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Human Induced Impact on Malir River Basin Karachi, Pakistan

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Abstract: The aim of present study was is to create awareness about the current status of irrigation water (ground/ water) quality and usability for cultivation. The irrigation system of study area is devoid of artificial system and receives insufficient precipitation. Levels of selected heavy metals such as Cd, Cr, Cu, Fe, Ni, Zn, Mn, Hg and Pb were estimated in water samples used for irrigation. A majority of the samples collected from the catchment area of Malir River, sub-urban eastern area of Karachi (near the sewage and industrial drain). Almost all the samples were are within WHO irrigation (water) standards of year 2004 (except for TDS). Iron showed a negative correlation with pH, TDS and all detected metal ions, where as positive correlation exist between Mn and Zn. Heavy metal concentrations were found to be elevated ions in almost all samples of vegetables, fruits and fodders irrigated in the study area particularly concentrations of Mn, Pb, Hg and Zn, which are well beyond WHO prescribed standard prescribed limits.

Key words: River Basin · Malir · Irrigation · Karachi · Heavy metals

INTRODUCTION

The supply and demand of surface water is widening with increasing population especially in water starved region [1,2]. Besides over extraction of underground water depletes water table and accelerate the migration of contaminates from the land surface to aquifer [3] This makes good quality aquifer vulnerable [4,5]. Domestic and industrial effluent contributes to an increase concentration of different pollutants in ground water [6] as well as surface water [7-12]. Reuse of waste water can meet plant requirements but contaminate natural resources and produce degraded crops [13,14]. Majority of urban and sub-urban cultivation depends on waste water irrigation in most of water deficit countries [15-18].

Like many big cities of developing countries, Karachi is expanding every day. The city has a large number of industrial units generating approximately 1.3 million liters of effluents per day [19] with only about 5% of the industrial and domestic waters receiving significant treatment and the rest untreated waste discharge directly into Malir and Lyari rivers. In addition, numbers of small industries discharge their effluents directly into the hydrological system causing an imbalance to the environment. It is expected that samples collected from these catchment basins contain high concentration of trace metals as these pollutants accumulate in nature over a long period of time. Deterioration in water quality and contamination of ground water aquifer systems may produce negative impact on Human health.

The catchment areas of Malir and Lyari rivers irrigation system is devoid of artificial irrigation system and is totally dependent either on rain water or on ground/reuse waste water, where the rain water is limited. The safety of ground water supplies is very important in and around Karachi close to Arabian Sea. However the attention to groundwater has remained limited and there are gaps in groundwater information and management elements in the national water resources and environmental plans with inadequate regulatory frameworks and institutional resources for ground water management and monitoring in Pakistan. In this research we investigated the natural and human induced impacts on irrigation water in suburb of Karachi.

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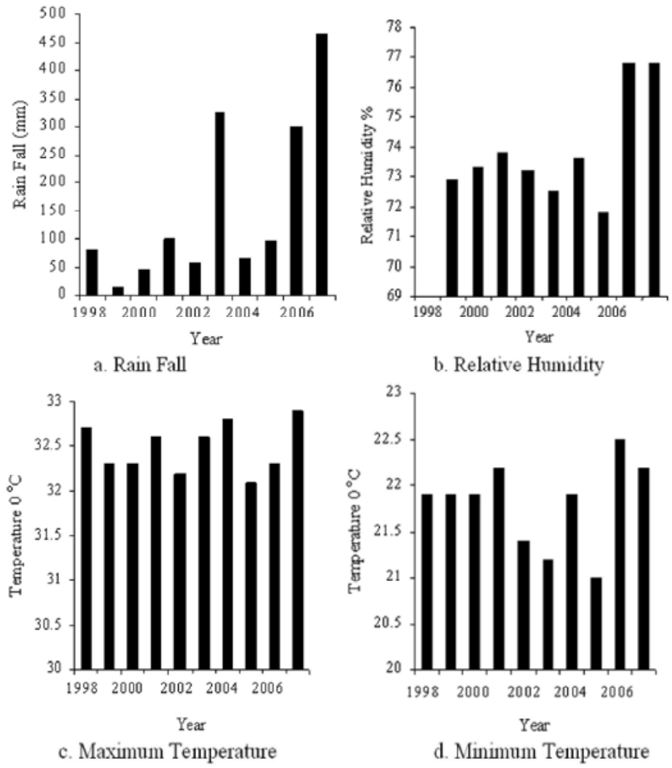

Fig. 1: Summary of general meteorological parameters of Karachi.

