Physicochemical and Biological Assessment of Drinking Water Quality and its Impact on Coastal Community Health of Goth Ibrahim Hyderi, Karachi, Pakistan

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Abstract: Appraisal study has been carried out on municipal supplied tap and groundwater used for drinking in Goth Ibrahim Hyderi. Study site is an undeveloped rural area of the coastal belt of district Malir, Karachi. Ten samples each from groundwater and municipally supplied water were randomly collected according to the size of population from residential and commercial areas of Goth Ibrahim Hyderi. Data reveal that both the sources are chemically polluted and sewage impacted. About 60% wells have a very high TDS (mean: 3094 mg/L). The concentration of corresponding solutes (Na, K, Ca) and anions (Cl, SO_4, HCO_3) is also found to be very high. Similarly, tap water of Baloc, Kariya and Katch is also high in its salinity. About 70% and 40% of collected samples of tap water and groundwater respectively are sewage impacted as indicated by the occurrence of fecal coliforms and E. coli. The present study revealed that both water sources (municipal and groundwater) are found unfit for drinking purpose in terms of their chemical and microbiological load.

Keywords: Municipal water, groundwater, quality, community health.

Introduction

Water is known as universal solvent which has the ability to dissolve many substances of organic or inorganic nature. It is an essential component of human life and it is not possible to have water in its pure form due to the fact that it cannot be held up in the vacuum because it is highly reactive solvent (Benard, et al., 2012). Fresh water resources are becoming scarce day-by-day due to the fast rate of water quality deterioration (Mahananda et al., 2005). Water necessity is never exaggerated to human health, population growth and economic development. Healthy drinking water supply is one of the important environmental concerns which government organizations and communities strive for every day globally. Hence, clean water supply is crucial to provide safe water to communities. In general, urban community relies on surface water or sometimes both surface and groundwater as a source of drinking water. Groundwater is relatively clean and safe as compared to surface water and it requires less treatment (Abbas et al., 2015). Drinking water quality is explained in terms of physical, chemical and biological parameters. Physical quality parameters include physical state of water, which explains aesthetic characters (transparency, color, and odor etc.). On the other hand, chemical parameters deal with the unwanted ions like mercury, arsenic, zinc, chlorine and other toxic substances, leading cause chronic effects upon consumption (Srivastava, et al., 2017). The distribution of these contaminants in the aquifer is attributed to geological setting geo-environmental conditions, geochemistry and anthropogenic sources (Chen, 2002; Velea et al., 2009).

Groundwater is the only alternative to fulfill the increasing demand for water in the absence of good quality and sufficient quantity of surface water.

Groundwater pollution is vulnerable to both human health and the local environment (Akhtar et al., 2016). Recently, groundwater quality has become an important concern for water resource due to rapid population increase, industrialization and excessive fertilizer and pesticide application (Babu, et al., 2015). It is difficult to restore groundwater quality once it is polluted. Groundwater contamination leads to poor water quality for drinking, health problems, high cost of cleaning and alternative water supplies (Saleem, et al., 2012). Various chemicals occurring in water sources may cause adverse human health effects, make the acceptability of water, dubious and decrease the effectiveness of water treatment. The health impacts associated with chemicals in drinking water are mainly those which after long term exposure, cause adverse effects (Zinabu, et al., 2015). In such situation, the vital role of community participation in the sustainable development of watersheds must be realized. Land degradation of watersheds is influenced by upstream activities (agriculture, urban and industrial development) which further affect water quality and quantity downstream. Moreover, population increase, climatic change and economic development, expand water conflicts (Hostettler, 2005). In developing countries, about 1.7 million deaths occur each year by drinking unsafe water. It occurs mainly through infectious diarrhea where nine out of ten such deaths occur in children (Munir, et al., 2016).

