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Ground water analysis of Karachi with reference to adverse effect on human health and its comparison with other cities of Pakistan

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This paper presents investigation of physico-chemical parameters (Hardness, pH, Conductivity and Total Dissolved Solids) and quantitative chemical analysis (Ca, Mg, Na, K, Cl^-, SO_4^{2-}, NO_3^-, NO_2^-, CO_3^{2-} and HCO_3) of the ground waters of Karachi city for the purpose of suitability for human consumption. The results obtained were compared to the data of the ground waters of some other major cities (Lahore, Rawapindi, Multan, Faisalabad, Peshawar, Mardan, Quetta and Gawader) of Pakistan. It was observed that the chemical composition of the ground waters of Karachi are substantially deteriorated as compared to the other cities of Pakistan and do not accede to the required standards of World Health Organizations as a consequences of which diverse dangerous diseases can effect the human health in Karachi.

Key words: Trace metals, groundwater analysis, pollution, toxicity, industrial wastes.

INTRODUCTION

Groundwater is a very important natural resource widely used for different purposes like drinking, irrigation, industrial use, etc. It can be used only if it is available in sufficient amount of acceptable quality and usually it is of suitable quality suitability for drinking unless not impaired by various human activities in urban environments. Due to increasing demand, particularly in urban areas where water quality may be impaired, groundwater is becoming a natural resource of strategic importance. The sustainability of groundwater resources depends on its quantity and quality. The earth's hydrological cycle acts like a giant water pump that continually transfers freshwater from the oceans to the land and back again Figure 1 (Clarke, 1991).

More than 60% urban population of Pakistan is consuming ground waters for drinking and domestic purpose without maintaining the standard of World Health Organizations. The shortage of water in Karachi city due to rapid increase in population and industrial activities, has forced the people to meet their requirements from ground water sources such as wells, borings, and hand pumps (Government of Pakistan, 1997).

The three large industrial areas known as Sind Industrial Trading Estate (SITE), Korangi Industrial Trading Estate (KITE) and Landhi Industrial Trading Estate (LITE) are discharging large quantities of effluents comprising of organic matter, heavy metals, oil, greases, liquid and solid wastes directly through Malir and Lyari rivers, and indirectly through their tributaries causing consequently environmental degradation in various ecosystems of the city.

The industrial estates mainly consist of lather, textile, paint, car batteries, metal industries, thermal power stations, ceramics, oil refinery, electrical appliances, soap and pharmaceutical based industrial units and discharging their effluents into the rivers mentioned above. The toxic metals and organic dye pollution containing waste directly poured into the Lyari and Malir rivers without any treatment. The domestic sewage of thickly populated Karachi city is also poured into the City rivers.

The area under study where a large number of small and medium size industrial units are planted and more than 10 million population have been involved in various problems of the diseases of this area due to severe toxic pollution of water caused by leakages of pipes and inappropriate system of the sewerages of the small units of the industries and factories of the concerned areas.

