

GROUNDWATER QUALITY AND FATE OF PUBLIC HEALTH IN NEW KARACHI TOWN, KARACHI, PAKISTAN

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ABSTRACT

The aim of present study was to evaluate the groundwater quality and its potential impacts by drinking on the health of New Karachi Town residents. For this purpose, a total of 25 groundwater samples were randomly collected through boring wells at a depth range of 9-61 meters from the study area. Data revealed that all the chemical parameters exceeded their guideline values of WHO for drinking purpose in most of the wells. TDS content of groundwater is very high (mean: 4781.6 mg/L) which exceeded the WHO limit (500 mg/L) for drinking purpose. Highly elevated concentration of Na (mean: 1397mg/L), K (mean: 39.72 mg/L), Ca (mean: 308.7 mg/L), Mg (mean: 1408.65 mg/L), Cl (mean: 2502.345 mg/L), HCO₃ (mean: 441 mg/L) and SO₄ (mean: 332.4376 mg/L) is reported in more than 85% wells which is against the corresponding WHO guideline for drinking purpose. Very high concentration of these major ions (Mg, K, Ca, Na, Cl, SO₄ and HCO₃) is indicating the sewage mixing with groundwater in study area. Groundwater in New Karachi town is not suitable for drinking purpose and may cause serious health impacts of acute and chronic nature.

Keywords: Groundwater quality, physico-chemical parameters, health impacts, New Karachi Town.

Introduction

Water is essential component of all forms of life and it is mainly obtained from two sources, i.e. surface water which includes rivers, canals, fresh water lakes, streams etc. and ground water like well water and borehole water (McMurry and Fay, 2004). More than half of the world depends on groundwater for survi-

val (UNESCO, 1992) and in present scenario, rapid increase in population results decrease in water resources. In order to fulfill the demand, ground water acts as a major source. According to World Health Organization (WHO) about 80% of all the diseases are water borne. Water quality is the reflection of its composition which is affected by natural and anthropogenic activities

in terms of measurable quantities (Kumar, 1997). Therefore the capability to predict the behavior of contaminants in flowing groundwater is of vital importance for the reliable assessment of hazardous or risks arising from groundwater contamination problems, and the design of efficient and effective techniques to mitigate them. Karachi is the largest and densely populated city of Pakistan where water is supplied through pipelines. However, due to rapidly growing population and scarcity of municipally supplied water demand-supply balance is adversely affected in the city. As a result, people living in the city are now more depending upon the groundwater. The over abstraction of groundwater depletes water table and accelerate the contaminants transport from the land surface to aquifer (Shah and Roy, 2002), which ultimately affect the aquifers badly. Domestic and industrial effluent contributes to an increase in concentration of different pollutants in ground water (Raghunath et al., 2002). Moreover, the quality of groundwater is not yet properly determined in the city to ensure its potential use for domestic purpose especially for drinking.

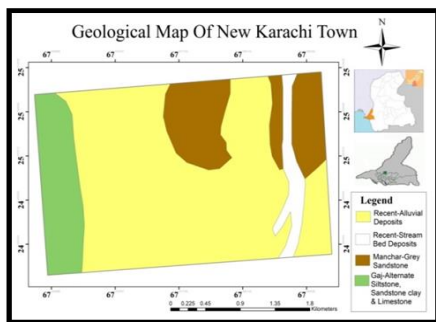
Therefore, a large section of population is under threat of diseases caused by drinking bad quality groundwater. Hence, there is an urgent need to screen the groundwater of Karachi city for its suitability for drinking purpose. Present study is aimed at evaluating the groundwater quality and its potential impact on the health of residents living in New Karachi Town.

Study Area

New Karachi Town of the central district of Karachi is selected as study area, located in northern part of Karachi positioned between $67^{\circ}3'10.674''\text{E}$ - $67^{\circ}5'12.5196''\text{E}$ longitudes and $24^{\circ}57'55.5552''\text{N}$ - $24^{\circ}59'59.802''\text{N}$ latitudes (Fig. 1). New Karachi is residential town as well as an industrial zone covering an area of 20.47 sq. km with dense population of 1,038,865 (KSMP, 2007). This town is dominated by middle class population with satisfactory literacy rate. Lyari River is located at a distance of 5.2 km in northeast of New Karachi which is serving as recharging body of groundwater during non rainy season. Geologically, the surface of this town is mostly covered with alluvium

which is highly conductive due to the dominance of sandy silt. Subsurface rocks are mainly comprises of sandstone with interbedded shales and subordinate limestones followed by soft to hard sandstone and argillaceous limestone (Pithawalla and Martin-Kaye, 1946; Shah, 2009).