The quality of well and waste water samples was studied analyzed to achieve the careful awareness about the current status of groundwater quality and usability for irrigation.

Geo-Chemistry: The area under study lies on the South eastern corner of the Karachi. It is marking the southern most extension of the Pab range. The exposed rocks in the area are Nari and Gaj formation of Oligocene age. These two formations are exposed continuously from the western coast of Karachi to northeastern Sindh, forming a series of asymmetrical folds plunging south west. The intensity of folding decreases eastwards and after the Lyari syncline, the dip of the beds is low. As a result in the southern part of the study area, only upper Gaj rocks are exposed. The drag clay unit of upper Gaj formation consists of multicolored clay with few bends of fossile ferrous, limestone and soft sand stones[20]. The catchments are as of Malir, Lyari and Hub rivers are situated in the north of the study area.

The major and trace elements are derived from the older formation such as Shirinab, Samber, Goru, Parh and Khadro formation. Shirinab formation has Lead (Pb) and Baruim (Ba) mineralization and serves as a source of enrichment of these toxic elements in the water. The exposed igneous rocks including Bela ophioliles is a good source of Chromium, Nickel, Magnesium and Iron in the ground water [20,21]. In the major part of the area, water is present at very shallow depth from 10-25 m. The water-saturated zones are present within the weathering profile of the rocks or in the recent wind blown sand. Stable aquifers are present in the terrace deposits of Malir, Lyari and Hub rivers, which are 150-200 meters thick. The sources of irrigation include wells water, municipal water and stagnant water in localities (at farms), but industrial drained waste water is also used for agricultural purpose containing adequate quantities of toxic metals content in its composition [21,22].

Climate: The study area is located in the northern tropical zone of the earth, where most of the desert belts of the world in which a major mountain belt oriented north-south and the Arabian sea located to the south of the coast [23], the city tends to have a relatively mild climate with low precipitation, the bulk of which occurs during July, August, monsoon season, winters are mild and while the summers are hot. However the proximity to the sea maintains the humidity level. The total average rainfall in and around Karachi is less than 200mm per year based on last 50 years record [24]. Most of it falls in a few storms during the monsoon of July and August. The rainfall is very irregular and is characterized with long droughts for period of years, very frequent during 2000 and 2004 (Fig. 1).

Objectives: The present study is undertaken to achieve the careful awareness about the current status of ground water quality and usability of irrigation.

MATERIALS AND METHODS

Ground water sample were collected from the entire Malir river catchment in such a manner that does not deteriorate or get contaminated with any substance. It was sampled from the wells only when the wells was pumped sufficiently long enough to ensure that pH, temperature, specific conductivity stabilized and samples represent the ground water of the study area. These samples were collected from the considerable distance from the sewage and industrial drain, after the effluent had mixed with uncontaminated or less contaminated surface water, to understand the encroachment of pollutants into the groundwater system or sub-surface water. These water bodies are used for agricultural purpose.

The physical parameters, pH and total dissolved solids (TDS) were performed on unfiltered samples with the help of HECH pH meter (also mention model number). Standard methods for the examination of water and waste water of United State Environmental Protection Agency (USEPA also mention year) were used for the determination of heavy metals viz; for Cd, Cr, Cu, Fe, Ni, Zn, Mn, Hg and Pb. Standard procedures were adopted for the determination of heavy metals in the fruits, vegetables and fodders. (Also briefly mention the samples preparation for the detection of mentioned species of heavy metals along with references)

Correlation Study: Correlation analysis was applied to the multivariate data set to investigate the degree of similarities and probable inter relations among chemical and physical parameter [25].

RESULTS AND DISCUSSION

Karachi groundwater resources have been over exploited, often at the expense of deteriorating water and land quality [26]. However, not all groundwater problems are caused by over-extraction. Pollutants released to the ground can work there way down into groundwater. In recent years, the growth of industry, technology, population and water use has increased the stress upon both land and water resources of Karachi including sub-urban areas. This study revealed that local Geology has not shown any significant influence on groundwater of the study area. In alluvial deposit of sand, silt, gravel and clay, where the large number of unconfined aquifer occurs. there were No geological impacts were noticed on chemical composition of groundwater in which salt concentration reflects presence of clay and retained over there in ground water bodies in the form of perched water bodies. Furthermore hydrological pathway of these aquifers also shows unconfined aquifers and not influenced by local Geology.