Goth Ibrahim Hyderi is a thickly populated area in the

proximity of Karachi coast. Due to dense population and unplanned development, the community is facing acute shortage of municipal water supply. Drinking water is mainly supplied by Karachi Water and Sewerage Board (KWSB) beside groundwater from shallow aquifers (depth range: 5-10 meters). Various industries are located in the vicinity of the study area like poultry feed mill, fishing dried area, fish mill and bone mill, etc. Drainage and sewage are common problems due to damaged pipes, leakage and crossed pipelines. Industrial effluent and municipal wastewater discharge outside the industrial and residential areas (Fig. 1). Up to now, no study has been carried out to determine the water quality being used by the dwellers in the study area. Hence present study is aimed at assessing the physicochemical and the biological characteristics of both surface and groundwater, which is in use by the residents of Goth Ibrahim Hyderi.

Fig. 1 Map of study area and sampling locations at Goth Ibrahim Hyderi Bin Qasim, Karachi.

Materials and Methods

Study Area

The study area lies between 24^0 45^0 to 25^0 37^0 north latitudes 67^0 06^0 to 67^0 34^0 east longitudes on the coastal belt of Karachi city (Fig. 2). Administratively, Goth Ibrahim Hyderi is part of Taluka Bin Qasim, district Malir Karachi (District Census Report of Malir 1998).The total area of Malir district is about 2268 square kilometers.

Water Sampling

Before collecting the samples, the information about drinking water and waterborne diseases was noted down through non-government organizations (NGOs), community based organization (CBO) and other socially active members of the community. The water samples were taken during August-December 2016 by block analyses (BA) method. The global positioning system (GPS) was used to note down the coordinates of all sampling points for either surface or groundwater. The latitude and longitude values have

been shown in Table 2 and Figure 2. Surface (n =10) and groundwater samples (n =10) were collected from various locations of Goth Ibrahim Hyderi which include Fullani Muhalla, Balouch Muhalla, Machhi Parro, Kariyanni Parro, Charann Parro, Mamdanni Parro, Umer Colony, Khaskhely Parro, Kaddani Muhalla, Katchhi Parro (Table 1).

Table 1 Sampling station names and codes and coordinates.

| Sample codes	Name of Sampling Station	Latitudes (°N)	Longitude (°E)
Fulla	Fullanni Muhalla	24 ° 47'58.19" N	67 ° 8'07.93" E
Baloc	Baloch Muhalla	24 ° 47'25.05" N	67 ° 8'12.76" E
Machh	Machhi Parro	24 ° 47'46.23" N	67 ° 8'30.33" E
Kariya	Kariyanni Paarro	24 ° 47'47.50" N	67 ° 8'19.13" E
Chara	Charann Parra	24 ° 47'37.82" N	67 ° 8'24.15" E
Mamd	Mamdanni Parra	24 ° 47'45.95" N	67 ° 8'20.76" E
Umer	Umer colony,	24 ° 47'51.00" N	67 ° 8'14.57" E
Khask	Khaskhely Parra	24 ° 47'40.97" N	67 ° 8'28.25" E
Kadda	Kaddanni Muhalla	24 ° 47'59.35" N	67° 28.79" E
Katch	Katchhi Parra	24 ° 47'53.73" N	67 ° 8'38.91" E
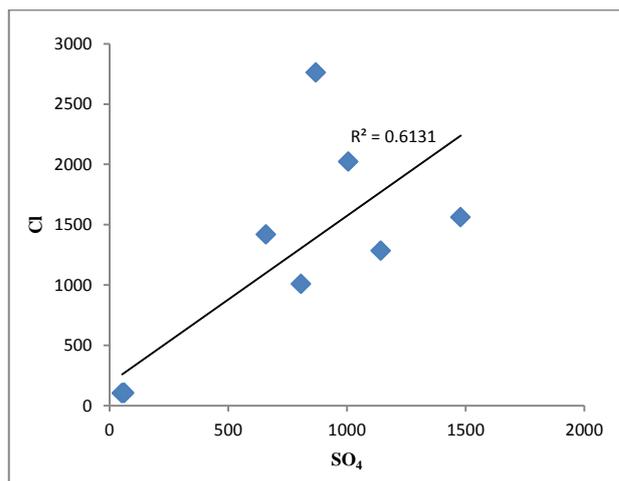
Fig. 2 Relationship between SO_4 and Cl in groundwater samples.

