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# Detection of Hazardous Contaminants in Ground Water Resources: An Alarming Situation for Public Health in Karachi, Pakistan

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**Abstract**

Due to industrialization and over population, surface water resources are out of reach from many people so consumption of ground water is the only choice to overcome the water scarcity. Naturally, ground water is one of the significant and potable water resource but some geographical conditions and anthropogenic activities deteriorate the water quality and make it objectionable for drinking. This study was conducted to evaluate the ground water quality of Karachi, Pakistan. For this, 42 ground water samples were collected from different districts of Karachi and analyzed their physicochemical and microbiological characteristics and compared with both international (WHO) and national (SEQS) drinking water standards. Observations of the study declared that overall contamination (physicochemical and microbial) in the ground water samples of different districts of Karachi was as follow West (21%), South (20%), Central (17%), Malir (16%), Korangi (14%) and East (12%). Physical assessment of the study area declared that pH and turbidity of the ground water samples varies in the range of (6.54-7.9) and (0-1.01 NTU) which exist in the standard prescribed limit. Whereas, detection of chemical contaminants particularly TDS (457-12090 mg/L), hardness (118.8-3645 mg/L) and chloride (190-4918 mg/L) content in most of the samples were also exceed from the prescribed limit. Additionally, arsenic was abundantly present ranging from 3.52-13.63 mg/L in all collected samples of Karachi city while the concentration of cadmium (range: 0.0005-0.5012 mg/L) and lead (range: 0.201-1.817 mg/L) were also high in few samples, from the permissible limit of drinking water. Microbial contamination was also detected in which coliforms were present in the range of 0-150 CFU/100mL, which also unfit the water quality. This deteriorated ground water quality of Karachi can be improved by maintenance of proper sanitary conditions of the communities and implementation of water treatments, otherwise consumption of such water may develop serious health related consequences in the consumers.

***Keywords**:* Ground water, Potable, Contaminants, Arsenic, Lead, Cadmium.

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## Introduction

Water is one of the basic necessities of life, which is required for the biological system for performing their metabolic activities. But some factors may deteriorate the water quality and alter its physical, chemical and biological characteristics whereas persistent consumption of the contaminated water mainly caused gastrointestinal problems and other health related consequences [1]. According to the literature, approx. 2.8 billion people of the world consume contaminated water so the death ratio of water borne illness reaches up to 6-8 million [2] whereas around 5 million children die each year due to consumption of this contaminated water [3]. In the contaminated water, microbial contamination is hazardous for human health and their effects develop instantly but toxicity of chemical contamination does not promptly develop and they produce persistent and long-lasting effects. Therefore, numerous outbreaks of microbial contaminated ground water have been reported but there are few descriptive illustrations are available for the toxicity of chemical constituents [4]. Thus, in developing countries, it is the chief concern for their authorities to supply the contamination free drinking water to the communities.

Although earth cover 71% portion with water but in this ratio maximum portion (97%) is covered with the saline water and only 3% water is available in the form of fresh water. In this fresh water, only 1% is present in the form of surface water resources like in river and lakes and 75% part exist in the form of polar ice bergs and glaciers which is unavailable to use while remaining 24% water is present in the form of ground water [5]. Due to over population and progressive industrial growth surface water resources are in danger not only in Pakistan but all over the world so, usage of ground water resources become induced for agricultural, industrial, domestic and drinking purposes to fulfill the water needs. According to an estimation, around 1.5 billion population of earth rely on the ground water resources to fulfill their water needs [6]. In the developed countries such as England, America, Germany and Denmark, 30%, 50%, 70% and 99% water requirements were fulfilled by the ground water resources, respectively [7]. In Asian countries like in Bangladesh 97% drinking and 80% agricultural requirements depends on the ground water. Whereas in Pakistan 35% and in India 60% agricultural practices performed by using the ground water resources and this ratio is increasing gradually [8].

Naturally, ground water resources are free from all types of contamination and are in easily access to the public sector but poor human practices such as seepage of waste water from pipelines, discharge of industrial chemicals into water bodies and extensive use of fertilizers on the agricultural land makes the ground water quality objectionable [9]. Moreover, hygienic conditions and depth of bore holes also affect the contamination ratio [10]. Among all toxic pollutants, inorganic chemicals are dominantly present in the ground water resources [11], in which heavy metals are one of them. Heavy metals are highly stable and can persist in the biological system (human and animal tissues) for a long period of time so they termed as “Persistent Bio Accumulative Toxic Chemicals” (PBTs) [12]. Whereas, persistent consumption of heavy metals contaminated water may cause various health related consequences including gastroenteritis, typhoid, cholera, dysentery and hepatitis [13].

