A Base Line Survey on the Status of Quality of Drinking Water Resources and Its Contaminants of theDistrict Shaheed Benazirabad, Sindh, Pakistan

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Abstract

Objective: The present study was performed to assess drinking water quality and its impacts on health risk assessment in the District Shaheed Benazirabad, Sindh, Pakistan.The study can also provide information about the possible causes of water pollution to increase the public awareness.

Study Design: Experimental and Descriptive Cross-sectional Study.

Place and Duration of the Study: All the experiments was carried out at Water Testing & Research Laboratory, Department of Community Medicine, PUMHSW-Nawabshah.The study aimed to analyze the groundwater samples were collected from Taluka Sakrand, District Shaheed Benazirabad from Jan. 2018 to Mar. 2018.

Material and Methods: Local residents of the Taluka are using bore wells, electric pumps, hand pumps and tube wells. One hundred and sixty five (165) groundwater samples were collected from Taluka Sakrand. Analysis of different chemical characteristics of water samples was performed with portable conductivity meter Orion Star A 322 in the field. pH was measured by portable Orion Star A 321 pH meter.Alkalinity, total Hardness, Cl, SO_4, Na, K, Ca, Mg, Cu, Co, Mn, Zn, Fe, Pb, Ni and Cd were estimated by (HACH) DR 3900 Spectrophotometer. Arsenic was estimated using (Merck Arsenic field testing Kit (0.01-0.5 mg/l) Darmstadt, Germany).

Results: The results; this work reports the analysis of groundwater samples from District Shaheed Benazirabad located at the center of Sindh Province. The samples analyzed were compared with standard values of WHO for drinking water.The physical & chemical parameters of the groundwater samples had the ranges, pH 6.52-8.31, electrical conductivity 357-3780 µS/cm total dissolved solids (TDS) 228-1996 mg/L, HCO_3 94-1190 mg/L, total hardness (TH) 115-1275 mg/L, chloride 35-582 mg/L, SO_4 24-697 mg/L respectively. The concentration of essential metal ions (Na, Ca, Mg and K) was found in the ranges 30-682 mg/L, 15-283 mg/L, 13-186 mg/L and 3-62 mg/L respectively. The concentration of Heavy metals was found in the ranges Cu 30-1690 µg/L, Co 2-45 µg/L, Mn 5-198 µg/L, Zn 20-300 µg/L, Fe 40-925 µg/L, Pb 3-125 µg/L, Ni 5-90 µg/L, Cd 3-35 µg/L and As 5-100 µg/L.

Conclusion: The analysis revealed that in a number of ground water samples (50.30 %) studied majority of the parameters were above the upper limit prescribed by WHO. A large number of sites had groundwater samples which were highly contaminated with toxic metals. The high salt concentration in the drinking water of Taluka Sakrand suggests a further research work and some action plans must be implemented to resolve this problem. The results of the examination would make environmental awareness to people of the study area.

Keyword: Physico-chemical parameters, Drinking water quality, Arsenic contamination, Heavy metal concentrations.

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INTRODUCTION

In the Province of Sindh, drinking water mostly comes from surface water and less from groundwater, because groundwater in the major portion of the province is saline and unsuitable for drinking. The majority of water supply schemes are not functioning properly. A chemical symphony of groundwater is governed by anthropogenic activities; composition of rainfall, mineralogy and geological structure of the watershed aquifers and geological processes within the aquifer medium[1].The surface water is subjected to microbiological contamination during its travel and should be treated according to the public health engineering rules before consumption as a source of drinking water[2].

