OPEN ACCESS

Kashf Journal of Multidisciplinary Research
Vol: 02 - Issue 11 (2025)
P-ISSN: 3007-1992 E-ISSN: 3007-200X
https://kjmr.com.pk

ASSESSMENT OF GROUNDWATER QUALITY AND CONTAMINATION SOURCES IN TALUKA MIRWAH, DISTRICT KHAIRPUR, SINDH

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Article Info

Abstract

This study was conducted to assess the physico-chemical and trace metal quality of groundwater from seven villages of Taluka Thari Mirwah, District Khairpur, by analyzing 47 sampling locations. The objective was to evaluate the suitability of groundwater for drinking and domestic purposes in accordance with WHO and EPA Pakistan guidelines. Standard analytical methods were employed to measure pH, total hardness (TH), electrical conductivity (EC), total dissolved solids (TDS), chlorides (Cl^-), sulfates (SO_4^{2-}), nitrates (NO_3–N), alkalinity, sodium (Na), calcium (Ca), and trace metals including manganese (Mn), nickel (Ni), zinc (Zn), copper (Cu), cobalt (Co), chromium (Cr), iron (Fe), and cadmium (Cd). Results indicated that pH values were within the permissible limits, while elevated levels of TDS (1440.5 mg/L), chloride (788.76 mg/L), sulfate (296.63 mg/L), TH (1168 mg/L), and alkalinity (733.33 mg/L) exceeded the WHO/EPA guidelines in several locations. Additionally, sodium and calcium reached 504 mg/L and 462 mg/L, respectively, surpassing recommended limits. Trace metal concentrations varied, with the highest levels detected as Mn (0.421 mg/L), Ni (0.105 mg/L), Zn (0.593 mg/L), Cu (0.49 mg/L), Co (0.023 mg/L), Cr (0.033 mg/L), Fe (0.808 mg/L), and Cd (0.01 mg/L). These elevated values, particularly from areas surrounding Taluka Thari Mirwah, suggest potential health risks and indicate groundwater contamination. In conclusion, while the pH values confirm neutral conditions, the high concentrations of salts and heavy metals raise serious concerns regarding the potability and safety of groundwater in the studied villages, necessitating mitigation measures and regular monitoring.

Keywords:

Atomic Absorption Spectrophotometer, contaminant, ground water, trace metals

INTRODUCTION

Drinking water is defined as water that is free of damaging minerals and pathogenic organisms; otherwise, it can lead to cholera, typhoid, kidney stones, and other illnesses. Water is very important drink for humans and all known forms of life. Drinking water should be appropriate not only for human utilization but also for washing and purposes since chemical and other components of the water would give a rise to economical harm also (Hussain et al., 2024). Millions of people die and are afflicted by international waterborne diseases, particularly children in developing nations (Iwar, Utsev, & Hassan, 2021; Jain, Yevatikar, & Raxamwar, 2022).Water quality analysis is a significant matter in groundwater research. It is regrettable to report that certain drinking water in several nations has been contaminated, affecting the people's health and financial situation. It is a fact that tainted water is one of the leading causes of death, accounting for 27,000 deaths daily in the world's poorest nations (Shar et al., 2020). Since they are inherent to the Earth's crust, heavy metals cannot be broken down or eliminated. They pass through our bodies in trace amounts through food, drinking water, and the air. Certain trace elements can be fatal in larger concentrations, even though they are necessary to maintain the human body's metabolism. Drinking water contamination can result in heavy metal toxicity (Pothuraju et al., 2025). Environmentalists, who are also proficient in multivariate statistical techniques, such as principal component analysis, cluster analysis, metal concentration analysis, and correlation analysis, can be useful instruments for determining the sources of contamination and allocating natural versus man-made contributions that are otherwise mixed (Mishra, et al, 2021). The direct disposal of waste materials onto the land surface is a major contributor to groundwater contamination. The garbage can form separate mounds or spread out over the ground (Murphy, et al, 2010; Umar, et al, 2023). Any metal with a density more than 5 gcm^{-3} is considered heavy metal. This word most frequently refers to hazardous metals. They consist of the elements Al, As, Cd, Cr, Co, Pb, Hg, Ni, Se, and Zn. Surface water can become contaminated by these metals or their compounds when they are released from farms, industry, municipal urban water runoffs, and agricultural operations. Large amounts of raw materials, by-products, co-products, and finished goods of human activity are among their many varieties. These pollutants, many of which are harmful, end up in the air, water, and sediments (Abubakar, Abubakar, Ja'afaru, & Yusuf, 2024). Due to their extremely low concentrations, heavy metals that are often found in nature do not pose a threat to our ecosystem. Nevertheless, these metals take on a harmful role if their levels exceed that required for a healthy lifestyle (Sirajudeen & Pravinkumar, 2021). Another significant source of water contamination is acid rain. Another significant water contaminant is acid rain. There are also a number of additional pollutants and contaminants found in water, such as iron (Fe), magnesium (Mg), lithium (Li), zinc (Zn), copper (Cu), chromium (Cr), nickel (Ni), cobalt (Co), vanadium (V), arsenic (As), molybdenum (Mo), selenium (Se), lead (Pb), and many more. Health professionals, government organisations, and environmentalists have all expressed concern about the existence of hazardous metals in the environment. This is mostly because of the health risks they pose as non-essential metals that offer little to no benefit to people (Babuji, et al, 2024). The excellent performance of the atomic absorption spectrometry, AAS as a precise and rapid analytical tool, permits the fast achievement of data on samples introduced into a flame. One of the attractive characters of the AAS technique is its ease of procedure (Tokatli, et al, 2024). Flame atomic absorption spectrometry (FAAS) is a well recognized, exceptionally precious technique for the purpose of trace amounts of metals analysis (Li & Yang, 2021).Drinking water of Taluka Thari Mirwah is contaminated because of it may be due to the usage of fertilizers, pesticides, insecticides, large number of brick chimneys and saline soil. Sixty million people are poisoned by excessive fluoride; dissolved from granite rocks in ground water can cause bone deformation in children. The world's most of the drinking water is contaminated with human sewage and pathogens as well as parasites. According to an estimate in 2006; 1.8 million deaths were causing each year due to contaminated drinking water. Piped network and hand pump for drinking water purpose in Pakistan is about 66% (Zhu, et al., 2022). According to an approximation that in Pakistan, 30% of all diseases and 40% of all deaths occur because of reduced water quality (Jayaraman, et al, 2024). In the country every fifth person suffers from diseases because of contaminated drinking water (Walling & Webb, 2024). Drinking water quality in our country is miserably low for the reason that; little attention, lack of drinking-water quality monitoring and surveillance programs, weak institutional measures and lack of well equipped laboratories (Addisie, 2022). Our main purpose of study is to report on the estimation of physicochemical and heavy metal of drinking water (ground water) samples from hand pumps of villages of Taluka Thari Mirwah under study.