Figure-1
Geological map of New Karachi Town



2. Materials and Methods

2.1 Sample Collection

Twenty five groundwater samples were collected from boring wells at a depth range of 9-61 meters. Groundwater was electrically pumped for 2-3 minutes to get true samples. Location of the wells was marked with the help of Global Positioning System (GPS) on the google earth image (Fig. 2). Groundwater samples were collected in plastic

bottles of 1.5 liter capacity for physico-chemical analysis. Bottles were properly washed and rinsed thoroughly with distilled water and then with groundwater at sampling site. To determine nitrate concentration groundwater samples were collected in bottles of 100 ml capacity and one ml boric acid solution was injected through sterile syringe in each water sample to cease any further reaction.

Figure-2
Samples location plotted on Google Earth Image.



2.2 Groundwater Analysis

All the physico-chemical tests were carried out in the laboratory of Geology Department, University of Karachi. The pH and TDS/EC of collected groundwater samples (n=25) were measured with the glass electrode pH meter (Adwa AD 111) and EC meter (Adwa AD 330) res-

pectively. Sodium and potassium concentration was determined by the flame photometer (Model No. JENWAY PFP7). Sulphate content was tested by gravimetric method, while bicarbonate and chloride were estimated by Argemetric titration method. The method used for the analysis of calcium and total hardness was EDTA Titration Standard Method (1992). Magnesium was estimated as the difference between hardness and calcium with the help of a formula. Groundwater samples preserved in the boric acid were analyzed to determine the nitrate concentration by Cadmium Reduction method (HA CH-8171) on Spectrophotometer.

3. Results and Discussions

3.1 Physicochemical Parameters

Groundwater quality of collected samples (n=25) from various parts of New Karachi town is found to be worst for drinking purpose. The results of all physicochemical parameters have been summarized in Table 1.

Total Dissolved Solids

Extremely wide range of total dissolved content (TDS) is reported (mean: 4781.6 mg/L) which violate the WHO permissible

limit (500 mg/L) in all the groundwater samples where it ranges between 1060-23900 mg/L (Table 1). Similarly, all collected samples deviated from Pakistani permissible limit (1000 mg/L) of TDS for drinking purpose. The TDS concentration is a secondary drinking water standard and, therefore, is regulated because it is more of an aesthetic rather than a health hazard. The occurrence of very high content of TDS in the groundwater of 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 impacts. It is supported by the significant correlation of TDS with most of the major ions (Ca, Mg, Na, K, Cl) in the groundwater of study area (Fig. 2).

Groundwater pH

Groundwater pH of New Karachi Town fluctuates between slightly acidic to slightly alkaline (range: 6.68-7.93; mean: 7.3) which is within the WHO guideline (6.5-8.5) for drinking water. Gro-

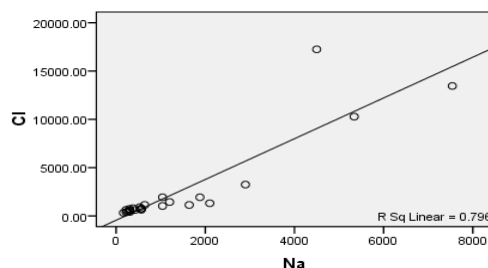
undwater pH of study area showed strong negative correlation with K ($r = -.62$) and moderate negative with Ca ($r = -.46$) and Mg ($r = -.49$) suggesting that these major ions are strongly influenced by the lowering of groundwater pH in study site (Table 2). Since pH of drinking water is considered as secondary pollutant by WHO therefore High alkalinity does not pose a health risk, but can cause aesthetic problems, such as an alkali taste to the water that makes coffee taste bitter; scale build-up in plumbing; and lowered efficiency of electric water heaters.

Sodium and Chloride

All the collected groundwater samples exceeded permissible concentration of Na and Cl (Table 1). The distribution of Na and Cl concentration is very heterogeneous where both varied in the range of 165-7540 mg/L and 319.05-17246.425 mg/L respectively. The mean concentration of both Na (1397 mg/L) and Cl (2502 mg/L) is found to exceed the WHO allowed values of 200 and 250 mg/L respectively. A strong correlation between Na and Cl is found (Table 2, Fig. 2) which indicates that common factor is responsible for increase in con-

centration of these two ions in the groundwater of study area.

Figure-2
Relationship between Na and Cl.



In general, sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride (WHO, 1979). Acute effects may include nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary oedema (DNHW 1992; Elton et al, 1963). The effect on infants is different from those adults because of immaturity of infant kidneys. Infant with severe gastrointestinal infections can suffer from fluid loss leading to dehydration and raised sodium levels in plasma (hypermnatraemia) permanent neurological damage is common under such conditions (Sax, 1975, WHO, 1979). High levels of sodium in

drinking water are associated with 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).