The groundwater is polluted due to various natural and anthropogenic factors. The disposal of untreated effluents from industries and household sewage, seepage of fertilizers and land degradation are the main sources of groundwater pollution[3]. The aquatic environment and water quality are the major factor affect the state of health and disease in both animals and human. Quality of water depends on natural processes; weathering, soil erosion and anthropogenic activities (urban, industrial, agricultural, etc,) which result in increasing exploitation of water resources. A lot of researchers all over the world are investigating anthropogenic contagious of the ecosystem [4-6]. Geogenically these impurities enter groundwater if they are present plentifully in the earth's crust or in residues surrounding the aquifer, where as impurities from anthropogenic environments make their way into groundwater by solubilizing in water from rainfall or through irrigation returns that finally enter groundwater[7]. Due to chemical interactions between water and geological environments, numerous chemical compounds are found in groundwater in various concentrations[8]. Over the past several decades, elevated arsenic concentrations in groundwater have drawn the attention of many researchers[9]. In South East Asia, this issue is even more pronounced. Several studies revealed that the key arsenic source of ground water is geological, and that it is mostly derived from the chemical exchange between the groundwater and aquifer sediments[10]. As water enters the water table by permeation through soil, it takes many pollutants during this process. These are mostly the salts of essential and heavy metals. Heavy metals are present in traces, but are more toxic than essential metals and may cause many health complications[11]. Conditions are more alarming in rural areas, where drinking and irrigation water system mostly depends on groundwater because of low annual precipitation and semi-arid climate[12]. Among metals such as Na, K, Mg and Ca are essential and are required at certain concentrations for normal body function and growth. In excess, they also have an adverse effect on the human body. Adverse effects of these metals include abdomen pain, headache, blood pressure and kidney damage[13]. According to the World Health Organization (WHO) declaration, access to potable water is a basic right for all. However, in developing and also developed countries, many people rely on groundwater and surface water for drinking purposes, unaware of its quality. Water contains organic as well as inorganic pollutants. The Presence of these contaminants above permissible concentration; causes health problems to users. It is necessary to check the quality of water, especially the concentration of arsenic and essential metals before it is used for drinking purpose[14]. Contamination of groundwater results from processes which the water faces from the instant it was introduced in the atmosphere at the time it is released by a well or hand pump. Forty percent of deaths in Pakistan are attributed to waterborne diseases directly or indirectly ultimately[15].Polluted water is a main source of human diseases misery and fatality. There are many sources of water contaminated with; toxic waste. Inappropriately planned rural sanitary services also supply contagion with underground water[16].The quality of groundwater in Pakistan is deteriorating day by day. A serious problem appears due to stagnant management of effluent water, which penetrates into soil with the passage of time and can become a part of nature and groundwater. This work has been carried out to assess the water quality of groundwater after review of the compiled work on the quality of groundwater in different parts of Pakistan[17-22]. Water pollution is a burning issue of the era. Pure water is a basic need and right of every citizen. Due to unavailability of bottled and piped water, the people of the study area use underground water for drinking purpose. The quality of water that people use for survival needs to be analyzed in the laboratory to learn its pollution level and suitability for the people. No research has been carried out on toxic metals of drinking water quality and its impacts on health risk.Therefore, this study aimed to identify the sources of drinking water contaminations and their potential health risk assessment in Taluka Sakrand residents. The results will be useful for the water managers and the local population for better planning of their available resources.

MATERIALS AND METHODS

1.2 Physical and Chemical Parameters all the reagents used were of analytical grade and all the glassware used was washed properly with double distilled water before use. The study aimed to analyze the groundwater samples of Taluka Sakrand, District Shaheed Benazirabad. One hundred and sixty five (165) groundwater samples were collected from Taluka Sakrand. Physical and chemical characteristics of different water samples were measured in the field and in the laboratory. The homogenized sample was transferred to clean 500 ml plastic bottle. For sampling, clean polyethylene containers of volume 500 ml were used and the samples received were immediately processed for analysis. The temperature of air at meter above the surface of the water was recorded by a thermometer. Analysis of different chemical characteristics of water samples was performed with portable conductivity meter Orion Star A 322 in the field. pH was measured by portable Orion Star A 321 pH meter (Orion Research Inc. Boston USA). Alkalinity, total Hardness and chloride were using (Digital Titrator Model 16900 Hach Company Loveland, USA) and verify results with standard procedures recommended by the American Public Health Association (APHA)[23-25]. Na, K, Ca, Mg, SO_4, Cu, Co, Mn, Zn, Fe, Pb, Ni and Cd were estimated by DR-3900 Spectrophotometer (HACH Company World Headquaters, Loveland USA). Arsenic was estimated using (Merck Arsenic field testing Kit (0.01-0.5 mg/l) Darmstadt, Germany).

The Sodium Absorption Ratio (SAR) values were calculated using the following

$$SAR = \frac{Na}{\sqrt{1/2(Ca^{2+}+Mg^{2+})}} \quad (1)$$

formula;

RESULTS

The problem of natural arsenic in groundwater is of growing concern for the health of people worldwide because of its carcinogenic properties. In the Province of Sindh, the concentration of arsenic in groundwater is one of the major problems. Arsenic contamination in groundwater affects the Indus alluvial and deltaic plains in Sindh.

