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An Assessment of Groundwater Quality for Drinking Purpose in Tando Adam City of Sindh, Pakistan

Humaira Naz[1], Shella Bano[2]*, Kashif Ahmed Memon[2], Ali Ghulam Sahito[2]

[1]Centre for Pure and Applied Geology, University of Sindh, Jamshoro, Pakistan
[2]Department of Geology, University of Karachi, Paksitan

*Email: shella@uok.edu.pk

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Abstract: The present study is aimed to assess the groundwater quality of Tando Adam city of district Sanghar, Sindh. Total twenty groundwater samples were randomly collected from handpump wells installed on different locations at various depths (50-90ft). The groundwater samples were analyzed for physicochemical and microbiological parameters to determine suitability for drinking purposes. Analytical results showed that most of water samples have elevated contents of Total Dissolved Solids (TDS) exceeding the permissible limit (<1000mg/l) for drinking water. The concentration of cations (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}) and anions (Cl^{-}, HCO_3^{-}, SO_4^{-2}) were so high that World Health Organization (WHO) standards seem overcrossing in >80% water samples. Local geology, poor irrigation practices, and anthropogenic activities are responsible for higher ion concentrations in the area. Furthermore, Microbiological contamination was found positive in half of the groundwater samples due to sewage contamination, poor sanitation and dumping of waste near well sites. The groundwater quality of the study area is highly contaminated and not suitable for human consumption but despite being commonly used for drinking purpose.

Keywords: Drinking Water quality, physicochemical parameters, Tando Adam city.

Introduction

Groundwater is one of the most precious sources of water being used widely for human consumption, agriculture and industrial activities across the world (Khalid, 2019). It also serves as an important natural water source About one-third of the world's population rely on groundwater for drinking purpose because of its good quality and high cleanliness level (Jamshidzadeh and Barzi, 2018). Both natural and anthropogenic sources are posing serious threats to the quality and quantity of groundwater (Talib et al., 2019). As a result, millions of people have lost their lives due to consumption of contaminated water and the absence of potable water (Shahab et al., 2016).

Pakistan is facing severe shortage of freshwater while abrupt decrease in both surface and groundwater resources has been noticed in the past few decades due to overpopulation (Tariq et al., 2020). Furthermore, lack of water management practices and increased contamination levels the existing water resources are also declining the quality and quantity of water (Hashmi et al., 2009). About 60% of Pakistan's population depends on groundwater for drinking and domestic purpose, but in Sindh province, 44% of the population lack access to safe drinking water (Alamgir et al., 2016). It is due to seawater intrusion, high fluoride concentration, elevated arsenic and microbial contamination (Bano, 2019, Naseem et al., 2018).

Present study is carried out in Tando Adam city of district Sanghartha latitude 25.7682° N longitude 68.6559° E (Fig.1). The area is part of a fertile plain located on the eastern bank of the Indus river in NE of Hyderabad. This city is a famous trading centre and is well known for its textile mills, food industries and agriculture (SIDA, 2012, WWF, 2008). Agricultural activities in the area mostly depend on conjunctive irrigation system. Seepage from a well-established canal irrigation system is the main source of groundwater recharge, but canal water is highly contaminated due to mixing of sewage and industrial effluents, which is the main cause of water born diseases in the area (Khan et al., 2018). Present study is aimed to assess the groundwater quality and its suitability for drinking purposes according to WHO standards.

Study area is part of the Indus alluvial plain which extends from the lower Punjab to the Arabian Sea and is filled with post-glacial sediments in the Pleistocene incised-valley system (Kazmi, 1984; Giosan et al., 2006a). Most of the area consists of Recent detritus deposits of extinct streams, older terrace and flood plain deposits (RSS, 1979). Some parts of the study area constitute older aeolian deposits characterized by longitudinal dunes and intervening playa deposits. These deposits are poorly sorted and mainly consist of fine to medium-grained sand, clay and minute silt (Khan, 2014; Holmes, 1968). However, the sub-surface geology of the area constitute Cretaceous and Tertiary rocks of limestone, dolomite, marl, chert, marly limestone, and chalky limestone with chert interactions (Shah, 2009).