Deterioration of drinking water quality became globally a serious threat, in Pakistan only 25% population has water which meets the drinking water standards [14]. According to literature the annual ratio of water related illness in Pakistan is 3 million [15]. Whereas its death ratio is up to 1 million, declared that every 5$^{th}$ individual suffered from water borne illness [16]. Karachi is one of the metropolitan city of Pakistan where industrialization and population is increasing rapidly therefore ground water resources become the consumption choice by many people because of insufficiency of surface water resources. There are many industrial sites such as SITE (Sindh Industrial Trading Estate), KITE (Korangi Industrial Trading Estate) and LITE (Landhi Industrial Trading Estate) which are producing highly toxic chemical wastes into both surface and ground water resources. Additionally, the intermixing of domestic or sewage waste in the water bodies is also responsible for producing different health related consequences in the population. In this regard, this study was conducted for detecting the hazardous contaminants in the ground water resources of different districts of Karachi city. Although, various research studies were previously conducted where ground water quality of specific geographical area of Karachi city was targeted but in the present study samples from all districts of Karachi city were collected and evaluated for their quality by assessing microbial, physical and chemical contamination. The degree of contamination in each district of Karachi city was also described. Briefly, this research is a snapshot in which district wise contamination was highlighted so that the concern authorities can easily approach the respective area and can immediately develop management strategies.

## Materials and Method

### *Sample Collection*

From all six districts (Karachi East, Karachi West, Karachi South, Karachi Central, Malir and Korangi) of Karachi, a total of 42 ground water samples were collected (Fig. 1). After sample collection, both microbiological and physico-chemical parameters were assessed by following the standard protocols of American Public Health Association (APHA) [17] and American Society for Testing and Materials (ASTM) [18].

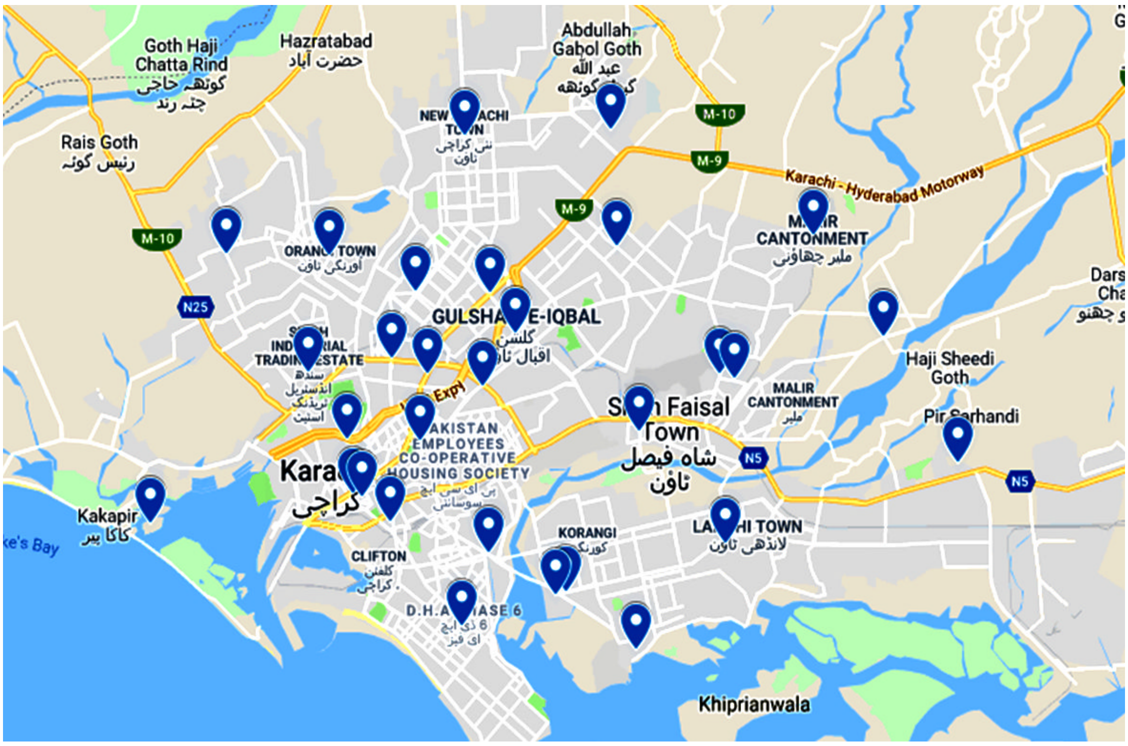


*Figure 1.* **Ground water sampling collection sites from different districts of Karachi city, Pakistan**

### *Microbiological assessment*

In microbiological assessment, number of heterotrophs (aerobic), coliforms, fecal coliforms and fungal contaminants were analyzed. The number of heterotrophs (aerobic) were assessed by pour plate method using nutrient agar [19]. Detection of coliforms and fecal coliforms are widely used for assessing the water quality therefore in present study Most Probable Number (MPN) method was used for the assessment of coliforms and fecal coliforms [19]. Whereas for the isolation of fungal contaminants, direct plate and dilution plate methods were used. Sabouraud's Dextrose Agar (SDA) was used in both direct and dilution plate methods. After fungal isolation, isolates were identified by their macroscopic and microscopic characteristics [19].