Calcium and magnesium

Calcium and Mg contents showed wide deviation where both varied between 30-1754 mg/L and 367-6967 mg/L with a mean of 308 mg/L and 1408 mg/L respectively (Table-1). Except three for Ca, all the wells showed elevated Ca and Mg concentration which is far above corresponding WHO reference values of 75 and 150 mg/L respectively. All the collected samples showed relatively more Mg concentration than Ca which indicates intense groundwater interaction with dolomitic rocks (Sarala and Ravi, 2012). A study has revealed that there is possible association between the risk of gastric cancer and their levels of calcium and magnesium (Yang, 1998). Conversely, some studies suggest that there is a significant protective effect of calcium intake from drinking water on the risk of gastric cancer.

Magnesium is an enzyme (Na-K Atpase) activator and reg-

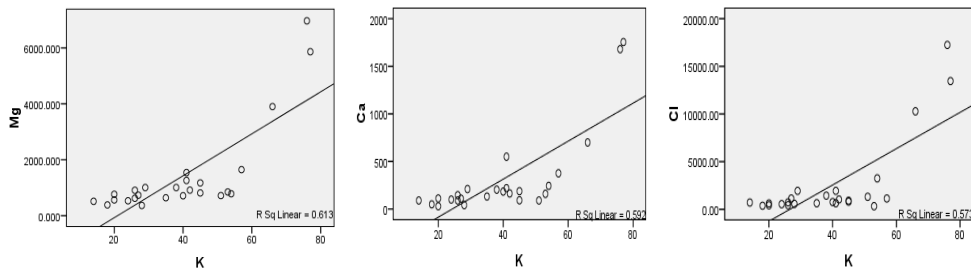
ulates cellular energy metabolism vesicular tones and the cell membranes and transport. Magnesium deficiency may increase contracity of blood vessels. A lack of magnesium leads to decrease in the concentration of intracellular potassium and increase in calcium levels (Yang, 1998). Earlier studies have found positive correlation between water calcium and magnesium and blood pressure (Sengupta, 2013; Sauvant, 2002; Kesteloot, 1998; Joffres, 1987; Kesteloot, 1985). Magnesium also expect to protective effects against gastric cancer but only the group with the highest level of magnesium exposure (Kneller, 1991). Recent studies confirmed strong essential role of magnesium in the prevention of cardiovascular diseases (Del Gobbo et al, 2013; Chiuve et al, 2013). In Finland and South Africa it was found that incidence of death ascribed to Ischemic heart diseases is inversely correlated with concentration of magnesium in drinking water (Punsar, 1979). Similarly, in a Swedish study the skeletal muscle magnesium levels were significantly higher in persons living in areas with higher magnesium water (WHO, 2009).

Table-1
Physico-chemical parameters determined in groundwater samples
(n = 25) of New Karachi Town

S. No.	Physical Properties			Major Cations				Major Anions			
	Depth	pH	TDS	Na	K	Ca	Mg	Cl	NO ₃	SO ₄	HCO ₃
	meters	-	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WHO Limit	-	6.5-8.5	500	200	12	75	150	250	10	250	300
Mean	29.66	7.32	4781.6	1397	39.72	308.7	1408.65	2502.34	8.38	332.4376	441
Max	61	7.93	23900	7540	77	1754	6967.94	17246.43	25.16	569.8	875
Min	9	6.68	1060	165	14	30	367.449	319.05	1.33	203.5	225
St. Dev	13.75	0.27	6112.85	1848.4	17.37	450.8	1663.61	4370.53	6.05	82.90	139.73

Anomalously, all the collected samples are very high in K content (range: 14-77 mg/L). Mean concentration of K is found to be more than three times the WHO guideline for drinking water. Potassium showed strong correlation with major ions like Ca ($r = 0.77$) Mg ($r = 0.78$) and Cl ($r = 0.75$) suggesting that its mobility is associated with the leaching of major ions in the study area.

Figure-3
Showing the relationship of K with Ca, Mg and Cl.



A study carried out by Robert et al., (1954) suggested that potassium deficiency may alter the ratio in which sodium and chloride are reabsorbed from glomerular filtrate. Such an alteration leads to changes not only in extracellular concentrations but also in extracellular volume.

Bicarbonate

Bicarbonate concentration occurred between 225-875 mg/L with a mean of 441 mg/L where except two samples, all the collected samples (n=25) are found to be affected by elevated bicarbonate content. In the aquifers, HCO_3 may be released from the dissolution of carbonate minerals and degradation of organic matter under local reducing conditions. (Jeong 2001, Shamsudduha et al., 2008, Lang et al., 2006, Petalas et al., 1996, Petalas and Anagnostopoulos, 2006). Since the correlation between bicarbonate and calcium is found to be negative ($r = -.22$) indicating that bicarbonate is not sourced from dissolution of carbonate minerals. Similarly weak correlation of bicarbonate with TDS does not support the mineral dissolution which is converse to some studies (e.g. Montety et al., 2008, Beaudeau et al., 1999). On the other hand high concentration of bicarbonate in the groundwater of study area suggests that aquifer recharge is quite old. It is due to the fact that younger groundwaters and surface waters contain less concentration of bicarbonate, while it is preponderantly high in old and reducing

groundwaters (McArthur et al., 2001).

