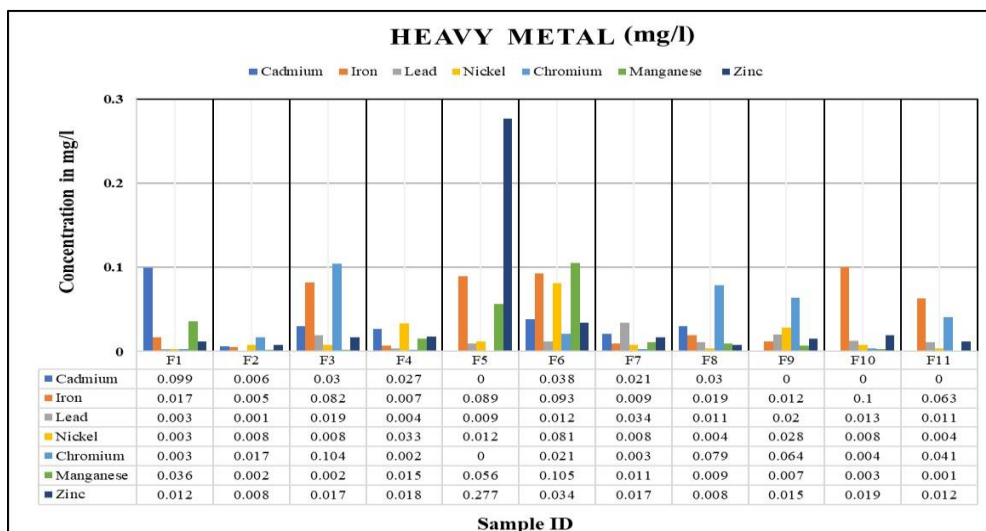


Fig. 7 Graphical representation of the results obtained by performing heavy metal analysis.

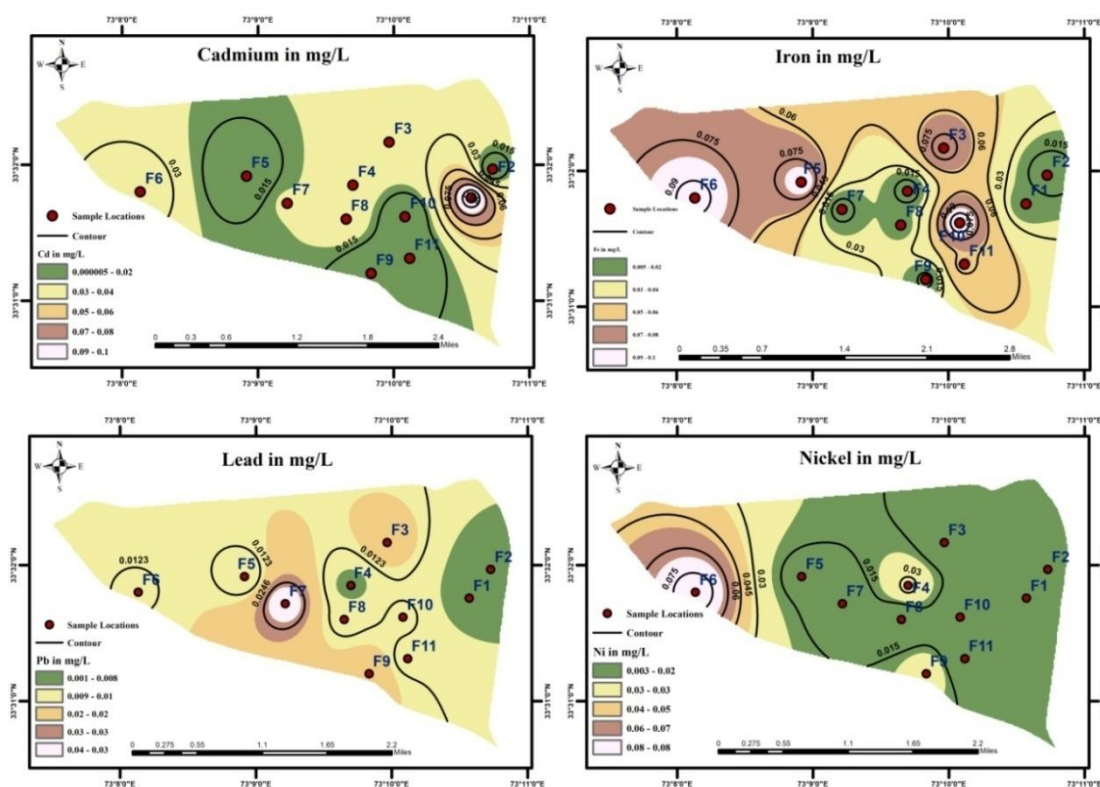


Fig. 8 (a) An Interpolation map displaying the concentration of cadmium, iron, lead and nickel in the samples.