Groundwater in the villages of Taluka Thari Mirwah, District Khairpur, Sindh, Pakistan is severely contaminated, making it largely unsuitable for drinking and other domestic uses. The primary contaminants are heavy metals, as well as a high concentration of dissolved solids, salts, and other minerals. This widespread contamination is a significant public health risk for the local population.The presence of contaminants like bacteria and high salinity contributes to a high prevalence of waterborne diseases such as diarrhea, cholera, and hepatitis. The lack of safe drinking water also places a significant burden on communities, especially in rural areas where alternative sources are often unavailable.

Materials and Methods

Study area

The climate of Thari Mirwah, located in District Khairpur, Sindh, Pakistan, is arid to semi-arid, featuring very hot, humid summers and short, mild winters. The temperature in summer is scorching, with average highs often going above 40∘C (104∘F) from May to July; June is typically the hottest month. Winters are brief and mild, with average daily highs below 27∘C (81∘F), and January is the coolest month. The region receives very little rainfall, with most precipitation occurring during the irregular monsoon season, which can sometimes lead to flash floods. The low rainfall combined with high evaporation rates contributes significantly to water scarcity. The primary source of aquifer recharge is seepage from the Indus River and the Mirwah canal irrigation system. Unfortunately, projects to line these canals have reduced this seepage, diminishing the "sweet water"recharge that once helped dilute contaminants, and as a result, the groundwater quality has declined even further in some areas.

Materials

All the reagents and chemicals were purchased from Fluka, Riedel de Haën, Merck, Fisher scientific, Sigma Aldrich and Labchem Products. Four calibration standards for each metal (Cu, Cr, Cd, Co, Fe, Mn, Ni, and Zn) were prepared. Reagent blanks were prepared to adjust the instrument at zero reading. For this purpose de-ionized water and double distilled water were used to prevent interferences.

Sample Collection

Forty seven samples of drinking water were collected from seven sampling points of area under study. Study areas include seven villages; Village NandhiThari, Village Hamad Abad, Village Deparja, Village Ghazi Khan, Village Yar Mohammad Pathan, Village Khariri and Village Nawab Din Shar of Taluka Thari Mirwah as shown in figure 1. Main source of drinking water in this area is ground water, which is used for drinking, cooking, agricultural and washing purposes. Before sample collection; plastic bottles were washed with detergent, soaked overnight and rinsed with de-ionized water. Hand pump was run till fresh water, rinsed three times with same sample; samples in triplicate from each sampling point were taken in 1.5 L capacity of plastic bottles. The pH, temperature (^{0}C), and EC (µS/cm) were recorded on the spot. Samples were labelled properly and transported to the laboratory for heavy metal analysis.