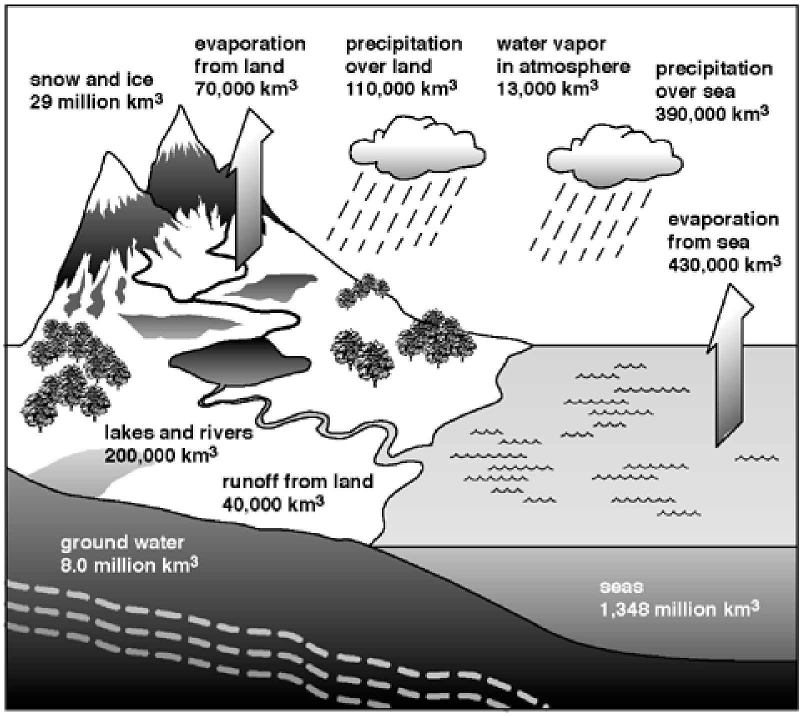

Figure 1. The hydrologicle cycle (Clarke, 1991).

Moreover, the overloaded sewerage system is also subjected to leakage, often overflowing and choking (Figure 2).

Although a large number of population is using well water without any scientific evaluation (WHO Standards) of the ground water quality of Karachi city and its neighborhood yet no monitoring is accomplished to maintain quality standards.

This study will serve as a data baseline of the ground water quality of Karachi city and its suburbs in future for further comparative studies of any hydro geological changes to help engineers and scientists for the purpose of future planning . The data of this work will help to government bodies for the establishing of public awareness programs about the quality of ground water for drinking purposes.

Subsequent decline in industrial abstraction of urban groundwater in the late twentieth century and introduction of several new sources of groundwater recharge (through leakage from water mains and sewers) have led to rising of water table levels in many cities with consequent basement and tunnel flooding and geotechnical problems (Greswell, 1994; Lerner, 1997; Lerner and Barrett, 1996; Yang et al., 1997).

Similarly, water-based diseases are caused by aquatic organisms that spend part of their life cycle in the water and another part as parasites of animals. These organisms can thrive in either polluted or unpolluted water. The parasites, usually take the form of worms, using intermediate animal vectors such as snails to thrive, and then directly infecting humans either by boring through the skin or by being swallowed (Table 1).

Development and management of urban groundwater resources require a thorough understanding of the quantity and quality of water recharging urban aquifers. Without knowing this, one cannot make decisions for abstracting groundwater from urban areas to fulfill the needs of the people and industries.

Therefore, this basic data on the basis of chemical composition of the ground water of Karachi city comparison with other cities of Pakistan can be used for employing a viable physico-chemical process to obtain the water of desired purity because in the city of Karachi the seepage of domestic and industrial wastewater are found as the main source of contamination of ground waters, therefore, an urgent need was felt for the carrying out this research for the development of awareness among the inhabitants of Karachi regarding pollution and procure treatment of drinking water from the side of public sector.

MATERIALS AND METHOD

Sampling

Samples were collected from private owner wells, hand pumps and borings; have been analyzed to assess the

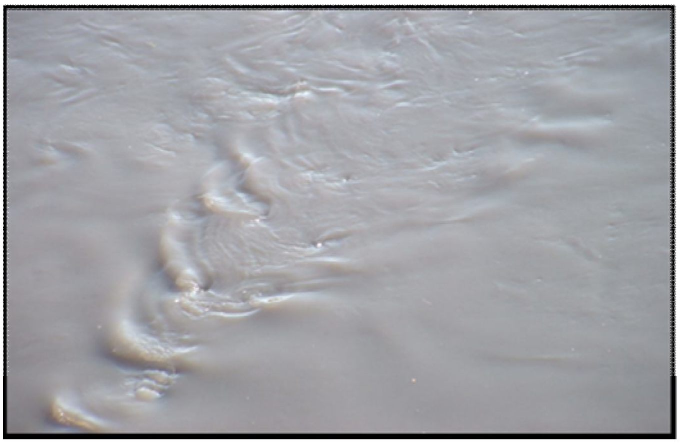

Figure 2. Lyari River carries heavily loaded industrial and domestic effluents. Photo: March 2007.

Table 1. Major water-related diseases.