The average of three tap water samples collected from adjacent three houses was taken as a mean sample for physicochemical analysis. All the water samples were collected in polystyrene bottles of 750 ml capacity. These sterilized bottles were rinsed thoroughly with distilled water and subsequently with sample water. For bacterial analysis, water samples were collected in polystyrene bottles of 250 ml volume. Boric and nitric acids were used to preserve the collected samples.

Water Analysis

The water samples were collected in sterile bottles of 1000 ml capacity each and stored in a box maintaining temperature of 25 ^{0}C. The bottles were washed properly with distilled water and rinsed thoroughly with sample water before collecting the samples. All samples were analyzed for physicochemical and microbial tests in the laboratory of Pakistan Council for Research in Water Resources (PCRWR). All the protocols for sample analysis were followed as per specifications outlined in standard method of water (APHA, AWWA and WEF 1998).

mg/L), Kariya (TDS: 1842; Hardness: 440 mg/L) and Katch (TDS: 1868; Hardness: 439 mg/L). The pH varies between 7-7.5 which is within the national and WHO (1996) guidelines for drinking water.

Calcium and magnesium contents vary in the range of 32-98 and 15-49 mg/L with a mean of 54.3 and 25.7 mg/L respectively. The results show that tap water is deficient in both Ca and Mg content. On the other hand, Na (mean: 165.4 mg/L) and K (20.63 mg/L) concentrations are objectionable against the WHO (1996) guideline values of 200 and 12 respectively. Similarly, elevated sulphate (mean: 437 mg/L) and

Table 2 Physicochemical and microbiological analysis results of tap water samples.

Sample Locations	EC	TDS	pH	Hard	Ca	Mg	Na	K	HCO$_3$	SO$_4$	Cl$^-$	NO$_3$	F	Total coliforms	Fecal coliforms	E.coli
Unit	µS/cm	mg/L	-	mg/L										MPN/ 100ml	MPN/ 100ml	Cfu/ 100ml
Fulla	706	452	7.49	190	32	27	68	7	140	71	95	1.182	0.34	130	55	0
Baloc	1778	1138	7.31	305	66	34	247	33.7	164	247	321	1.555	0.553	0	0	0
Machh	691	442	7.1	170	40	17	76	7.5	140	60	97	1.512	0.311	190	85	3
Kariya	2878	1842	7.39	440	95	49	420	60.5	187	434	549	2.043	0.793	230	80	4
Chara	723	463	7.06	180	44	17	80	6.1	150	64	93	1.006	0.314	110	45	0
Mamd	774	495	7.45	170	44	15	92	8.4	130	70	125	1.271	0.323	240	70	3
Umer	709	454	7.33	170	40	17	80	7.1	140	58	103	1.106	0.341	150	60	3
Khask	742	475	7.39	170	42	16	86	7.75	135	64	114	1.188	0.342	0	0	0
Kadda	707	453	7.08	170	42	17	78	6.8	145	62	95	1.259	0.313	150	65	2
Katch	2918	1868	7.49	439	98	48	427	61.5	185	437	563	2.124	0.803	0	0	0
NEQS Limits	NGVS	1000	6.5-8.5	500	75	150	200	12	NGVS	250	250	10	1.5	0/100ml	0/100ml	0/100ml