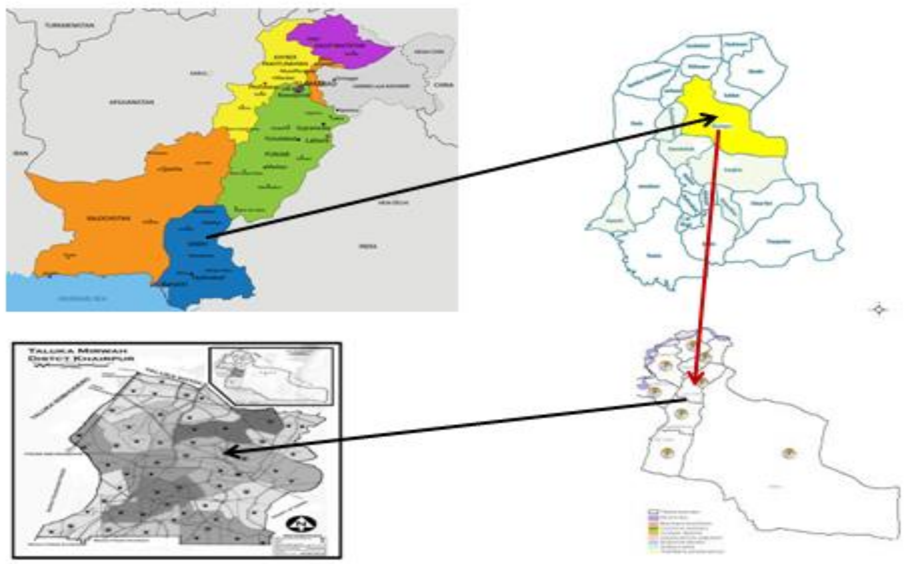

Figure: 1 Sampling Location for the Groundwater Analysis

Sample Preparation

The samples were brought and prepared in Shah Abdul Latif University Khairpur, in the Department of Chemistry to conduct the research work. For heavy metal analysis; 250 mL of each sample of ground water was taken into 500 mL beaker, heated on electric hot plate below boiling point to about 80 ^{0}C, and volume was reduced to about 25 mL in measuring flasks. To preserve the sample, 1 mL of pure HNO3 was added. De-ionized water was added to bring the volume up to par. To avoid contaminating the samples, all glassware were treated with 5M HNO_3, then cleaned with distilled water and then de-ionized water. Samples were taken for examination of heavy metals after being filtered with Whatmann # 42 filter paper.

Preparation of Standard Solutions

For standard solutions (1000mg/L) preparations, specific amount of metal (salt) of under study elements were weighed accurately on chemical balance (Metler Toledo Germany). The weighed amounts of metal salts were transferred into a 100 mL volumetric flask, for metal dissolution de-ionized water was used. Cr Chromium (III) nitrate monohydrate >98.00%, Cd Cadmium chloride dihydrate >98.00% ,Co, Cobalt(II) chloride, Cu Copper (II) Sulfate pentahydrate, Fe Fe(II) sulfate, Ni Nickel (II) acetate dihydrate 98%, Mn Manganese (II)sulfate monohydrate >98%, Zn Zinc chloride 98.00%, HNO_3 Nitric acid 68.50-69.50% HCl Hydrochloric acid 37.00-38.00%, H_2SO_4Sulfuric acid 95-97%.

Analyses

Physicochemical parameters, such as total hardness (TH), chlorides (Cl^{-1}), total alkalinity respectively were detected by standard methods whereas; sulphates (SO_4^{-2}) and nitrates (NO_3^{-1}) at wavelengths of 420 nm and 410 nm by using UV-Visible Double Beam Spectrophotometer (Cecil-1900). Using an atomic absorption spectrophotometer (Perkin Elmer AA Analyst-100) manufactured by the Perkin Elmer Company, heavy metals such as Na and Ca were examined. The corresponding hollow cathode lamps (Perkin Elmer LUMINA TM Shelton, CT 06484-4794 USA) were employed and set with related hollow cathode lamps, and a flame made of an acetylene/air mixture was used to analyse the quantity of elements under research. Every metal underwent three measurements.

Results and Discussion

Physicochemical Analysis

In Taluka Thari Mirwah total seven villages and 47 sampling points were selected for study. In the Table: 1 and figure: 2, percent level of each parameter under study is given. Water quality test methods of physicochemical parameters are given in the table 2.Statistical normal distribution of physicochemical parameters for 47 samples is mentioned in Table3.

pH

The activity of hydrogen ions is measured by the pH. The pH levels fell between 6.81 and 8.4, which is within the WHO and EPA's acceptable range. The EPA states that corrosion and a harsh, metallic taste are the two most evident consequences of a pH below 6.5. A pH exceeding 8.5 can be seen to cause deposits, a slippery feeling, and a soda-like flavour. The pH of adjacent water sources is negatively impacted by a variety of human activities. Acid rain can result from the emission of sulphur dioxide and nitrogen oxides from cars and industrial processes (World Health, 2022).

Electrical Conductivity

An electrolyte's conductivity in solution is a measurement of how well it conducts electricity. The table No:3 indicates the results; that maximum and minimum conductance of 2810 µS/cm and 280µS/cm in samples TM-214 and TM-158 respectively. It is evident from the figure: 3 (a) that EC of only three samples were found below than 500 mg/L; whereas EC amounts above than 1000 mg/L were determined in 25 samples. The figure 3 (a)shows that 50% water samples are polluted by higher amounts of EC(Jayaraman et al., 2024; Walling & Webb, 2024).

Total Dissolved Solids

Total dissolved solids, or TDS, is a measure of the overall concentration of dissolved materials in water. The highest TDS of1882.7mg/L is shown by the sample no: TM-214. (Yıldırım & Koçan, 2023). Figure 3(b) points out that the concentration above than 1000 mg/L was obtained in 15 samples; while it was below than 500 mg/L in 12 samples. The figure 3(b) indicates that 70% samples showed the TDS levels below than WHO recommended level.

Chlorides

The maximum and minimum concentration of Cl^{-1} of 788.76 mg/L and 11.82 mg/L was determined in the samples TM-214 & TM-167.The higher concentration of chlorides may cause gastrointestinal problems, irritation and dehydration. A perceptible taste in water can result from chloride concentrations over around 250 mg/L, however the threshold is dependent on the related cations (Tahraoui, Belhadj, Hamitouche, Bouhedda, & Amrane, 2021).The figure: 3 (c) indicates that only six samples showed the higher level of chlorides than WHO specified level of 250 mg/L; all the remaining samples determined were below this level. The 87% samples were found safe; which can be observed from the figure: 3 (c)

Sulfate

Sulfate content above WHO permissible limit (250-500 mg/L) gives bitter taste to the drinking water and have laxative effect on people not adapted to the water. The highest concentration of SO_4^{-2} of 296.63 mg/L was determined from the sample no: TM-261 and the minimum of 41.94mg/L in the sample no: TM-219. In figure: 3 (d) it is obvious that only five samples displayed the sulfate concentration above than 250 mg/L; In the remaining samples, the sulphate content was below the WHO-recommended limit. Figure 3(d) shows that 87% of the water samples were found to be safe and sound (Gachie-Lopokoiyit & Umphrey, 2025; Xianhong, Shijun, Jian, & Jie).