Sulphate

Sulphate content is determined in the range of 203.5-569.8 mg/L with a mean of 332.438 mg/L. Except two, all the groundwater samples are beyond the permissible limit of WHO (250 mg/L) for drinking purpose (Table 1). High concentration of SO_4 in groundwater may be due to the discharge of industrial wastes and domestic sewage (Srivastava et al., 2012). Health impacts of sulphate in drinking water at concentration exceeding 500-700 mg/L have been reported as cause of diarrhea. Long-term and short-term exposure studies to determine a hazard assessment for sulfate are currently available in humans and animals (EPA, 2003).

Anecdotal reports and case studies suggest that people suffer gastrointestinal effects when exposed to drinking water containing high levels of sulfate (Backer, 2000). However, there have been few experimental studies of the effects of sulfate on adults. It is not yet possible to accurately determine the concentration of

sulfate in drinking water that will produce adverse human health effects. 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). In renal failure, sulfo-esters accumulate and hyper-sulfatemia contributes directly to the unmeasured anion gap characteristic of the condition. In contrast, sulfate in urine is readily assayed by a number of means, particularly nephelometry after precipitation as a barium salt. Sulfate is most commonly assayed today as part of the clinical workup for nephrolithiasis, because sulfate is a major contributor to the ionic strength of urine and alters the equilibrium constants governing saturation and precipitation of calcium salts.

A controlled study in normal adults carried by Heizer et al., (1997) revealed that in 1200 mg/L sulfate caused a significant but clinically mild increase in mean stool mass per six day pool from 621 to 922 gm but no change in stool frequency and no complaint of diarrhea. Another

study conducted by Patel et al., (2009) suggest 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.

Nitrate

Nitrate content is found to be extremely variable (range: 1.336-25.16) with mean value of 8.3 mg/L (Table 1). About one third of total collected samples showed NO_3 concentration >10 mg/L while rest of the samples are within permissible limit of WHO (2011) for drinking water. The occurrence of high nitrate in large section of wells indicates that nitrate reducing bacteria are active in the groundwater of study area. Naturally occurring nitrate levels in surface and groundwater are generally a few milligrams per liter. However, it may be increased due to percolation of through nitrate rich rocks and as a result of agricultural practices. Nitrate did not show correlation with any of the major ions in the groundwater of study area suggesting that source of nitrate is other than rocks

(Table 2). It is further supported by exceptionally high bicarbonate content suggesting that organic matter decomposition is followed by nitrate reduction in the groundwater of study area (Davis and De Wiest, 1966).

Nitrate inhibits the accumulation of iodide in thyroid gland. A study carried out by Gatseva et al., (2008) in Bulgaria revealed that high-nitrate level in drinking water is risk factor for thyroid dysfunction in vulnerable population groups. Similarly, high nitrate concentrations in drinking water cause severe methaemoglobinaemia and clinical cyanosis in infants and adults. Children and adolescents have lower levels of methaemoglobin. The other clinical consequences of high nitrate ingestion are recurrent stomatitis (Gupta et al., 1999) and recurrent diarrhea and respiratory infections in children (Gupta et al., 2000). A study carried by Gupta et al., (2000) revealed that high nitrate caused severe methaemoglobinaemia (7-27% of Hb) in all age groups, especially in the age group of < 1 year and above 18 years. Another study carried by Gupta et al., (1999) concluded that there is

relationship between drinking water nitrate concentration, cytochrome b5 reductase activity, and recurrent stomatitis. Some other studies have shown that nitrates in drinking water besides causing methaemoglobinaemia can result in various other clinical manifestations like recurrent stomatitis, recurrent respiratory tract infections (RRTI) etc (Kumar et al., 2002).

4. Conclusion

Groundwater quality of New Karachi town is found to be worst for drinking purpose. Incidence of non-compliance with regulation in most of the wells is documented where parameters deteriorating the quality of water are TDS, Mg, Ca, Na, K, SO₄, HCO₃ and Cl. Sewage mixing through Lyari River is increasing the pollution of groundwater in study area. Drinking such polluted water may be fatal and lead to frightful consequences in the form of short and long term health impacts. Detailed studies are needed on urgent basis to trace the sources and mechanism of groundwater pollution in the study area and other parts of Karachi to remediate the problem on emergent basis.

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