Results and Discussion

Tap water chemistry

Highly variable values (range: 691-2981 µS/cm) of electrical conductivity (EC) have been recorded for tap water samples (Table 1). Total dissolved solids (TDS) and hardness contents are generally within the permissible limit of WHO (1996), (500 mg/L) set for drinking purpose, but three samples have objectionable TDS and relatively high hardness values which were collected from Baloc (TDS:1138, Hardness: 305

chloride (563 mg/L) contents are reported in the tap water samples of Baloc, Kariya and Kutch (Table 1). Nitrate concentration varies in the range of 1-2 mg/L which is within the permissible limit (10 mg/L) of WHO (1996) set for drinking water. Although fluoride did not cross the upper limit of WHO (1996) (1.5 mg/L) for drinking water, but it occurs in very low amount (mean: 0.4 mg/L).

Groundwater chemistry

The pH of collecting groundwater samples is slightly

Table 3 Physicochemical and microbiological analysis results of groundwater samples.

Sample Locations	EC	TDS	pH	Hard	Ca	Mg	Na	K	HCO$_3$	SO$_4$	Cl$^-$	NO$_3$	F	Total coliforms	Fecal coliforms	E.coli
Unit	µS/cm	mg/L	-	mg/L										MPN/ 100ml	MPN/ 100ml	Cfu/ 100ml
Fulla	8260	5286	7.5	1090	240	119	1270	203	310	1480	1560	3.954	1.317	0	0	0
Baloc	5078	3250	7.57	710	154	79	766	114	235	807	1006	3.018	1.272	0	0	0
Machh	675	432	7.11	170	40	17	72	7.6	130	53	100	1.273	0.341	85	20	0
Kariya	693	444	7.29	180	36	22	70	7.1	130	60	103	1.126	0.314	133	31	0
Chara	8485	5430	7.37	921	189	109	1429	43	276	1007	2022	3.614	1.299	0	0	0
Mamd	695	445	7.26	170	34	22	72	7.6	130	61	104	1.103	0.315	141	17	0
Umer	6800	4352	7.14	1050	240	109	980	106	650	660	1418	3.925	1.33	0	0	0
Khask	9389	6592	7.21	940	180	120	1840	28	280	870	2760	3.742	1.305	0	0	0
Kadda	6669	4268	7.53	901	197	98	1018	157	272	1143	1283	3.486	1.294	0	0	0
Katch	696	445	7.25	170	34	22	74	7.8	130	62	104	1.091	0.314	168	29	0
NEQS Limits	NGVS	1000	6.5-8.5	500	75	150	200	12	NGVS	250	250	10	1.5	0/100ml	0/100ml	0/100ml

alkaline (range: 7.1-7.5; mean: 7.3) which is consistent with the WHO (1996) allowed range of 6.5-8.5. Groundwater salinity is found to be very high which is evident by the elevated electrical conductivity (range: 675-9389; mean: 4744 mg/L) and extremely high TDS content (range: 432-6592; mean: 3094 mg/L). Very high sulphate (range: 53-1480; mean: 620.3 mg/L) and chloride concentrations are reported in 60% samples, suggesting the recent recharge of saline water (Anawar et al., 2013) and seawater intrusion due to the proximity of Karachi coast. Calcium and Mg concentrations vary in the range of 34-240 and 17-120 mg/L respectively. A large number (60%) of samples is found high in their Ca and Mg concentrations (Table 2) which strongly negate use of such groundwater for drinking purpose. Highly variable concentration is manifested by Na (range: 70-1840 mg/L) and K (7-203 mg/L) ions. These two solutes exceed the corresponding permissible limit of 200 and 12 mg/L in 60% of total groundwater samples respectively (Table 2). Although no guideline values have been set by WHO (1996) for HCO_3 concentration in drinking water, but relatively high (HCO_3> 250 mg/L) concentration is determined in 60% of collecting samples (Table 2). The same pattern is expressed by sulphate (range: 53-1480; mean: 620 mg/L) and chloride (range: 100-2760; mean: 1046 mg/L) contents

where E. coli occurs between 2-4 Cfu/100 ml. Four out of total (n = 10) groundwater samples are found contaminated with total and fecal coliforms in the range of 85-168 and 17-31MPN/100 ml respectively. However, all groundwater wells are found free from the occurrence of E. coli.