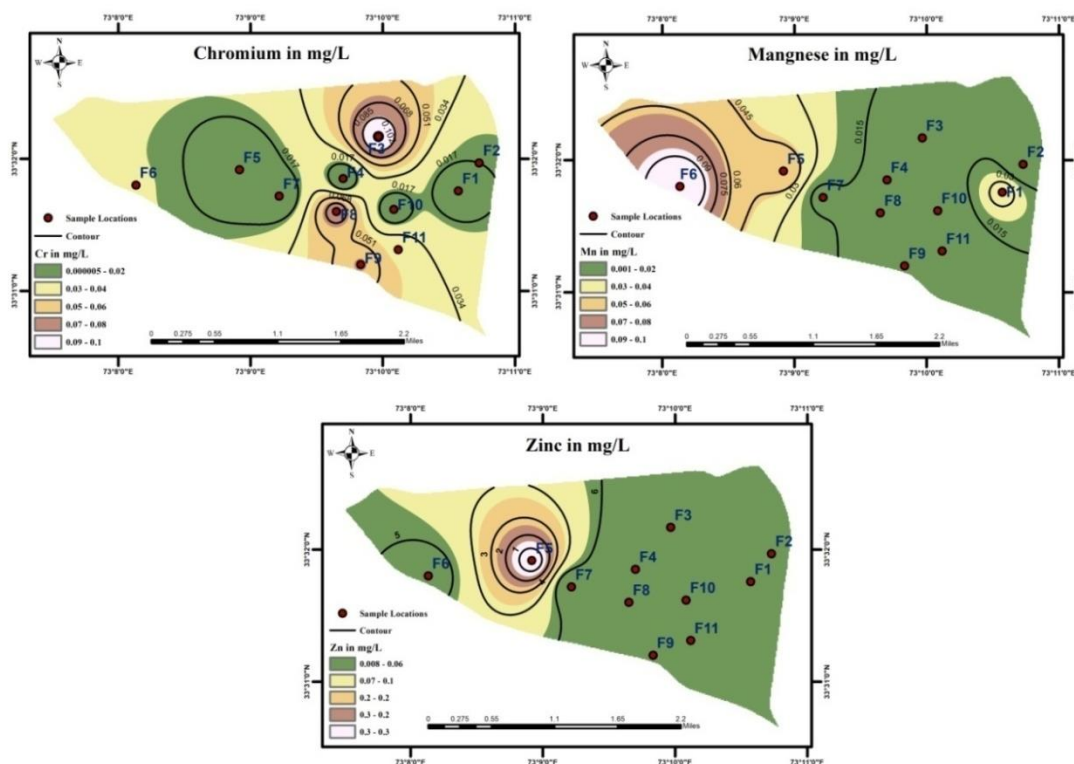


Fig. 8 (b) Interpolation map showing concentration of chromium, manganese and zinc in samples.

The presence of *E. coli* bacteria (table 3) was detected in the samples. Pre-filtration water samples from sectors G, J, A, F St 13, and H St 8 were found to have *E. coli*. *E. coli* was still found in water samples from sectors G, E, F St 13, H Power Avenue, and H St 8 after filtration in above mentioned table 3. Filtration facilities in sectors G, F, and H use filter paper, which must be replaced every six months owing to microbial contamination. Unfortunately, these facilities are incapable of removing *E. coli* properly. A rise in bacterial colonies suggests that sewage has contaminated the water.

The observed pH levels generally align with acceptable standards in all filtration plants as the standards prescribed by the PAK-EPA. However, in Fig 3 variations in TDS concentrations, especially in F1 and F2, raise concerns as high levels of TDS can pose health risks such as acute myocardial infarction and ischemic heart diseases (Muhammad *et al.*, 2011). Electrical conductivity values within PAK-EPA limits indicate no direct impact on human health. The comprehensive data before and after filtration assures the efficacy of treatment processes in maintaining safe electrical conductivity levels. Total hardness concentrations within PAK-EPA limits, except in F1, F2, and F6, highlight effective filtration. Calcium levels, crucial for human health, fall within permissible ranges pre and post-filtration, with the potential to prevent health issues like cardiovascular diseases (Soylak *et al.*, 2002). High concentrations of cadmium, lead, nickel, chromium, manganese, and zinc in certain sectors highlight the urgency for rigorous monitoring and regulatory measures to mitigate health risks associated with heavy metal exposure. Iron concentrations within the PAK-EPA limit indicate minimal risk, but its excess can lead to severe health issues, emphasizing the need for continued monitoring and control measures. Exceeding lead concentrations in specific filtration plants (F3, F6, F7, F8, F9, F10, and F11) underline the significance of addressing lead sources to safeguard multiple organ systems from potential deleterious effects as reported few cases in children from the study area. Nickel concentrations exceeding limits in F4, F6, and F9, along with chromium surpassing limits in F3, F8, and F9, demand immediate attention due to their harmful effects on skin and potential carcinogenicity. High manganese concentrations, especially in F3, F8, and F9, raise concerns about potential health effects, emphasizing the need for remediation to protect against growth depression and kidney damage. The absence of arsenic is reassuring, as its detection would have raised significant health concerns, including links to skin, bladder, and lung cancer, reinforcing the overall importance of regular water quality assessments and remediation strategies (Farooqi *et al.*, 2007).

Conclusion

In conclusion, the analysis of water quality parameters, heavy metal concentrations, and microbial contamination in DHA Phase II, Islamabad, indicates the need to be more concerned about the effectiveness of water treatment processes. The physicochemical parameters generally adhered to PAK-EPA standards, but high TDS and total hardness levels in specific filtration plants raised concerns. Heavy metal concentrations exceeded PAK-EPA standards, highlighting the need for rigorous monitoring and regulatory measures. The presence of *E. coli* bacteria in pre-filtration and post-filtration samples suggests persistent microbial contamination. The treatment process resulted in marginal adjustments, maintaining the overall composition but indicating potential sources of contamination from industrial and drainage activities. In light of these findings, it is imperative to address the identified challenges to ensure the provision of safe and potable water to residents. Improved filtration processes, continuous monitoring, and stricter adherence to regulatory standards are crucial in mitigating the impact of industrial activities and microbial contamination. Additionally, collaboration between relevant authorities, the community, and industrial stakeholders is essential to formulate effective strategies for sustaining water quality in DHA Phase II, Islamabad.

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