Nitrate-Nitrogen

The excess of Nitrate-N above 10 mg/L causes blue baby disease in children up to the age of four months and is also harmful for pregnant women. Its concentration in all the samples in area under study was below than 10 mg/L WHO/EPA guidelines. It's important to know that boiling water does not reduce nitrates; whereas it causes some of the water to evaporate, which increases the concentration of nitrates in the remaining water (Marhamati, Afshari, Kiani, Jannat, & Hashemi, 2021).

Total Hardness

According to WHO (2004) classification of hardness of water is given as; soft (0-50 mg/L $CaCO_3$), moderate soft (50-100 mg/L $CaCO_3$), Moderate hard (150-200 mg/L $CaCO_3$), Hard (200-300 mg/L $CaCO_3$), and very hard (over 300 mg/L $CaCO_3$). The highest level of total hardness of1168.33 mg/L was analyzed in the sample no: TM-214 mg/L, where as its lowest value of 48.3 mg/L was found in sample no: TM-167 (Adjovu, Stephen, James, & Ahmad, 2023; Ananda, 2023). Round about 26% of the total water samples under study were found highly polluted due to the presence higher amounts of TH; which can be estimated by looking at figure 3 (e)

Alkalinity

The WHO recommends alkalinity levels of 120 and 600 mg/L, respectively. An alkalinity value of 733.33 mg/L was found to be the maximum in samples TM-211 and TM-212. With sample number TM-158, the lowest level of 166.67 mg/L was found. Alkalinity is the "buffering capacity" of the water, and low alkalinity in areas with a substantial amount of granites, some conglomerates, and sandstones can lead to low buffering capacity (Almasoudi & Jamoussi, 2024). Figure 3(f) demonstrates that 14 samples are polluted because their alkalinity levels above the WHO recommended limit of 500 mg/L. About 70% of the water samples were deemed safe because of their lower alkalinity levels, as seen in figure 5(vi).

Metals in Ground Water Samples

Results of the AAS analysis (mg/L) of Na, Ca, Mn, Ni, Zn, Cu, Co, Cr, Fe and Cd in ground water samples from the study area are given in box plots and scatter plots in the figures 4(i) to 4(x) and figure 6(i) to 6(x). Statistical normal distribution of chemical parameters of 47 samples is calculated in Table: 4.

Sodium

Numerous man-made sodium sources, such as road salt, water purification chemicals, household water softeners, and wastewater effluents, can add substantial amounts of sodium to surface water (Mente, O'Donnell, & Yusuf, 2021). The maximum concentration of sodium was found in samples: TM-209, TM-210, TM-211 and TM-214 and TM-260 as 278.181 mg/L, 245.644 mg/L, 274.352 mg/L, 504.028 mg/L and 226.505 mg/L which exceeds the WHO maximum permissible limit (200 mg/L). Figures 4(i) and 6(i) show that about 94% of the water samples were determined to be within the WHO guideline range.

Calcium

Calcium is important for living organisms. Calcium is the richest metal by mass in many animals, as a major substance used in mineralization of skeleton and shells. Low serum calcium levels are a sign of hypocalcaemia, or calcium shortage. Long-term calcium insufficiency may cause rickets, osteoporosis, cataracts, dental abnormalities, and changes in the brain. Maintaining bone health throughout life requires consuming enough calcium (Kiani et al., 2022).Samples TM-215, TM-217, TM-218, TM-219, TM-220, TM-221 and TM-222 displayed the higher level of calcium than permissible Limit as 205.114, 342.013, 320.658, 316.654, 292.630, 307.312and 331.336mg/L respectively. Figures 4(ii) and 6(ii) shows that 85% drinking water samples declared calcium levels within WHO range.

Manganese

Manganese is a necessary element for the body, but the amount of exposure to it is critical. While small doses of manganese may offer a neuro-protective effect by decreasing cell death, excessive exposure can lead to serious neurological disorders like Alzheimer's and Parkinson's disease. These conditions are characterized by cell death and a disruption of the body's internal balance, or homeostasis. The body regulates its manganese levels through receptors and ion channels that manage intake, storage, and excretion. When there's too much manganese, the body reduces the receptors that absorb it and increases those that excrete it. However, if manganese levels continue to build up, they can cause the formation of reactive oxygen species (ROS), which damages mitochondria. This mitochondrial dysfunction triggers a chain reaction that leads to programmed cell death, also known as apoptosis. Specifically, it releases cytochrome c, which activates a series of enzymes called caspases, ultimately leading to DNA fragmentation and the death of the cell (Mitra et al., 2022).