Health impacts of drinking water in Goth Ibrahim Hyderi

Very high TDS content in the tap water of Baloc (TDS: 1138 mg/L), Kariya (TDS: 1842; mg/L) and Katch (TDS: 1868 mg/L) is reported. Similarly elevated TDS (range: 432-6592; mean: 3094 mg/L) is documented in the groundwater samples of Fulla, Balou, Chara, Umer, Khask and Kadda. Total dissolved solids content is a collective quality parameter which is controlled by certain ions (Muhammad et al., 2018). TDS is concerned with aesthetic character rather than a health hazard. The occurrence of very elevated TDS in the groundwater of the study area is alarming due to the fact that an elevated total dissolved solids (TDS) concentration indicates the excess of certain ions in the water which have individual health effects. Hence, high level of TDS content in drinking water is indirect evidence of ionic imbalance which leads to the severe health

Table 4 Descriptive statistics of water quality parameters for Tap water and groundwater samples.

Parameters	Tap Water				Ground Water			
	Min.	Max.	Mean	Std. Dev	Min.	Max.	Mean	Std. Dev.
EC	691	2918	1262.6	923.046	675	9389	4744	3677.65
TDS	442	1868	808.2	590.816	432	6592	3094.4	2440.99
pH	7.06	7.49	7.31	0.169	7.11	7.57	7.323	0.1631
Hard.	170	440	240.4	112.75	170	1090	630.2	406.328
Ca	32	98	54.3	23.86	34	240	134.4	88.4561
Mg	15	49	25.7	13.42	17	120	71.7	45.3384
Na	68	427	165.4	145.79	70	1840	759.1	656.797
K	6.1	61.5	20.63	22.83	7.1	203	68.11	71.9259
HCO_3	130	187	151.6	20.31	130	650	254.3	157.515
SO_4	58	437	156.7	157.66	53	1480	620.3	529.245
Cl^-	93	563	215.5	192.16	100	2760	1046	937.468
NO_3	1.006	2.124	1.425	0.38	1.091	3.954	2.6332	1.30476
F	0.311	0.803	0.44	0.20	0.314	1.33	0.9101	0.50729
Total coliforms	0	240	120	92.25	0	168	52.7	70.9038
Fecal coliforms	0	85	46	33.73	0	31	9.7	13.1238
E.coli	0	4	1.5	1.65	0	0	0	0

which show their excessive amount in 60% wells. On the other hand, nitrate and fluoride concentration span within their safe range of 1-4 and 0.3-1.3 mg/L.

Microbiological character of drinking water

About 70% of total collected samples (n = 10) from tap water sources have total coliforms in a wide range of 110-240 MPN/100 ml. These same samples have shown the presence of fecal coliforms varying between 45-85 MPN/100 ml. On the other hand, occurrence of E. coli is reported in 50% of total tap water samples

impacts. It is evident by the highly variable and increased concentration of major solutes (Ca, Mg, Na, K) and anions (Cl, SO_4, HCO_3) in the groundwater of Goth Ibrahim Hyderi (Table 1, 2). High TDS in three tap water samples may be attributed to the leakage of water supply line and sewage mixing.

Calcium and magnesium contents vary in the range of 32-98 and 15-49 mg/L with a mean of 54.3 and 25.7 mg/L respectively. The results have shown that tap water is deficient in both Ca and Mg content. Some studies have shown that there is a significant protective

effect of calcium intake from drinking water on the risk of gastric cancer (Yang et al., 1998). Contrary to that a large number (60%) of groundwater samples are found high in their Ca content (Table 2) which strongly negate the use of such groundwater for drinking purpose. A study conducted by Yang (1998) revealed the sympathetic relationship between the risk of gastric cancer and corresponding levels of calcium and magnesium.