Disease	*Cause and Route of Transmission*	*Geographic Extent*	*Number of Cases[a]*	*Deaths Per Year*
Major water-borne diseases				
Amoebic dysentery	Protozoa travel the fecal-oral route via contaminated water, food, person-to-person contact.	Worldwide	500 million per year	*
Bacillary dysentery	Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.	Worldwide	*	*
Diarrheal disease (including amoebic and bacillary dysentery)	Various bacteria, viruses, and protozoa travel the fecal-oral route via contaminated water, food, person-to-person contact.	Worldwide	4 billion currently	3-4 million
Cholera	Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.	South America, Africa, Asia	384,000 per year	20,000
Hepatitis A	Virus travels the fecal-oral route via contaminated water, food, person-to-person contact.	Worldwide	600,000 to 3 million per year	2,400 to 12,000
Paratyphoid and typhoid	Bacteria travel the fecal-oral route via contaminated water, food, person-to-person contact.	80% in Asia; 20% in Latin America, Africa	16 million currently	600,000
Polio	Virus travels the fecal-oral route via contaminated water, food, person-to-person contact.	66% in India; 34% in Near East, Asia, Africa	82,000 currently	9,000
Major water-based diseases				
Ascariasis	Fertilized eggs are passed out in human feces. Larvae in eggs develop in warm soil. Human ingests soil on food. Hatched larvae penetrate intestinal wall, where they mature.	Africa, Asia, Latin America	250 million currently	60,000
Clonorchiasis	Worms reproduce in gastropod snails, then are swallowed by freshwater fish or other snails. When humans eat raw or undercooked fish, the worms migrate to the bile ducts and lay eggs.	Southeast Asia	28 million currently	None reported

Table 1 contd.

Dracunculiasis (guinea worm)	Worm Dracunculus ingested by Cyclops (a crustacean). When humans digest Cyclops, worm larvae are released into the stomach. Larvae penetrate intestinal wall, then develop into worms, migrating through tissues. After a year, adult worm reaches skin surface of lower extremities. Female comes in contact with water, then discharges larvae into water.	78% in Sudan; 22% in other sub-Saharan Africa and a few cases in India and Yemen	153,000 per year	None reported
Paragonimiasis	Worms living in pulmonary cysts lay eggs in human lungs, which are coughed up and then swallowed. Worm eggs are passed out in feces and break when in fresh water. Larvae find snail host in which to replicate, then move into freshwater crab or crayfish. Humans eat uncooked seafood. Worms migrate in pairs from stomach through intestinal wall and diaphragm to lungs, where they mate.	Far East, Latin America	5 million currently	None reported
Schistosomiasis (bilharzia)	Eggs of the schistosome worm are passed out in human feces. Eggs hatch on contact with water, releasing the parasite miracidium. Parasite moves into a freshwater snail, where it replicates. It is released back into water, then penetrates human skin within seconds and moves into blood vessels. Within 30 to 45 days, miracidium grows into worm, which can lay 200 to 2,000 eggs per day for an average of 5 years.	Africa, Near East, rain forest belt in Central Africa, Western Pacific, Kampuchea, Laos	200 million currently	20,000
Major water-related vector diseases				
Denque	Virus is picked up by a mosquito from an infected human or animal. The virus incubates for 8 to 12 days and replicates. The next time the mosquito takes a blood meal, the virus is injected into a human's blood.	All tropical environments; concentrated in Asia, Central and South America	50-100 million per year	24,000
Filariasis (includes elephantiasis)	Worm larvae are ingested by a mosquito and develop. When the infected mosquito bites a human, the larvae penetrate the puncture and reach the lymphatics, where they reproduce.	Africa, Eastern Mediterranean, Asia, South America	120 million currently	None reported
Malaria	Protozoa develop in gut of a mosquito and are passed on in its saliva each time it takes a new blood meal. Parasites are then carried by the blood to the human's liver, where they invade the cells and multiply.	Africa, Southeast Asia, India, South America	300-500 million per year (clinical)	2 million
Onchocerciasis	Worm embryos are ingested by black flies. Embryos then develop into larvae within the black flies, and the flies inject the larvae into humans when they bite.	Sub-Saharan Africa, Latin America	18 million currently	None reported**
Rift Valley fever (RVF)	Virus usually exists in animal hosts. Virus is picked up by mosquitos and other blood-sucking insects and injected into the blood of humans. Humans also are infected while working with body fluids of dead animals.	Sub-Saharan Africa	NA	1% of cases