The Standard Organisation of Nigeria states that Mn is a hazardous substance that can lead to neurological conditions in people. Only 0.2 mg/L is permissible level of Mn, above this may cause health hazards. The nos: TM-251 (0.275 mg/L), TM-214 (0.421 mg/L), TM-215 (0.224 mg/L), TM-218 (0.242 mg/L) and TM-219 (0.291 mg/L) showed higher concentrations of Mn than permissible level, while the rest of samples have WHO safe limit of Mn. The higher level of Mn in ground water may be from natural sources. Figures 4(iii) and 5(iii) notify that 83% samples are found within secure levels of WHO.

Nickel

Based on studies of occupational exposure, nickel's primary toxic effects appear to target the respiratory tract following inhalation, the skin after direct contact, and the reproductive system after oral exposure. Nickel is a known carcinogen and can also cause sensitization reactions in humans. It also possesses embryotoxic and teratogenic properties and can cross the placenta. Furthermore, studies show that nickel exposure can decrease levels of other essential minerals, such as magnesium, manganese, and zinc, and that nickel and zinc have an antagonistic relationship in both animals and humans (Begum et al., 2022).

WHO limit of Ni in drinking water is 0.02 mg/L. Most of the drinking water of area under study is contaminated with higher concentration of Ni. Maximum of 0.105 mg/L of Nickel was analyzed from sample TM-217. Figure 4 (iv) Dot plot indicates that 25 samples showed nickel content above the fixed level. The box plot of nickel in figure 6(iv) suggests that 62% of samples were contaminated due to the higher levels of nickel.

Zinc

Zinc is a crucial mineral for body development. An essential mineral that is vital to health, zinc is linked to cellular metabolism. More than 200 enzymes require zinc to operate properly, and it is essential for healthy growth and development, immunological system function, DNA and protein synthesis, and cell division. Severe zinc insufficiency has been seen in individuals with inherited zinc metabolic diseases such as acrodermatitis enteropathica and in patients receiving intravenous zinc-deficient solutions. Symptoms of zinc deficiency can include skin lesions, diarrhoea, poor appetite, night blindness, decreased taste and smell acuity, hair loss, low sperm count, impotence, sluggish wound healing, and increased susceptibility to infection(Kiani et al., 2022).Analyses indicated that in all the samples concentration of Zn was below WHO guideline Higher and lower level of (0.220 mg/L and 0.020 mg/L) Zn was found in the samples TM-215 and TM-205 respectively. Figure 4(iv) and 5(iv) announces that all the samples regarding study area are found below prescribed limit.

Copper

It is commonly recognised that Wilson's illness causes copper to build up in the liver. Since elevated copper levels can result in oxidative stress, hepato copper deposition is both pathogenic and pathognomonic. In cholestatic liver disorders, elevated hepatic levels of copper are also noted. However, they are not a source of hepatic infection and instead arise from decreased biliary excretion of copper (Mitra et al., 2022). All of the samples had copper levels below the WHO maximum allowable limit of 2.0 mg/L. Sample TM-206 had the highest copper concentration, measuring 0.049 mg/L, while sample TM-255 had the lowest, detecting 0.006 mg/L. The dot plot given in figure 4(vi) shows that concentration range of copper. P-value is below than 0.005 so our results are significant.

Cobalt

Cobalt, which is used to create alloys, is abundant in the environment and can be found in rocks, water, flora, and soils. Even if it doesn't release much, it poses a serious risk to people. The human body is impacted by cobalt in both positive and negative ways. Massive releases into the ecosystem can be lethal, while small quantities of cobalt often have no detrimental effects. In contrast to other cardiomyopathy conditions, cobalt exposure results in reversible systolic heart depression. Cobalt can cause gradual, deadly cardiomyopathy. Nonetheless, survivors' heart function typically recovers (Mitra et al., 2022). Maximum allowable concentration of cobalt according to WHO/EPA guideline is 0.1 mg/L. Maximum and minimum values of Co analyzed were 0.023 mg/L and 0.00 mg/L in the sample TM-262 and TM-213 respectively. The figure 4(vii) signifies that all water samples were below than WHO limit. The significant results were obtained for cobalt because of the P-value is less than 0.005 at 95% confidence level.

Chromium

Chromium is a poisonous and carcinogenic element. Both chromium (III) and chromium (IV) (VI) are stable oxidation states found in the environment. One of the less dangerous forms of chromium is chromium (III). In the course of industrial activities, they can interconvert to one another. On the other hand, because chromium (III) is less poisonous than chromium (VI), its conversion is less environmentally damaging. Numerous companies that are harmful to local climates employ chromium. The ferrochrome business emits the most chromium when compared to the environment's natural emissions (Mitra et al., 2022).The chromium concentration in selected study area was found to be 0.033 mg/L in sample TM-220 which was below WHO maximum permissible guideline. Minimum of 0.007 mg/L of Cr concentration was displayed by the samples TM-158 and TM-162. From Figure 4(viii), it is evident that all samples showed the chromium content below the WHO level. Figure: 6(viii) shows that concentration of chromium in all samples was below than WHO level.

Iron

Iron (Fe) is naturally plentiful in earth’s crust. Iron is found very important element for animals and plants. Many important proteins and their major functions, oxygen storage and transport are carried out by iron. Premenopausal women and small children are particularly at risk for iron insufficiency, which is the most common nutritional shortfall. Depletion of iron reserves results in microcytic hypochromic anaemia, which is characterised by smaller red blood cells with less haemoglobin than normal red blood cells. Iron is a major contributor to haemoglobin formation. Fatigue, apathy, weakness, paleness, trouble breathing when exerted, and a decreased ability to withstand low temperatures are all signs of anaemia (Kiani et al., 2022).The highest concentration of 0.808 mg/L of iron was detected in the sample TM-159 which was above WHO maximum limit (0.3 mg/L). The minimum of 0.013 mg/L of iron was declared in studied villages which can be observed from the figure 4 (ix). The box plot of iron {figure 6(ix)} signifies that 98% of water samples were found within secure levels of WHO. P-value for iron is less than 0.005 so; the results are significant at 95% confidence level.