The occurrence of very high sodium and potassium concentrations in tap water and 60% of groundwater sources implies that the water is unfit for drinking. In general, sodium is not acutely toxic because mature kidneys excrete sodium efficiently. However, deaths have been reported following accidental overdoses of sodium chloride (WHO, 1979). Acute effects of high sodium intake include vomiting, nausea, convulsions, cerebral and pulmonary oedema, muscular twitching and rigidity (DNHW 1992; Elton et al, 1963). The effect varies on both infants and adults where immaturity of infant kidneys leads to acute effects. Similarly, infant with severe gastrointestinal infections can suffer from fluid loss leading to dehydration and increased sodium levels in plasma (hyper matraemia). Permanent neurological damage is common under such conditions (Sax, 1975, WHO, 1979). The excessive amount of sodium in drinking water is attributed to increased blood pressure in children (Tuthill, 1981; Fatula, 1967) but some other studies have shown that there is no such association found (Tuthill, 1985; Pomrehn et al, 1983; Armstrong, 1982).

Similarly, elevated sulphate and chloride contents are reported in the tap water samples of Baloc, Kariya and Kutch and 60% wells in the study area. Strong correlation ($r^2 = 0.6$) is shown by chloride and sulphate of groundwater in Goth Ibrahim Hyderi (Fig. 4). It suggests the mixing of groundwater which is high in concentration of both these ions. Other sources of elevated SO_4 in groundwater may be due to the discharge of industrial wastes and domestic sewage (Srivastava et al., 2012). It is possible that large contribution of this anion is from sewage mixing, which is indicated by the occurrence of pathogenic bacteria in a large number of wells (Table 2). Urinary excretion is the principal mechanism of disposal for the excess sulfate produced by sulfur amino acid oxidation, and the kidney is the primary site of regulation (Cole and Evrovski, 2000).

Elevated concentration of sulphate (exceeding 500-700 mg/L) in drinking water has been reported to cause diarrhea. Long and short-term exposure studies to determine sulfate hazard are available in humans and animals (EPA, 2003). Some case studies suggest that gastrointestinal disorders occur when exposed to high levels of sulfate in drinking water (Backer, 2000). However, only a few experimental studies have been carried out on sulfate effects on adults. It is still gloomy to accurately determine the concentration of sulfate in drinking water, which will cause adverse

health effects. In renal failure, sulfo-esters accumulate and hyper-sulfatemia contributes directly to the unmeasured anion gap characteristic of the condition. In contrast, sulfate is readily assayed in urine by a number of means, particularly nephelometry after precipitation as a barium salt.

Sulfate is frequently assayed today for nephrolithiasis because the ionic strength of urine is mainly contributed by sulfate, which alters the equilibrium constants governing saturation and precipitation of calcium salts. According to Heizer et al., (1997) drinking water with 1200 mg/L sulfate can cause a significant, but clinically mild increase in mean stool mass per six day. Another study by Patel et al., (2009) suggests that a hypertonic low-volume sulfate solution would be an effective cathartic for colon cleansing and that sulfate induced catharsis would be less likely than phosphate catharsis to produce calcium salt deposition in renal tubules.

Conclusion

Water from both the surface (tap) and groundwater, being used by community in the study area, is found to be unhealthy for drinking. Both the sources of drinking water are found contaminated in terms of chemical and biological quality. About 60% groundwater samples are chemically contaminated and 50% wells are sewage impacted. Similarly, 30% tap water sources are found contaminated in their solute chemistry and 70% taps are found sewage impacted as indicated by the occurrence of fecal coliforms and E. coli. The present study has sketched the alarming picture of drinking water quality in Goth Ibrahim Hyderi however a detailed study is needed to find out the sources and mechanism of such contamination in the limited water resource available in the area.

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