The main pollutants of water in study area are domestic, industrial and agricultural wastewater discharges. The major portion of wastewater in eastern suburban part of Karachi discharged into the groundwater or Malir River. At present there are very limited wastewater treatment facilities in the area. In addition, the agricultural wastewater from agricultural areas also enters into the sub-surface water. Agricultural wastewater contains high level of NPK phosphorous, nitrogen, potassium and pesticides. Since the sub-surface water in the area has not been surveyed completely, the exact amount of fertilizer and pesticide infiltrated are not known. However, the amount of pollution would be significant because of the short distance between effluent and groundwater. Pollution from pesticide increases the level of metals such as Cu, Zn and Cr [27,28].

pH: The pH ranges from 7.19 to 8.44 (slightly alkaline) in the study area (Table 1). This comes in the WHO range of pH (6.5-8.5). The sampling points nearer to the drain showed slightly higher pH values compared to more distant points. This may be due to intrusion of sewage to the shallow groundwater. The algae present in the sewage water may have accelerated the conversion of anionic compounds into hydroxyl form which ultimately increased the pH value [29]. It is suggested that smaller metal solubility in response to higher pH is commonly marked for Zn zinc and Cd cadmium metal that tend not to complex strongly with soluble organic [30].

TDS: The distribution pattern of total dissolved solids (TDS) indicates that TDS is concentrated around the industrial drain. TDS concentration has reached level up to upto a level of 3075mg/l (Table 2). Since TDS comprises the sum of the total pollutants. It can be taken as an indicator of pollution. The international guide line for irrigation water suggests sever effects for water with TDS above 2000mg/l. Some of the dissolved salts get precipitated along the path of migration so a decrease in the levels of TDS in the surface water.

Table 1: Range, Mean and Standard deviation of heavy metal content in groundwater

	pH	TDS	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
N Valid	28	28	28	28	28	28	28	28	28	28	28
Mean	7.87	1911.01	0	0	0	0.002	.012	0.157	0	.311	0.188
Standard Deviation	0.30	1143.77	0	0	0	0.011	.012	0.317	0	0.126	0.200
Minimum	7.190	304.0	0	0	0	0	.002	0.001	0	0.041	0.027
Maximum	8.44	5075.0	0	0	0	.061	.056	1.582	0	0.568	0.965

Also mention the measuring units of each species of elements in Table 1 and 2 as well as in whole text.

Table 2: Distribution of Heavy Metals in Groundwater

Sample points	pH	TDS	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1	8.21	2443.3	0	0	0	0	.037	.023	0	.141	.163
2	7.80	1275.3	0	0	0	0	.004	.001	0	.473	.123
3	8.06	1125.2	0	0	0	0	.008	.033	0	.185	.063
4	7.89	4205.0	0	0	0	0	.008	.392	0	.568	.100
5	8.40	304.0	0	0	0	0	.008	.012	0	.166	.086
6	7.96	1538.0	0	0	0	0	.006	.001	0	.190	.107
7	7.74	1446.0	0	0	0	0	.002	.142	0	.555	.286
8	8.09	1029.0	0	0	0	0	.006	1.58	0	.404	.965
9	7.80	1224.0	0	0	0	0	.004	0.067	0	.270	.124
10	8.44	1514.0	0	0	0	0	.037	.073	0	.326	.082
11	8.24	1300.0	0	0	0	0	.013	.276	0	.362	.149
12	7.93	1174.0	0	0	0	0.020	.017	.106	0	.138	.107
13	7.62	1300.0	0	0	0	0	.023	.141	0	.176	.328
14	8.24	2610.0	0	0	0	0	.004	.680	0	.322	.276
15	8.08	1588.0	0	0	0	0	.019	.090	0	.295	.123
16	7.79	2175.0	0	0	0	0	.026	.320	0	.357	.123
17	7.40	1158.0	0	0	0	0	.004	.121	0	.286	.209
18	7.89	2175.0	0	0	0	0	.002	.105	0	.368	.027
19	7.80	787.0	0	0	0	0	.013	.008	0	.041	.050
20	7.86	1607.0	0	0	0	0	.008	.049	0	.389	.125
21	7.70	1886.0	0	0	0	0	.017	.001	0	.410	.076
22	7.46	5075.0	0	0	0	0	.056	.013	0	.424	.719
23	7.59	3335.0	0	0	0	0	.004	.001	0	.168	.178
24	7.80	1748.0	0	0	0	0	.015	.001	0	.371	.149
25	7.19	562.0	0	0	0	0.061	.008	.043	0	.363	.092
26	7.49	2392.5	0	0	0	0	.006	.121	0	.286	.209
27	7.74	4422.5	0	0	0	0	.002	.001	0	.343	.121
28	8.24	2109.8	0	0	0	0	.004	.012	0	.344	.115