Cadmium

Neurotoxicity from cadmium exposure results in a variety of neurodegenerative illnesses, including multiple sclerosis, Parkinson's disease, Alzheimer's disease, and amyotrophic lateral sclerosis. This toxicity has a significant negative effect on the central nervous system (CNS) and peripheral nervous system (PNS), leading to a number of clinical problems. Learning impairments, neurological disorders, mental retardation, peripheral neuropathy, and olfactory dysfunction are among the symptoms. Additionally, it affects motor function and modifies behaviour in both children and adults. On a cellular level, cadmium disrupts normal cell activities like differentiation, proliferation, and death. The neurotoxicity of cadmium is largely due to apoptosis (programmed cell death) in neural cells, which is triggered by factors such as impaired neurogenesis, inhibited neuron gene expression, epigenetic effects, and endocrine disruption(Mitra et al., 2022).Cd is toxic and carcinogenic metal. The samples TM-251 to TM-256 (n=6), TM-198 (n=1), TM-201(n=1), TM-205 toTM-213(n=9), TM-216 to TM-222 (n=7), and TM-258 to TM-262 (n=5) showed the higher concentration of cadmium. Out of 47 samples 35 were contaminated by cadmium. Eighteen samples were found to have cadmium levels below the WHO threshold of 0.003 mg/L, as shown in figure 4(x); the lowest and maximum values are 0.010 and 0.001 mg/L, respectively. Box plot of cadmium given in the figure 6(x) indicates that 38% samples are free from cadmium contamination; the significances of the results at 95% confidence level was observed.

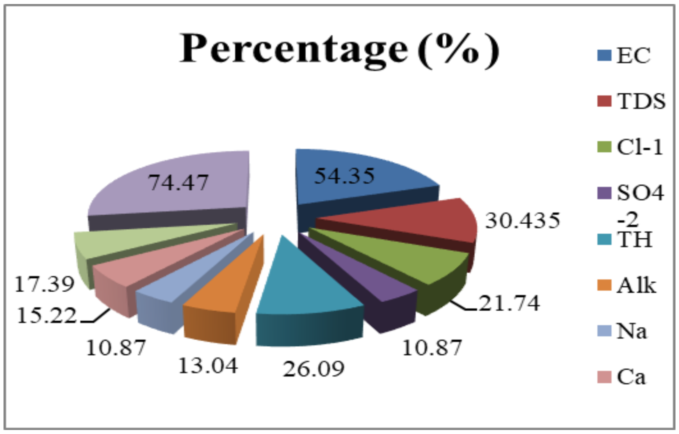

Figure: 2. Percent Level of Contamination of Studied Parameters of Drinking Water

Table: 1 Sample Collection sites from Taluka Mirwah, District Khairpur

S. No	Village Name	No. of Samples
1	Village Nandhi Thari,	7
2	Village Hamad Abad	9
3	Village Deparja	8
4	Village Ghazi Khan	6
5	Village Yar Mohammad Pathan	3
6	Village Khariri	8
7	Village Nawab Din Shar	6

Table: 2. Water Quality Test Methods of Physicochemical Parameters

Parameters	Symbol	Test methods	Unit	WHO Limit
Hydrogen Ion Concentration	pH	Potentiometric	pH	6.5-8.5
Electrical Conductance	EC	Conductometric	µS/cm	2000
Total Dissolved Solids	TDS	TDS meter	mg/L	1000
Total Alkalinity	TA	Titrimetric	mg/L	500
Total Hardness	TH	EDTA Titrimetric	mg/L	300
Sulfates	$SO4^{-2}$	Turbidimetric	mg/L	250
Nitrate-N	$N\text{-}NO_3^{-1}$	UV/Visible Spectrophotometric	mg/L	50
Chlorides	Cl^{-1}	Argentometric	mg/L	250

Table: 3 Statistical Normal Distribution of Physicochemical Parameters (N = 47)

	$[H^+]$	EC	TDS	Cl^{-1}	SO_4^{-2}	P	$NO^{-1}{}_3\text{-N}$	TH	TA
Max	8.39	2810.0	1882.7	788.8	296.63	0.490	3.564	1168.33	733.33
Min	6.81	280.0	187.6	11.8	41.94	0.002	0.000	48.33	166.67
Mean	7.54	1239.6	830.5	168.3	162.49	0.024	0.357	279.33	453.96
Median	7.52	1080.0	723.6	127.0	157.70	0.014	0.041	165.00	450.00
Mode	7.52	830.0	556.1	121.1	150.20	0.002	0.000	115.00	433.33
SD	0.39	614.6	411.8	143.0	64.84	0.070	0.718	270.67	132.00

Table: 4 Descriptive Statistics of Metals from Ground Water of Taluka Thari Mirwah (n = 47)