[a]Number of cases are reported as incidence ("per year")—the number of new cases occurring in a year—or as prevalence ("currently")—the number of cases existing at a point in time. * Included in diarrheal disease. ** No deaths but causes 270,000 reported cases of blindness annually.
NA = not available
Source: WHO 1996 (205) except amoebic dysentery, bacillary dysentery, dracunculiasis, dengue, and RVF from WHO 1998 (200); and clonorchiasis and paragonimiasis from Muller & Morera 1994 (119).

quality of ground water but the three different sites of Karachi were selected for the purpose of this study by standard methods (APHA, 1998). The collection of samples was so arranged from those areas of the

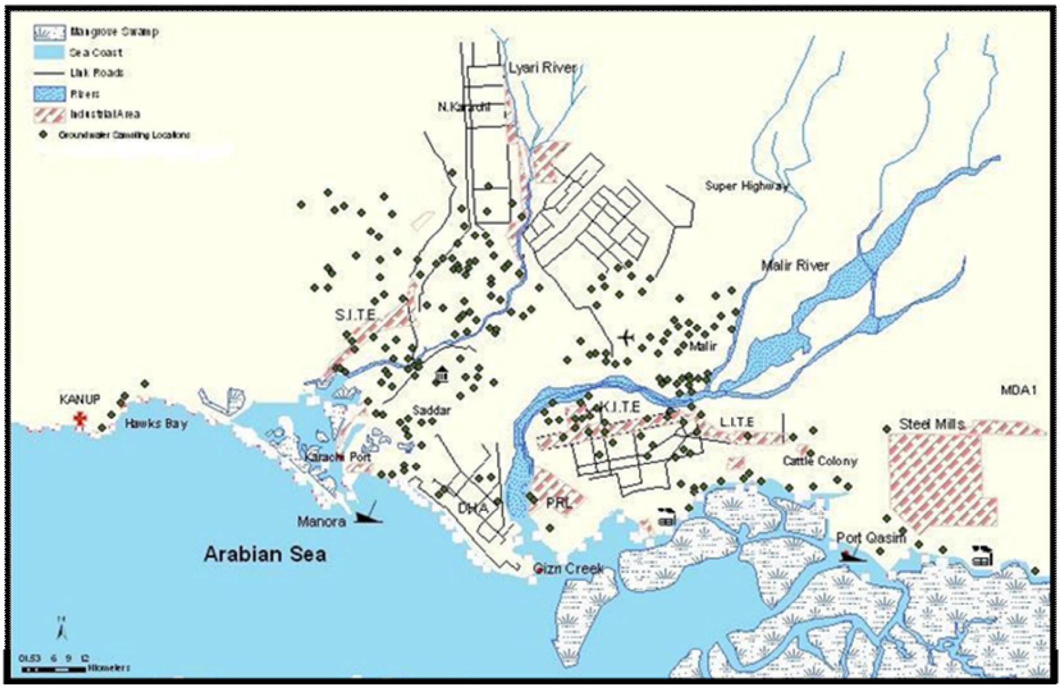

Figure 3. Map shows sampling sites for water groundwater samples.

Karachi where the residents of the concerned area are in problem from the view of ground water pollution. The collection of field samples was based on i) the industries, their types & densities, and ii) the population, densities and the level of incomes which affect the living conditions, and iii) the degree of pollution of varied nature. The Malir and Lyari rivers are intermittent streams and as such carrying no natural water throughout the year except during the rainy season of the monsoon period for a very short duration. In fact, the discharge of the industrial effluents and the sewage of the Karachi City give the rivers a sort of regular flow throughout the year (Figure 3).

Materials

During the performing of the experiment the following materials were used; HNO_3 plastic containers. pH meter and conductivity meter, analytical grade reagent (A.R) chemicals and UV/Visible spectro-photometric, flame-photometric, etc.

Preparation of samples

Then these samples were collected in 2.0 liter screw cap plastic containers which were cleaned sequentially with tap water rinse, about 24 hours soak in 1% HNO_3 and several distilled water rinses then air dried at room temperature, capped and labeled. All the samples were immediately brought to the laboratory and refrigerated at 4^0C. Analytical grade Reagent (A.R) chemicals were used in the preparation of reagents and standards.