A baseline study was conducted to assess the level of essential and heavy metal concentrations along with electrical conductivity (EC) , pH and total dissolved salts.One hundred and sixty five (165) water samples of the study area were examined. The physico-chemical parameters of the water samples were found in the following ranges; pH 6.52-8.31, electrical conductivity 357-3780 µS/cm, total dissolved solids (TDS) 228-1996 mg/L, HCO_3 94-1190 mg/L, total hardness (TH) 115-1275 mg/L, chloride 35-582 mg/L, SO_4 24-697 mg/L respectively. The concentration of essential metal ions (Na, Ca, Mg and K) was found in the ranges of 30-682 mg/L, 15-283 mg/L, 13-186 mg/L and 3-62 mg/L respectively. The concentration of Heavy metals was determined with Perkin Elmer-AAnalyst 800 found in the ranges Cu 30-1690 µg/L, Co 2-45 µg/L, Mn 5-198 µg/L, Zn 20-300 µg/L, Fe 40-925 µg/L, Pb 3-125

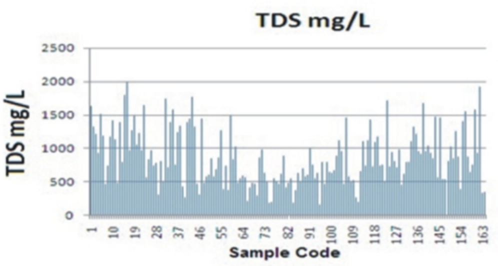
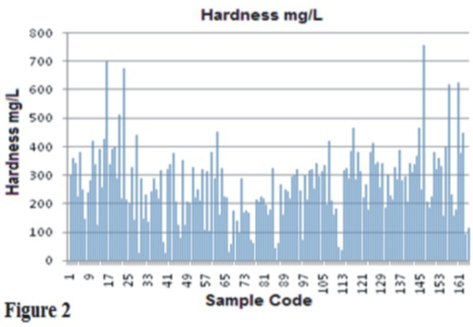


Figure 1



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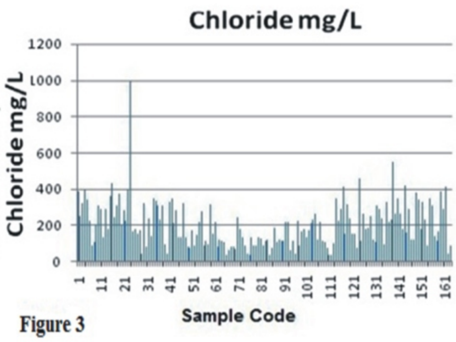

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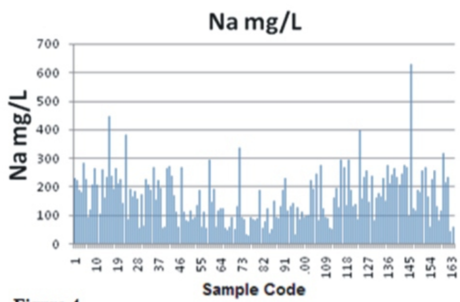

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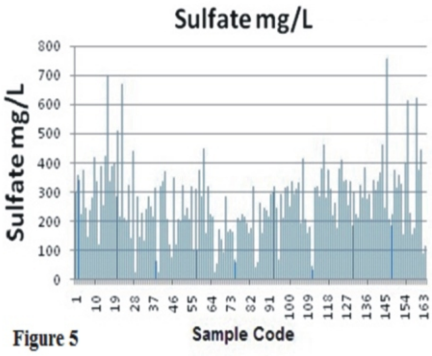

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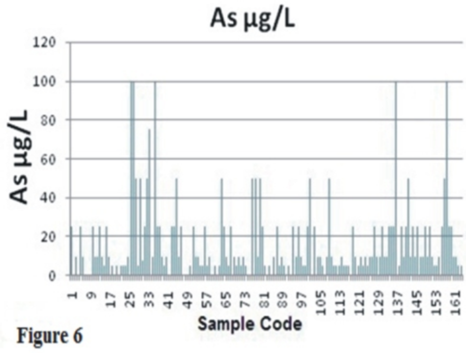

Figure 6

Table -1. Critical parameters of groundwater samples exceeding the permissible limits