Variable	Na (mg/L)	Ca (mg/L)	Mn (mg/L)	Ni (mg/L)	Zn (mg/L)	Cu (mg/L)	Co (mg/L)	Cr (mg/L)	Fe (mg/L)	Cd (mg/L)
Max	504.028	462.800	0.421	0.105	0.602	0.279	0.023	0.033	0.808	0.010
Min	4.487	14.353	0.002	0.000	0.017	0.006	0.000	0.007	0.013	0.001
Mean	103.401	106.783	0.061	0.030	0.141	0.028	0.011	0.016	0.068	0.005
Median	75.301	61.066	0.017	0.027	0.106	0.010	0.010	0.016	0.045	0.005
Mode	71.472	41.046	0.007	0.000	0.028	0.011	0.016	0.016	0.035	0.006
SD	91.551	107.951	0.093	0.026	0.136	0.041	0.004	0.005	0.114	0.003
WHO Limit	200	200	0.05	0.02	3.00	2.0	0.1	0.05	0.3	0.003

Table: 5 Correlation Coefficient Among Physicochemical Parameters

Variable	EC	TDS	Cl^{-1}	SO_4^{2-}	TH	TA
EC	1					
TDS	1.000**	1				
Cl^{-1}	.692**	.692**	1			
SO_4^{2-}	.326*	.326*	.460**	1		
TH	.776**	.776**	.509**	.144	1	
TA	.420**	.420**	.564**	.387**	.058	1
****. Correlation significant 0.01** and 0.05 *level-2**						

Correlation Coefficient Among Physicochemical Parameters

The hypothesis was tested and the metal distribution was examined using the method of statistical analysis (correlation coefficient), and the findings are compiled in Tables 5 and 6. Extremely strong positive correlation of 1.000 was found between total dissolved solids and conductance which was significant at the 0.01 level; it may indicate the similar source of pollution. Strong positive correlation of 0.692 was also observed between chlorides and conductance, chlorides and TDS. Strong positive correlation which was significant at the 0.01 level was calculated as; 0.460between sulfates and chlorides, 0.776between TH and conductance, TH and TDS, 0.509between TH and chlorides, 0.420 between alkalinity and conductance, alkalinity and TDS 0.564between alkalinity and chlorides, 0.387 between alkalinity and sulfates. The results are summarized in the Table 5.

Table: 6Correlation Coefficient Among Different Metals Under Study

Variable	Na	Ca	Mn	Ni	Zn	Cu	Co	Cr	Fe	Cd
Na	1.000									
Ca	0.502	1.000								
Mn	0.456	0.812	1.000							
Ni	0.355	0.418	0.322	1.000						
Zn	-0.243	-0.149	-0.028	0.120	1.000					
Cu	-0.187	-0.143	-0.043	-0.179	0.280	1.000				
Co	-0.049	-0.157	-0.020	-0.055	-0.117	-0.096	1.000			
Cr	0.295	0.550	0.459	0.130	-0.256	-0.304	0.134	1.000		
Fe	-0.147	-0.006	-0.022	-0.202	0.016	-0.073	0.064	0.161	1.000	
Cd	0.172	0.161	0.121	-0.020	-0.209	-0.047	-0.069	0.372	0.199	1.000

Correlation Coefficient Among Chemical Parameters

The activity and source of the total metal quantities in drinking water were determined by correlating them with each other and with different pairs of elemental components. It is possible that sodium and calcium share a same mineral source in ground water, as evidenced by the significant positive relationships found between sodium and calcium and manganese, calcium and manganese, and nickel and chromium. While cobalt showed a negative association with all of the metals, zinc showed a negative correlation with sodium and calcium, and copper with sodium, calcium, and nickel. Table 6 shows the correlation coefficient among chemical parameters.