### *Physico-Chemical Assessment*

In physicochemical analysis, pH and temperature are significant parameters for assessing the water quality. Both parameters directly or indirectly affect all the other parameters of water. In present study, both parameters were analyzed by pH meter (Hach, HQ 440d) [17]. Turbidity, is another physical parameter, defines the clarity of water which depends on the constituents dissolved in water. Nephelometer (Hach, 2100 AN) was used for the assessment of turbidity of ground water [18]. Total dissolved solids (TDS) defines the concentration of total cations and anions present in water, in this study gravimetric method was used for analyzing the TDS of ground water [17]. Taste is an aesthetic effect which may vary from person to person but mainly it depends on the chemical constituents of water. In present study, taste of ground water was determined as WHO recommended classification [20], which was based on the TDS concentration. Moreover, Total hardness of water as $CaCO_3$ was assessed by EDTA titrimetric method [17], which measures dissolved concentration of calcium and magnesium ions. Chloride concentration represents saline content of water which was measured by mercuric thiocyanate method [17]. Whereas, concentration of sodium and heavy metals were analyzed by the direct air-acetylene flame method of atomic absorption spectrophotometer (FAAS, PE AAnalyst-700) in which prior to sample processing, samples were digested by wet way method [17].

## Results and Discussion

In the present study, for the assessment of ground water quality, microbiological and physico-chemical parameters of the ground water samples were analyzed and compared with international, World Health Organization (WHO, 2011) and national, Sindh Environmental Quality Standards (SEQS, 2016) drinking water standards (Table 1).

***Table 1.*** **Physico-chemical and microbial assessment of ground water samples with international (WHO) and national (SEQS) drinking water standards.**

| Parameter | Mini-mum | Maxi-mum | Mean | Stan-dard deviation | Acceptable limit | |
|---|---|---|---|---|---|---|
| | | | | | ***SEQS (2016)*** | ***WHO (2011)*** |
| pH | 6.54 | 7.9 | 7.29 | 0.351 | 6.5-8.5 | 6.5-8.5 |
| Temperature (°C) | 26.3 | 26.8 | 26.49 | 0.121 | NM* | NM* |
| Turbidity | 0 | 1.01 | 0.269 | 0.283 | < 5 | < 5 |
| Taste | - | - | - | - | NO* | NO* |
| Total Dissolved Solids (mg/L) | 457 | 12090 | 2452.74 | 3193.042 | < 1000 | < 1000 |
| Total hardness as $CaCO_3$ (mg/L) | 118.8 | 3647 | 730.841 | 962.170 | < 500 | < 500 |
| Arsenic (mg/L) | 3.523 | 13.63 | 8.715 | 3.215 | < 0.05 | 0.01 |
| Lead (mg/L) | 0.201 | 1.817 | 1.11 | 0.832 | < 0.05 | 0.01 |
| Cadmium (mg/L) | 0.0005 | 0.5012 | 0.0529 | 0.142 | 0.01 | 0.003 |
| Zinc (mg/L) | 0.014 | 0.436 | 0.132 | 0.114 | 5.0 | 3.0 |
| Copper (mg/L) | 0 | 0.0426 | 0.014 | 0.011 | 2.0 | 2.0 |
| Iron (mg/L) | 0.007 | 0.075 | 0.036 | 0.028 | NM* | < 0.3 |
| Chloride (mg/L) | 190 | 4918 | 1041.11 | 1316.889 | < 250 | 250 |
| Sodium (mg/L) | 39.89 | 76.21 | 64.88 | 11.388 | NM* | < 200 |
| Total coliforms (CFU/100mL) | 0 | 150 | 14.57 | 31.890 | 0 | 0 |

NO*= Non objectionable, NM*= Not mentioned

### *Microbiological Assessment*

Microbiological assessment revealed that in the ground water samples of all districts of Karachi, coliforms were present with a range of 0-150 CFU/100mL (Table 1) whereas, ratio of coliforms contamination was high in the samples of South and West districts (Fig. 2). However, fecal coliforms were positive in the samples of South, West, Central and Korangi districts of Karachi (data not shown). Presence of coliforms and fecal coliforms in the ground water violate the drinking water standards of both WHO (2011) and SEQS (2016) and made the water quality objectionable. Fecal coliforms are the indicator of other pathogens because they are mainly present in "Black water" (sewage water or water having fecal contamination) so possible reason of their contamination in the ground water resources is the intermixing of sewage water. Contamination of coliforms and fecal coliforms in the ground water resources were also reported previously [21]. But discharge of industrial effluents from paper, pulp, cotton and sugar beet processing industries also induce their contamination ratio [22]. Consumption of such contaminated water may induce various water borne illnesses such as gastroenteritis, traveler's diarrhea, Hemolytic Uremic Syndrome (HUS) and other urinary tract infections [23].