Samples analysis

Physical measurement and chemical analysis were carried out in duplicate for each sample. Standard UV/Visible spectro-photometric, flame- photometric, gravimatric and titrimatric methods were employed for the analysis of the samples. pH and conductivity parameters were measured immediately after collection whereas all the other estimations were completed within the next eight hours after the sampling.

Quality control

For the purpose of the pH and conductivity parameters were measured immediately after collection whereas all the other estimations were completed within the next eight hours after the sampling.

Data analysis

The data was analyzed through statistical standard method which is presented in Table 2 to 4 as per

Table 2. Physico-chemical parameters in Karachi city ground water

Sampling Location	No. of Samples	pH	Hardness (mg/lit as $CaCO_3$)	Conductivity (μS/cm)	TDS (mg/lit)
KE1	3	7.3 (7-7.5)	1408(454-2030)	2975(1875-10880)	2975(1143-637)
KE2	7	7.8(7.5-8.4)	407(268-541)	2006(1342-2562)	1259(872-1632)
KE3	5	7.8 (7.2-8.3)	861 (629-1180)	5834 (3654-7584)	3177 (2218-4526)
KE4	6	7.5 (7.3-7.9)	554 (430-665)	3986 (2532-4521)	985 (560-1025)
KE5	8	7.5 (6.9-8.0)	265 (124-399)	2568 (1547-3568)	1987 (1458-2486)
KW1	6	7.5 (7.2-7.8)	240 (93-330)	3256 (1587-5478)	1472 (875-2587)
KW2	6	7.7 (7.3-8.2)	431 (166-823)	3229 (2144-4987)	742 (245-1457)
KW3	3	7.5 (7.1-7.8)	628 (436-995)	1588 (1200-1600)	769 (571-968)
KW4	8	7.3 (6.9-8.5)	450 (187-590)	2212 (1142-2786)	1254 (914-2350)
KW5	6	7.1 (6.8-7.3)	294 (180-360)	2057 (1069-2556)	1458 (985-1987)
KS1	5	7.4 (7.0-8.2)	178 (113-354)	3115 (2290-4256)	678 (500-856)
KS2	4	7.2 (7.2-7.5)	204 (98-338)	1014 (786-1458)	415 (325-498)
KS3	3	7.8 (7.2-8.1)	197 (101-245)	2145 (1425-2687)	1578 (847-2260)
KS4	3	7.3 7.3-7.3	1070 447-2229	4483 2380-8560	2734 1451-5221
KC1	5	7.6 (7.0-7.8)	200 (132-540)	1578 (887-2314)	666 (458-896)
KC2	5	7.5 (6.9-8.1)	234 (165-443)	2546 (1978-2956)	2056 (1753-2356)
KC3	5	7.2 (7.0-7.8	150 (88-279)	2321 (1121-4325)	725 (475-2014)
KC4	5	7.2 7-7.3	809 353-2532	3546 371-12860	2163 226-7844

Table 3. Concentration of cations and anions in ground water of Karachi city.

Sampling Location	Chloride (mg/l)	Sulfate (mg/l)	Nitrate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
KE1	2054	1043	-	563	143	-	-
KE2	281	194	54	72	47	222	27
KE3	707	549	71	132	131	288	30
KE4	747	392	39	89	81	202	15
KE5	333	183	62	68	84	565	19
KW1	578	178	57	78	97	120	26
KW2	679	278	19	56	53	102	36
KW3	648	228	-	251	62	-	-
KW4	337	296	23	82	47	69	21
KW5	567	218	14	56	77	98	20
KS1	258	297	65	48	42	125	30
KS2	487	157	24	78	39	265	12
KS3	669	213	15	69	58	125	07
KS4	863	626	-	428	163	-	-
KC1	214	98	10	89	62	87	25
KC2	198	139	11	63	55	36	23
KC3	426	259	54	65	40	57	23
KC4	1660	700	-	808	110	-	-