Materials and Methods

Groundwater samples from 20 shallow (50-90ft) handpumps were collected from Tando Adam city by marking their positions on Global Positioning System

(Fig.1).To get the representative groundwater samples in polyethylene bottles of 1.5 litres, wells were allowed to flow for 10 minutes (Akoto and Adiyiah 2007; Tahir et al. 2010). The electrical conductivity and pH of collected water samples were measured by using EC meter (AD 330) and pH meter (AD 111), respectively. While, soluble Ca^{+2}, Mg^{+2}, Cl and HCO_3 were determined by the titration method (USSL, 1954). Concentrations of sodium (Na^+) and potassium (K^+) were determined by Atomic Absorption Spectrophotometer and sulphate by using the Turbitimetric Spectrophotometric method. Nitrate concentrations were obtained by Brucine Spectrophotometer. A microbiological testing kit made by PCRWR, was used for the detection of bacteria.

Fig. 1. Sample location map of the study area.

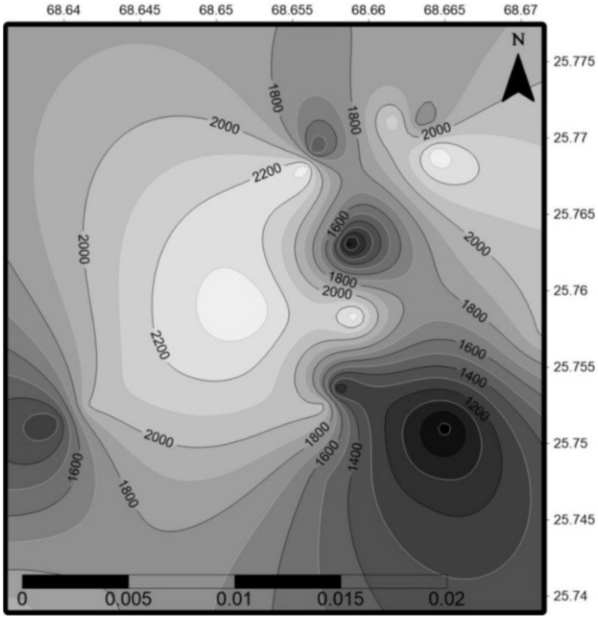

Fig. 2. The concentration of Total Dissolved Solids (TDS) in groundwaters of Tando Adam city.

Results and Discussion

Physical, chemical and microbiological characteristics of collected groundwater samples were measured to check their suitability for drinking purposes (Table 1). The data show that the pH of all groundwater samples was within the permissible limit (6.5-8.5) while, about 35% of groundwater samples showed higher turbidity values (5.41-7.9) than recommended limit (5NTU) for drinking water (WHO, 2006). High turbidity of water is often associated with a high level of disease-causing bacteria and viruses (Memon et al., 2016). Electrical Conductivity (EC) values vary between 1210-

Table 1. Physico-chemical and microbiological analysis of groundwater samples from Tando Adam city.