Table 3: Correlation coefficient (r) studies of various chemical attributes of Malir River basin, Karachi, Pakistan.

	pH	TDS	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
pH	1.000										
TDS	-0.190	1.000									
Cd	0.000	0.000	1.000								
Cr	0.000	0.000	0.000	1.000							
Cu	0.000	0.000	0.000	0.000	1.000						
Fe	-0.411	-0.262	0.000	0.000	0.000	1.000					
Hg	0.053	0.297	0.000	0.000	0.000	-.052	1.000				
Mn	0.217	-0.052	0.000	0.000	0.000	-.078	-0.140	1.000			
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Pb	-0.145	0.324	0.000	0.000	0.000	-0.008	-0.085	0.252	0.000	1.000	
Zn	-0.107	0.208	0.000	0.000	0.000	-0.116	0.269	0.704	0.000	0.236	1.000

The distribution of heavy metals in groundwater in the study area are shown in Table 2. Sampling points located in the study area show generally no elevated concentration of solutes and may be taken to represent base line conditions. Analytical results did not reveal the heavy metals loading initially anticipated for irrigation and industrial sites. The release of contaminants from sewer systems in addition to other types of improper disposal may also contribute significantly to the contamination of groundwater. However, retention of inorganic pollutants within the unsaturated zone and dilution in conjunction with the buffering capacity. (it is the ability to resist significant pH changes by neutralizing introduced acidic solution) The calcareous sand stone cement helps groundwater to retain near neutral pH values, with a pH range of 7 ranging from 6.4 to 8.0 standard pH units.

Generally redox groundwater conditions and the absence of any detectable iron in all but one groundwater sample also suggested low mobility potential and removal of heavy metals via co-precipitation during ferric hydroxide precipitation. Furthermore, Laboratory data published did support the assumption of heavy metal removal via sorption and surface precipitation on the ferric hydroxide sandstone coatings under the favorable Eh condition [31,32]. Ion concentrations are some times lower than other metals concentration so that transport on colloidal iron hydroxides limited in extent. The aquifer is apparently in capable of sorbing sufficient metals under the prevailing pH and Eh condition.

Correlation coefficient between the variable were calculated and listed in Table 3. The results of the study reveals that Iron is negatively correlated with all the rest metal ions detected, indicating that some of the dissolve salts of these metal ions get precipitated along with ferric hydroxide in the study area. Positive correlation exists in between Zn and Mn, suggested that they are moving together in the groundwater and uploading the pollutants from same source. Cation exchange capacity (CEC), sand and silt contents is are effective indicator of soil stability to attenuate metals [33]. Greater attenuation of metals is recorded up to varying degrees in all the soil types in presence NOM in Karachi [34]. Using the arithmetic average concentration of 28 monitoring sample from same number of cations the dominant heavy metals of the groundwater of the study area during monitoring period were as follows:

$$Mn > Zn > Pb > Hg > Fe > Cd = Cu = Ni.$$

Mean average percentage of metals is in compliance with WHO, 2004 (Table 2). Groundwater polluted by agricultural, industrial and sewage effluent is being used for irrigation purposes in and around Karachi; for last few decades, especially in the catchments area of Malir and Layari River. In such conditions toxic metals often accumulate in the soil and may gradually pass into edible parts of crops and into the food chain, posing considerable health risks to humans [35]. Mean average percentage of all metals estimated in fruits, vegetables and fodders cultivated in the study area are higher than permissible limit; were as elevated concentration were noted in each and every samples Table 2, particularly notable are the concentration of Mn, Pb, Hg, Zn. Lead and Mercury exhibit greater toxic effects and can be dangerous for health especially, when they enter the food chain through the irrigated waters. These elevated concentrations may not only enter into the solids, groundwater and water reservoirs, but also may cause danger to human and animals.

CONCLUSION

Heavy metal contamination of ground water is generally low and believed to be affected by (a) Retardation in the unsaturated zone (b) mixing and dilution within the well, (c) ferric hydroxide precipitation and heavy metal co-precipitation in the oxidizing groundwater environment (d) sorption processes on sand stone particles coated with ferric hydroxide, clay and natural organic matter. The overall conclusion drawn from the present research is that in spite of benefiting humans, industries without proper check are still a major cause of most dangerous pollution in Karachi. Reuse of waste water can meet plant requirements but produce degraded crops. The source of the pollution is, as in many other parts of the world, almost certainly a combination of in adequate sanitation and industrial discharge or spillage or dumping.

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