Parameters	Maximum	Minimum	Average	Percentage %	No. of Samples Exceeding Permissible Limits
pH	8.31	6.52	7.41	4.24	7
EC µS/cm	3780	357	2068	50.30	83
TDS mg/L	1996	228	1095	47.28	78
Total Hardness mg/L	1366	65	335	35.16	58
Chloride mg/L	755	24	265	45.46	75
Sulfate mg/L	628	30	166	43.03	71
Na mg/L	53	4	13	36.37	60
K mg/L	243	17	103	41.21	68
Ca mg/L	210	11	49	35.15	58
Mg mg/L	991	36	203	27.27	45
As µg/L	100	5	52	15.75	26

Table- 2. Classification of water on the basis of electrical conductivity

Electrical Conductivity µS/cm	Classification of Groundwater	No. of Samples
<1000	None Saline	35
<1500	Slightly Saline	46
<3000	Moderately Saline	50
>3000	Very Saline	34

Table -3.Classification of water on the basis of total hardness

Total Hardness mg/L	Type of Water	No. of Samples
0-60	Soft	Nil
61-120	Moderate Hard	Nil
121-180	Hard	4
>300	Very Hard	161

Table -4. Irrigation of water quality based on EC µs/cm

EC µS/cm	Water Class	Percentage of Samples
<250	Excellent	Nil
250-750	Good	17
750-2000	Permissible	95
2000-3000	Doubtful	35
>3000	Unsuitable	18

Table -5. Classification of water on the basis of sodium absorption ratio

Parameters	Range	Water class	Samples	Percentage
SAR	<6	Excellent	130	78.79%
	>6	Unsuitable	35	21.21%

Table-6 Heavy metal concentrations.

Parameters	Unit	Minimum	Maximum	Average	Percentage %	No. of Samples Exceeding Permissible Limit	WHO Permissible Limit
Fe	µg/L	40	1647	843	43.64%	72	<300
Zn	µg/L	20	300	160	33.94%	56	<100
Cu	µg/L	30	1690	865	32.73%	54	<1000
Mn	µg/L	5	198	101	29.70%	49	<50
Co	µg/L	8	45	26	23.03%	38	<20
Pb	µg/L	3	125	64	24.25%	40	<10
Ni	µg/L	5	90	47	21.22%	35	<20
Cd	µg/L	3	35	19	30.91%	51	<50
As	µg/L	5	100	52	15.76%	26	<10

µg/L, Ni 5-90 µg/L, Cd 3-35 µg/L and As 5-100 µg/L. Twenty six (26) samples had arsenic concentrations in the range (5-100 µg/L). The majority of the water samples were contaminated with toxic metals their concentration exceeding WHO permissible limit of drinking water quality standards[26, 27]. This investigation shows that ground water of major portions of the study area is unfit for drinking purpose. The results obtained are summarized in (Table-1-6).

DISCUSION:

In all the natural ecosystems, water acts as the primary transport of dissolved particulates The physical and chemical property characteristics of water vary due to seasonal changes. The rate at which water is added or removed from the system along with complete identification of hydrological characteristics is hence essential for understanding biological, chemical and physical processes that operate within the ecosystem. According to laws of Hydrology, water quality alongside a canal or river is good because of the natural filtration process, whereas, in the areas between two canals there is a lot of salinity because of seepage process. Recharge from canals produced good quality water at selected sites where downward infiltration occurs. Infiltration of rain water and effluent water in low lying depressions appear to be causing a rise in the water table in parts of Taluka. In some of Taluka people fill large cans of drinking water from taps fixed alongside the canal. The results of physical and chemical parameters of water samples reveal the varying nature of the groundwater of the study area. The differences in the quality of groundwater may be due to the topography of soil; diverse earth layers and the consequences of recharge sources (canals etc.) on groundwater. Each parameter is discussed separately below.

pH OF GROUNDWATER

The pH of water is a measure of its acidic and basic content that can be determined respectively by the production of hydrogen and hydroxyl ions. pH and temperature play a major role in the population and growth of bacteria. The normal, acceptable pH limits for water supply lies between 6.5-8.5 pH units. Hence, the overall quality of water is great-influenced by the pH value, as is well established that water with high pH tends to be scale forming and that of low pH normally corrosive to certain metals, asbestos, cement and lined pipes. At the study site pH of water samples varied within the ranges 6.52-8.31.

ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity of water depends on the concentration of ions and its nutrient status. Electrical conductivity of water samples collected at Taluka ranged between 357 to 3780 µS/cm. The standard level of EC is 400 µS/cm recognized by WHO.