S.ID	Coordinates		Location	*WS	Depth	EC	pH	TDS	Tur	Cations (mg/l)				Anions (mg/l)				Hard	*W.T	*M.P.	Ca/	Na/
	N	E			ft	(µs/cm)		mg/l	NTU	Ca	Mg	Na	K	Cl	HCO_3	SO_4	Nitr.				Mg	Cl
T1	25°46'05"	68°39'21"	Toor Colony	HP	50	3720	7.9	2381	8	138	50	580	15	640	370	479	22	345	Na-Cl	-ve	2.8	0.9
T2	25°45'09"	68°38'30"	Shahn. Chowk	HP	60	3150	7.8	2016	8	158	57	310	15	515	280	519	8.6	395	Na-Cl	+ve	2.8	0.6
T3	25°44'21"	68°38'11"	Pop.Juic factor	HP	90	3040	7.8	1946	5	142	51	130	9	820	300	548	21	355	Ca-Cl	+ve	2.8	0.2
T4	25°45'32"	68°39'08"	Q.Azam colony	HP	80	3720	7.6	2381	5	190	68	40	10	830	320	466	30	475	Ca-Cl	-ve	2.8	0.0
T5	25°46'08"	68°39'52"	Faraz Town	HP	90	3760	7.4	2406	5	170	61	180	9	150	300	498	28	425	$Ca-SO_4$	-ve	2.8	1.2
T6	25°45'49"	68°39'29"	Moham.chowk	HP	50	2410	7.6	1542	3	96	35	65	11	105	340	169	25	240	$Ca-HCO_3$	+ve	2.7	0.6
T7	25°46'09"	68°39'23"	Juman Shah	HP	65	2140	7.9	1370	5	166	32	156	17	345	400	218	14	220	Ca-Cl	+ve	5.2	0.5
T8	25°46'16"	68°39'48"	Latif gate	HP	70	2710	7.9	1734	4	94	34	390	14	150	210	121	12	235	Na-Cl	-ve	2.8	2.6
T9	25°46'16"	68°39'42"	BeraniPhatak	HP	50	3410	7.8	2182	7	144	52	210	10	70	325	172	30	360	$Na-HCO_3$	-ve	2.8	3.0
T10	25°46'16"	68°39'51"	K. Mohammad	HP	90	2810	7.4	1798	4	52	19	90	16	65	335	384	16	130	$Na-SO_4$	-ve	2.7	1.4
T11	25°46'38"	68°40'06"	SabziMandi	HP	50	2950	7.7	1888	3	378	72	250	12	495	450	384	26	500	Ca-Cl	-ve	5.3	0.5
T12	25°45'26"	68°40'17"	Hyder Shah	HP	60	3150	7.8	2016	5	240	86	255	16	85	295	238	15	600	$Ca-SO_4$	+ve	2.8	3.0
T13	25°45'30"	68°39'33"	Allahyar Goth	HP	50	3720	7.4	2381	3	202	73	265	21	100	365	193	20	505	$Na-HCO_3$	+ve	2.8	2.7
T14	25°45'47"	68°39'31"	JatiaParo	HP	50	1430	7.6	915	4	114	41	650	14	125	320	121	10	285	$Na-HCO_3$	+ve	2.8	5.2
T15	25°45'13"	68°39'29"	MakraniParo	HP	55	1720	7.7	1101	4	82	30	230	13	95	320	384	5.5	205	$Na-SO_4$	-ve	2.7	2.4
T16	25°45'04"	68°39'54"	Fauji Moor	HP	50	1340	7.5	858	3	140	50	200	16	75	420	169	12	350	$Na-HCO_3$	-ve	2.8	2.7
T17	25°44'48"	68°39'51"	Khudabad Goth	HP	50	1820	7.8	1165	3	118	42	240	20	100	280	200	4.5	295	$Na-HCO_3$	-ve	2.8	2.4
T18	25°44'53"	68°39'24"	Imran P. Pump	HP	60	2400	7.9	1536	4	82	30	310	11	35	470	120	18	205	$Na-HCO_3$	+ve	2.7	8.9
T19	25°45'09"	68°39'26"	H. K. BuxRajar	HP	50	3200	7.4	2048	3	350	43	250	20	50	340	210	29	300	$Ca-HCO_3$	+ve	8.1	5.0
T20	25°45'05"	68°38'21"	Green city	HP	60	1210	8.4	774	8	166	60	80	12	55	385	152	24	415	$Ca-HCO_3$	-ve	2.8	1.5
Min.						**1210**	**7**	**774**	**3**	**52**	**19**	**40**	**9**	**10**	**210**	**120**	**5**	130				
Max.						**3760**	**8**	**2406**	**8**	**378**	**86**	**650**	**21**	**830**	**470**	**548**	**30**	600	-	-		
Mean						**2691**	**8**	**1722**	**5**	**161**	**49**	**244**	**14**	**241**	**341**	**287**	**19**	342	-	-		
Highest desirable limit (WHO, 2011)						**750**	**6.5-8.5**	**1000**	**5**	**75**	**30**	**200**	**12**	**250**	**200**	**200**	**10**	500	-	-		
***WS= Water source, *W.T= Water Type, *M.P.= Microbiological Pollution**																						