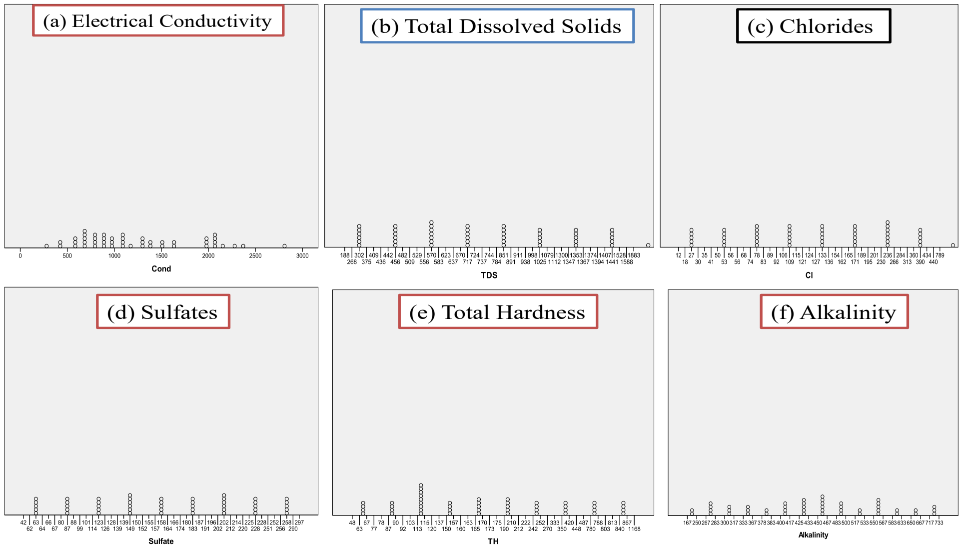

Figure: 3 Dot Plots of Physicochemical Parameters

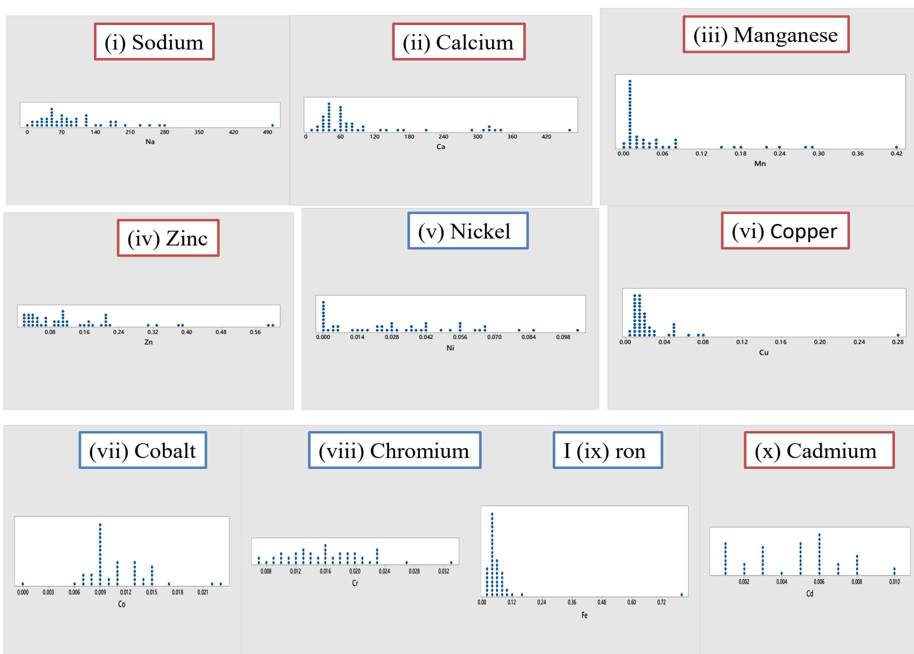

Figure: 4 Dot Plots of Chemical Parameters:

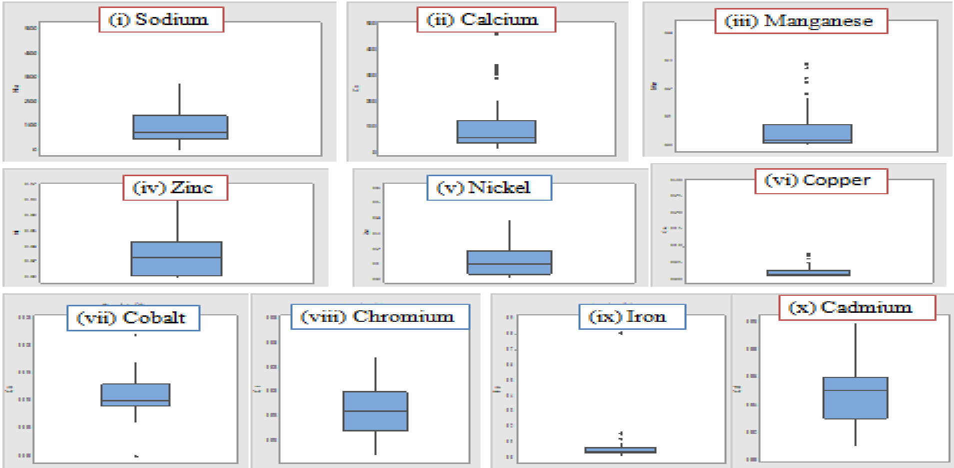

Figure: 5 Box Plots of Chemical Parameters

Conclusion

Physicochemical and trace metals of drinking water samples from ground water of villages; Village NandhiThari, Village Hamad Abad, Village Deparja, Village Ghazi Khan, Village Yar Mohammad Pathan, Village Khariri and Village Nawab Din Shar of Taluka Thari Mirwah were analyzed. The analytical results obtained indicate that the concentration of pH, Phosphate-P, Nitrate-N, Ni, Zn, Cu, Co and Fe were within the safe limit, below WHO maximum contaminant Level. Other parameters declared the upsetting level above WHO maximum guidelines. Which include EC (n=25), TDS (n=14), Cl^{-1} (n=10), $SO4^{-2}$ (N=5), TH (n=12), Alkalinity (n=6), Na (n=5), Ca (n=7), Mn (n=8) and Cd (n=27). It is observed from the above data that Cd is the only contaminant which is present in most of the samples and is health hazard for people who are using this water for domestic purpose. It is also concluded from the analysis that most contaminated drinking water is from the Village Khariri. The physicochemical and trace metals badly affect the quality of ground water is probably to occur from many of sources. It is strongly recommended that for quality of ground water; special measures should be taken to save from contamination. The aim of this study was to assess the physicochemical and contaminant level of ground water of seven villages of Taluka Thari Mirwah to estimate fitness for drinking purpose in agreement to the WHO/EPA standards for drinking water.

Author Contribution

Abdul Raheem shar conceptualized, collected samples, designed experiments, Abdul Qadeer and Sahib Ghanghro, collected data and prepared the draft of the article Noor Zaman and Noorul Hassan interpreted the data Sanam Rahujo and Rubina Naz Mirani, performed water analysis. Prof. Dr. Ghulam Qadir Shar supervised the whole work. All authors read, revised, and approved the final version of the manuscript.

Acknowledgements

The authors acknowledge the facilities provided by the Institute of Chemistry, Shah Abdul Latif University Khairpur and also technical support provided by department of water quality laboratory Pakistan Council of Research in water resources.

Conflict of Interest

The authors declare no conflict of interest

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