TOTAL DISSOLVE SOLIDS (TDS)

The total dissolved solid in a water sample is used to find out the effect of ions in a water resource. Elevated salt levels in the water have physiological effects on plants and animals. TDS varied between within the ranges 228 and 1996 mg/L at Taluka. TDS results for 47.28 % water samples were higher in comparison to WHO limits. This area is mostly residential. The variation in TDS may be due to diverse earth beds and drain sources. Water samples with high values of TDS are unsuitable for drinking purpose and may cause several health problems to living organisms and adversely affect the fertility of soil, if used for irrigation purpose (Table-1 & Figure-1).

SALINITY

Salinity is the suspended salt content of a water source. In saline underground water dominant ions are likely to be chloride and sodium, although potassium, magnesium and sulfate are also important constituents present in concentrations above the WHO guideline values for drinking water.

BICARBONATES AND HARDNESS

Water hardness is the capability of water to precipitate soap. Soap is precipitated mostly by the calcium and magnesium ions. The bicarbonate contents and hardness fluctuated between the ranges 94-1190 mg/L and 115-1275 mg/L respectively. A parallel behavior of bicarbonate with hardness was noted. One possible explanation for this could be linked with soil conditions and underground hydrology. Hardness of groundwater samples was above and within the safe limits prescribed by WHO for drinking water (Table-1) and hardness of groundwater samples indicated their hardness above 700 mg/L may be due to geological reasons. Water with higher hardness than WHO guidelines may cause gastric problems, dehydration, gas trouble, kidney stone and heart problems [28](Figure-3).

CHLORIDE AND SULFATE

The total chloride concentration of groundwater varied from 35 to 582 mg/L. The majority of the samples had chloride concentration above, the regulations (250 mg/L) set by WHO (Table-1). The chloride in water is present in the mixture with sodium, calcium and magnesium. Sources of chloride are mostly human waste, mineral rocks, irrigation discharge and industrial effluents like dying and bleaching materials. The water samples with higher chloride concentration may cause toxic effects to health.

Sources of sulfate in surface and subsurface water are mainly calcium sulfate and sodium sulfate. The sulfates enter water bodies from the dissolution of minerals containing sulfides and thiosulfates. Sulfate contributes to the permanent hardness of water. Elevated levels of sulfate in water cause bad taste and also shows corrosive action. The concentration of sulfate varied within 24-697 mg/L. Groundwater samples had sulfate contents above WHO limits in (Table-1). A parallel trend was found in the concentrations of chloride and sulfate in water samples analyzed.

CHEMISTRY OF METAL ELEMENTS

The concentration of essential metal ions (Na, Ca, Mg and K) varied between the ranges of 30-682 mg/L, 15-283 mg/L, 13-1186 mg/L and 3-62 mg/L respectively. It was observed that the concentrations of major metal contents are higher in ground water of the study area (Table-1).

Although sodium and potassium are not strictly considered as trace metals present in drinking water, yet they do constitute an important indicator of water quality. It is well known that certain metals such as Na are concentrated in body-fluids, and are circulated throughout the human body. These elements are known to participate in life sustaining processes operating throughout the complicated nervous system controlled by the brain[29].

The concentration of sodium in most areas of Taluka was relatively high. Higher sodium concentration may create a problem of hypertension and affect public health. As the reported values are higher than the maximum permissible limits there may exist serious threats of underground water pollution.

The concentration of major metal ions Na, K, Ca, and Mg varied with high concentration in groundwater samples. The concentration of major metal ions followed the decreasing order: Na > Ca > Mg > K

Sodium is present in all natural waters. The presence of sodium in water depends upon the anions present in that system and the temperature. The high concentration of sodium imparts tastes to the water and make it unfit for everyday use and leads to cardiovascular diseases and high blood pressure[20].Concentration of Na in water samples of the study area varied in the range 30-682 mg/L. The Na ion concentration of groundwater samples was found above and within the safe guidelines of 200 mg/L set by WHO for drinking water (given in Table-1). All the rest of the samples had higher values of Na ion concentration than WHO limits (Figure-5).

Potassium plays a key role in the metabolism process of animals and it is main micronutrient for living organisms (plants and animals). The WHO threshold of potassium in drinking water is 12 mg/L. As can be seen from (Table-1) the potassium concentration of the groundwater samples studied varied between 3-62 mg/L, including samples with K ion concentration above and within the permissible limits.