3760µs/cm with mean=2691 µs/cm (Table 1). All groundwater samples were found with higher EC values than the recommended limit (750 µs/cm). The concentration of TDS varies from 774-2406 mg/l (mean=1722 mg/l) and 85% of groundwaters exceeded the permissible limit of 1000mg/l for drinking purpose (Fig. 2). Total hardness ranges between 130-600 mg/l (mean 342 mg/l), and only 1% of groundwater samples exceeded the WHO permissible limit (500mg/l).

The concentration of Ca^{+2}in aquifers of the study area varies from 52-378mg/l with an average of 161mg/l (Table 1). About 95% of the groundwater samples were found with higher contents of calcium than the prescribed by WHO limit (75mg/l). Magnesium content varied between 19 to 86 mg/l with a mean of 49 mg/l and around 85% of the sample crossed WHO recommended guidelines (30mg/l) for drinking water. A good correlation (r=0.63) between Ca and Mg suggest that both cations are coming from the same calcite and dolomite source (Table 2). Furthermore, all groundwater samples have a Ca/Mg ratio (>1) indicating the dominance of calcite over dolomite dissolution in the aquifer of the study area (Jain et al. 2010). Sodium and potassium contents ranged between 40-650mg/l and 9 to 21mg/l with means 244mg/l and 14.05 mg/l, respectively (Table 1). The 60% groundwaters of the study area were found exceeding the WHO recommended guideline for sodium (200mg/l) and potassium (12mg/l).

Table 2. Correlation between physico-chemical parameters of Groundwater from Tando Adam city.

	pH	*TDS*	*Ca*	*Mg*	*Na*	*K*	*Cl*	*HCO3*	*SO4*	*Nitro.*
pH	1.00									
TDS	-0.35	1.00								
Ca	-0.15	0.34	1.00							
Mg	0.03	0.42	**0.63**	1.00						
Na	0.05	-0.03	-0.05	-0.05	1.00					
K	-0.23	-0.10	0.19	-0.04	0.23	1.00				
Cl	0.10	0.43	0.18	0.28	-0.02	-0.33	1.00			
HCO3	0.07	-0.20	0.24	0.01	-0.08	-0.03	-0.06	1.00		
SO4	-0.17	0.52	0.10	0.22	-0.14	-0.32	**0.74**	-0.18	1.00	
Nitro.	-0.12	0.56	0.47	0.35	-0.34	-0.42	0.22	0.24	0.15	1.00

Highly variable chloride content is noted in aquifers of Tando Adam city which varies from 35 to 830mg/l (Table 1). However, the mean chloride value (241mg/l) remained less than the standard limit (250mg/l) but 70% of groundwater samples evceeded this limit. The sulphate concentrations in the groundwater of the study area varied between120-548 with a mean of 287 mg/l. Around 60% of groundwaters exceeded the WHO prescribed limit of 200 mg/l. A strong correlation (r=0.74) between Cl^- and SO_4^{-2} ions reveal that both ions are coming from the same sources (Table 2). However, very high concentrations of sulphate indicate anthropogenic contamination mainly due to industries and agricultural activities in the area (Mostafa et al. 2017; Nicollie et al., 2010). Bicarbonate values ranged from 210-470 mg/l (mean 341) and all water samples were found beyond the WHO (200 mg/l) permissible limit for drinking water (Table 1). High bicarbonate contents indicate weathering of carbonate minerals and degradation of organic matter due to reducing conditions in the shallow aquifers of the area (Chkirbene et al., 2009; Shamsudduha et al., 2008).