Table 4. Parameters of ground water for some other location of Pakistan

S. No.	City/Town	PH	EC (µs/cm)	TDS (mg/L)	Hardness (mg/L as $CaCO_3$)	Sodium (mg/L)	Chloride (mg/L)
1	Lahore	7.7	500	380	240	40	47
2	Rawalpindi	8	700	450	260	48	33
3	Multan	8.1	800	550	270	60	130
4	Faisalabad	8.4	700	510	132	77	39
5	Peshawar	7.8	400	290	120	17	50
6	Mardan	7.4	430	320	170	18	30
7	Quetta	7.9	1035	700	325	36	77
8	Gawader	7.1	84500	61724	1142	700	9864
9	Karachi	8.4	10880	4526	2030	288	2054

requirement to the standard of research.

RESULTS AND DISCUSSION

From the observations and calculations, it was found that there are large variations in the levels of physico-chemical parameters and chemical composition of constituents inside the samples collected from three different localities of the area of Karachi City. Table 2 shows the phsico-chemical parameters of the analyzed samples with exception of few samples most of the water samples are neutral to alkaline in nature while some samples are generally containing hardness levels more than 500 mg/lit. The Electrical conductivity was varying among the sample locations and was found high in the samples taken from Karachi East (KE) and Karachi West (KW) districts which are due to the dissolution of salts (Hossadi, 1987).

So, generally the tendency of Total Dissolved Solids (TDS) in ground waters from residential areas is high. Few samples from Karachi Central (KC) and few from Karachi South (KS) have TDS less than 150 mg/lit while rest of the samples contained more than 300 mg/lit even 1000 mg/lit TDS due to the dissolved wastes of the industries in the ground concerned area. The industrial zones of KE and KW show higher levels of TDS than that of other residential areas.

Further the data of the Table 3 show the ranges and mean values of the anions and cations of the ground water samples. It was observed from the data that chloride was the most dominant anion in majority of the samples and is a dominant cation to contribute to TDS. The samples from KE contain the highest amount of the sodium that fall in the range up to 3499 mg/l which is not according to the level of the WHO. Most of the samples from the residential areas of KC and KW contain fewer sulfates than that of samples from KE and KW. Also, these samples have high level of chemical constituent because the locality situated near the sea shore and seawater intrusions cause such high level values.

The concentration of calcium ranges from 18 to 226 mg/l of samples from KS and KW, which are relatively less than compared to the KE. Similarly the samples collected from KE show significantly higher levels of magnesium more than 100mg/l. Potassium is present in relatively small concentration, ranging between 5 and 62 mg/lit, except for sample no 45 and 46 where level ranged between 140 and 310 mg/l.

The concentration of nitrate in the analyzed samples ranges between 6 to 163 mg/l. The relatively higher concentration of nitrate in the residential areas as compared to those near to industrial area indicates contamination of the waters with domestic waste water. High concentration of sodium chloride was found in the ground water of the concerned area due to the presence of sea water entrapped in sediments or solution of halite and related minerals in the evaporate deposits (Walton, 1970) caused by the sedimentary rocks of the area of marine origin. The high concentration of calcium and magnesium contents of the water might also be due to abundance of dolomite, magnesite and calcite in this arean (Davis and De Wiest, 1966).

Generally in sedimentary rocks, fresh water are located in siliceous sands and sand stones essentially formed by quartz having ionic composition: Ca>Na>Mg and Co_3^{2-} (Swain and Schneider, 1971). Sedimentary rocks also contribute a portion of their soluble constituents to the ground water because of their high solubility as compared with igneous rocks (Todd, 1959). The typical ionic composition of ground waters of Karachi and its neighborhood is: Na>Mg>Ca>K and Cl>SO_4 (Beg and Sitwat, 1988).

These are basically carbonate water under the influence of main sedimentary rocks. Their chemical composition has been changed during circulation due to various factors such as concentration, leaching, sea water intrusion, ion exchange and low rain fall leading to the ultimate ionic composition (Beg et al., 1994).