Calcium and magnesium are rich in rocks and soil, mainly originating from limestones and dolomites respectively. They are comparatively soluble and dissolve in surface water and enter ground water. There are no health concerns associated with calcium and magnesium, and water containing these metals may contribute towards human dietary needs; However, their high concentrations may cause scaling of pipes. The concentrations of Ca and Mg ions in the water samples of the area were found in the ranges of 15-283 mg/L and 13-186 mg/L respectively. Calcium and Magnesium in groundwater samples were found to be above and within WHO permissible limits as given in (Table-1). The rest of the water samples were observed to be very hard with high concentrations of Ca and Mg.

Minor metal contents of groundwater samples of taluka were determined after pre concentration of samples by evaporation of water 10 times. These were measured in the ranges, Fe 40-1647 µg/L, Zn 20-300 µg/L, Cu 30-1690 µg/L, Pb 3-125 µg/L, Ni 5-90 µg/L, Co 8-45 µg/L, Mn 5-198 µg/L, As 5-100 µg/L and Cd 3-35 µg/L are given in (Table-6). Iron is not hazardous to health, but is considered a secondary or aesthetic contaminant and is essential for good health. Iron helps to transport oxygen in the blood. Staining of laundry, plumbing fixtures and undesirable taste are nuisances associated with high iron concentration [30].The underground water of the study area was rich in iron, which adds a little to its quality, but several other parameters crossed the WHO threshold.

Zinc plays an important role in the enzymatic system of the human body, for example, enzymes like alkaline phosphate, idols etc, depend totally on zinc. On the other hand, when the level of zinc is exceeded, it causes depression ,fever, cough,malaise, salivation, vomiting and headache. The zinc contents of water samples were 20-300 µg/L.

Mostly copper contamination in drinking water occurs in the water deliverance system, as a result of rust of copper pipes or fittings. The copper level above the WHO limit can cause a bitter metallic taste in the water and result in blue-green stains on plumbing fixtures. Stomach-intestinal distress such as vomiting, nausea, stomach cramps and diarrhea are the health problems linked with copper contamination in water. Copper is also an essential micronutrients and is required by the body in very small amounts. People with the Wilson s disease, are more sensitive to copper deficiency. The copper concentration of water samples varied from 30-1690 µg/L and was within the allowed limits of WHO of <1000 µg/L.

During taking food uptake cadmium in human body, because of cadmium is primarily transported into the liver during blood. Other health effects that can be caused by cadmium are: severe vomiting, stomach pains and hypertension, reproductive failure osteomalacia, bone fracture, and possibly even infertility, brain damage, damage to the central nervous system, impaired hearing, physiological disorders, behavioral disorders, damage to the immune system, possibly DNA damage or cancer growth [31]. The underground water of study area seems to be contaminated with Cd, which is of great concern. Only six samples had Cd within below 3 µg/L. Use of underground water of the baseline area for drinking purpose, thus, may not be recommended because it may cause a number of health consequences.

SODIUM ADSORPTION RATIO (SAR)

Salt contents of irrigation water, places adverse effects on crop production via osmotic pressure of a solution. Elevated concentrations of Na to other metal damage soil structure. Sodium adsorption ratio (SAR) was calculated to check the suitability of the waters to be used for irrigation purpose. The results revealed that of the 165 groundwater samples analyzed, only (130 underground water samples) were suitable for irrigation with SAR value below 6 while remaining 35 samples were unsuitable for irrigation with SAR value above 6. This data are summarized in (Table-5).

CONCLUSION:

The analysis revealed that (50.30 %) of ground water samples of the study area belong to the category of hard to very hard water and most of the water samples are alkaline in nature.majority of the parameters were above the upper limit prescribed by WHO. A large number of sites had groundwater samples which were highly contaminated with toxic metals. The high salt concentration in the drinking water of Taluka Sakrand suggests a further research work and some action plans must be implemented to resolve this problem. Many metals present in drinking water at major, minor, and trace levels are essential for human health. However, their intake in excessive amounts may possibly cause severe health problems. Therefore the groundwater of Taluka Sakrand may not be considered safe to be used for drinking purposes. Hence drinking water quality and continuous assessment should be conducted at regular intervals to check the quality of drinking water.

ABBREVIATIONS:

EC: Electrical Conductivity; TDS: Total Dissolved Solids; EDTA: Ethylene dinitrile-Tetraacetic Acid Disodium Salt; SAR: Sodium Absorption Ratio; WHO: World Health Organization.

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