Hydrochemical Facies

To know the water type and chemical processes occurring between groundwater and aquifers matrix, water samples were plotted on Piper (1944) diagram (Herojeet et al., 2013). The distribution of groundwater samples in the Piper diagram shows that $NaHCO_3$ is dominant (30%) groundwater type in Tando Adam city, indicating that ion exchange reaction is taking place in aquifers of the study area (Chae et al., 2007; Ventrurelli et al., 2003). However, other hydrofacies are mixed type i.e. CaCl (20%), NaCl (15%), $CaHCO_3$(15%), $CaSO_4$(10%) and $NaSO_4$(10%), indicating that various geochemical phenomena are occurring in the aquifers of the area (Fig. 3). The occurrence of NaCl water type indicates the influence of sea-level rise during early Holocene period that left saline water into the sediments (Kazmi, 1984; Clift et al., 2002). Furthermore, Tando Adam city lies in an arid region where intensive evaporation also results in high groundwater salinity. The presence of CaCl (20%) hydrofacies indicates a cation exchange mechanism in alluvial aquifer sediments in which Na^+ions are absorbed and C^{a+2} ions are released resulting in change of water type from NaCl to CaCl (Alafarrah and Walraevens, 2018).

$CaHCO_3$ is another dominating hydrolases indicating that aquifers are getting freshwater recharge from surface water as canals are passing through the area (Trabelsi et al., 2007). Furthermore, 10% of water samples were $NaSO_4$, associated with intensive evaporation of water that have previously lost Ca and HCO_3 to calcite precipitation (Younger, 2004). In addition, the rest (10%) of the hydrofacies were $CaSO_4$ type indicating the dissolution of carbonate minerals (calcite, dolomite, gypsum and anhydrite) in the study area.

The nitrate concentration in groundwater of Tando Adam city shows great variability (4.5-30mg/l) with a mean of 19 mg/l (Table 1). About 80% of groundwater exceeded the WHO permissible limit of 10 mg/l. The high nitrate content in shallow aquifers is dominantly associated with the application of fertilizers, subsequent irrigation and recharge through the soil in various agricultural activities in the study area (Nicolle et al., 2010). Furthermore, it could be due to sewage impact as Tando Adam city is densely populated, where sanitation facilities are also lacking (Naseem, 2012). In the study area around half of the groundwater samples were found microbiologically polluted and not safe to consume (Chapman and Kimtach, 1996). It is due to the absence of a proper sewerage system and demolished catch-pits in the area that results in the discharge of solid waste into naalas (Siddiqui and Ahmed, 2011). Later this sewage water is driven towards agricultural areas and used for irrigation purpose. The leaching of salts from this wastewater also causes soil and groundwater pollution in the area.

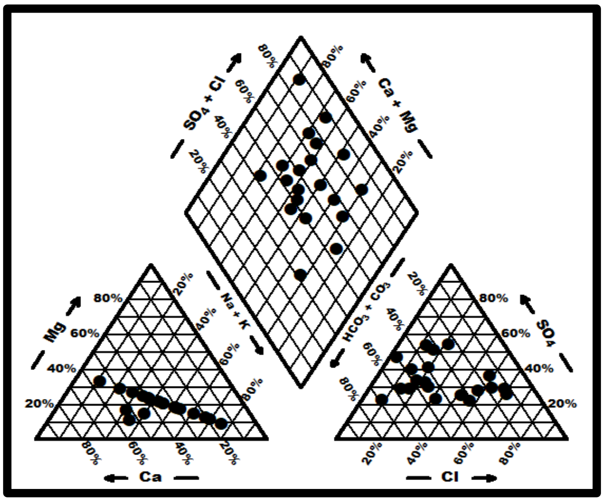

Fig. 3. Piper diagram showing water type in the study area.

Conclusion

It is concluded that the groundwater of Tando Adam city is highly contaminated due to elevated contents of TDS and microbial organisms. Besides, high groundwater salinity is due to extensive use of fertilizers and, throwing of industrial wastes in canal water. Further, unlined sanitation, open pit latrines and sewage water are causing microbial pollution of groundwater, causing also water-borne diseases in the local population. Moreover, groundwater is dominantly $NaHCO_3$ >$CaCl$>$NaCl$>$CaHCO_3$ >$CaSO_4$ > $NaSO_4$ type which indicates that exchange reactions, intense evaporation and freshwater recharge are taking place in the study area.

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