So, in the two districts KE and KW comprising two dominating industries viz. textile industry and leather industry, generate considerable pollution load. The reported analytical data on effluent of these industries in Karachi illustrate very high concentration of Na^+, K^+, Ca^{++}, Mg^{++}, SO_4^{2-} and Cl^-. The entire infrastructure relating to water supply and sewage system of the area have been

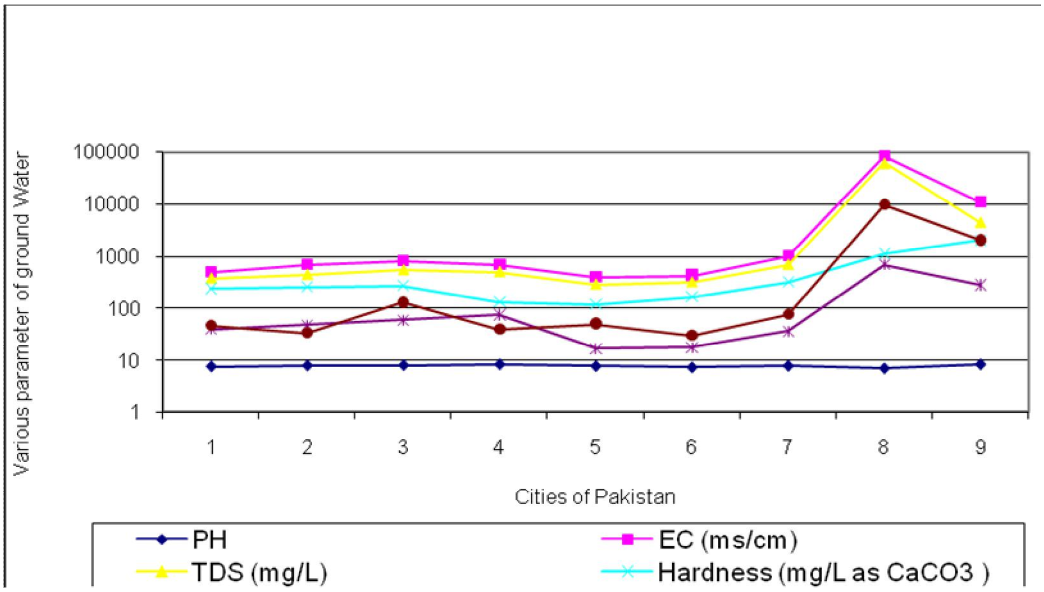

Figure 4. Various parameter of ground water of different cities of Pakistan.

seriously damaged due to the rapid unplanned expansion of industries, absence of wastewater treatment facilities and lack of proper repair and maintenance of the available sewerage system. The higher concentrations of chloride and nitrate are due to sewage pollution, and also indicate that the waters are contaminated at high degrees by untreated discharges of municipal waste.

The use of ground water has increased considerably due to the acute shortage of supply water and consequently the water- wells which were used to be about 20 to 25 feet in depth in 1960-80 has now fallen to the level of 40 to 60 feet in depth. Since the area which is located near the sea, the excessive extraction of water from many wells of the Karachi city specially KE at a rate exceeding "safe yield", has caused salt water encroachment. Thus most of the well waters have become enriched in ions characteristics of saline water.

Table 4 shows a comparison of ground waters quality of some major cities of Pakistan (Ahmed, 1991) with that of Karachi (Figure 4). Except for the highly saline water of Gawadar, the water of other cities is generally good and within the limits of WHO guidelines for drinking water. Generally the quality of ground waters in Karachi is varying but for KE and KW the chemical parameters are significantly higher than the recommended limits of WHO (WHO, 1994).

Conclusion

In conclusion it can be said that the ground water of the most areas of Karachi has been deteriorated as compared to the other cities of Pakistan due to inappropriate system of the seepage from domestic surface waters , huge amount of chemical constituents of industrial wastes waters , and sea water encroachment. Good quality well waters (WHO Standard) is scares in most areas of the Karachi and mostly the waters are brackish containing undesirable amounts of chemical constituents which are medically unfit for human consumption as well as for the general use of industries. Further, this study suggest that there is an urgent need for the monitoring of ground water sources of Karachi city and their protection from contamination by domestic, municipal and industrial pollution. At last but not the least important, the public awareness program must be launched in order to save the lives of peoples from the sever diseases. This scenario suggests that a desirable course of action should be taken to extract groundwater in the urban areas as a valuable resource and to solve the problems related to groundwater rising.

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