Besides coliforms and fecal coliforms, heterotrophic bacterial load (aerobic) was also detected which define the total number of viable microbial cells of both pathogenic and non-pathogenic organisms, they were found high in the samples of Korangi and East districts of Karachi. Variation in the heterotrophic count in ground water depends on the depth of boreholes and the sanitary condition of the sampling sites. Moreover, fungal contamination was also detected and the highest fungal load was observed in West and South districts of Karachi. In the present study, a total of five fungal species were isolated in which *Aspergillus flavus, A. fumigatus, A. niger, A. versicolor* and *A. terreus* were included. Among these isolates, dominating species were *A. flavus* and *A. versicolor* (data not shown). Fungal species and their growth mainly depend on the environmental factors like pH, temperature and the availability of organic content. Though, drinking water standards did not recommend the evaluation of fungal and heterotrophic count for assessing the water quality but their presence in drinking water cannot be negligible as it has been reported that fungal contamination in drinking water developed different opportunistic infections of eye, ear, lungs, skin and nails in humans [24].

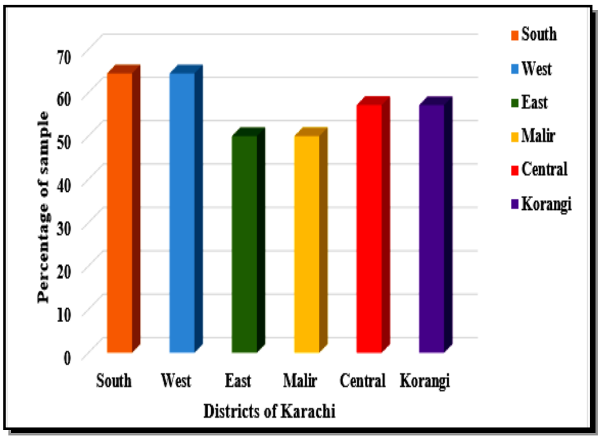


***Figure 2.*** **Percentage of violated samples by microbial assessment of ground water**

### *Physico-Chemical Assessment*

Physical assessment declared that pH and turbidity of ground water exist within the standard prescribed limit of drinking water (Table 1). Another study also reported permissible pH and turbidity level in the ground water [25]. However, no standard temperature range was prescribed which might be due to the seasonal variations in different geographical areas of earth. In our study, taste of ground water samples disrupts the water quality because of the excessive TDS constituents which were observed in the range of 457-12090 mg/L depicted in (Table 1). Among all districts, samples from West district have highly objectionable taste (Fig. 3).

Chemical assessment depicted that TDS, hardness and chloride content of ground water was high in most of the samples of West, South, Central and Malir districts of Karachi from the prescribed limit of drinking water (Fig. 4). In the literature, excessive TDS, chloride and hardness in ground water was also reported [26-28] respectively. In our study, observed range of TDS was (457-12090 mg/L), hardness was (118.8-3647 mg/L) and chloride was (190-4918 mg/L) (Table 1). Possible reason of exceeding these concentrations in ground water is intermixing of industrial, sewage or domestic waste. Consumption of water having high TDS and hardness may cause GIT problems and stones in the bladder and kidney respectively [29].

In the ground water samples of all districts, we observed permissible concentration of sodium, copper, iron and zinc (Table. 1), which simulates some other studies where permissible concentration of iron [27], sodium [28], copper and zinc was present in ground water samples [30].

In our study, arsenic concentration was found extremely high in the ground water samples of all the districts of Karachi (Fig. 5). It was found in the range of 3.52-13.63 mg/L, which exceeded the prescribed limit of drinking water (Table 1). Arsenic concentration in ground water depends on the depth of the boreholes [31] and it is obvious, from last few years that due to water scarcity, ground water in Karachi comes out after deep drilling of boreholes. Therefore, this deep drilling might be the reason of exceeding arsenic concentration in the ground water samples from all districts of Karachi. Similar to our findings, high arsenic concentration in ground water resources was also reported earlier [32]. Although, excessive concentration of arsenic and its compounds do not produce any aesthetic effect but its persistent consumption may develop chronic effects on human health in which bladder, lungs and skin cancers are the dominating one [33]. High dose of arsenic ingestion through water may also cause hyperpigmentation, cardiac, kidney, neural, and respiratory disorders. Moreover, development of type II diabetes mellitus also linked with the arsenic ingestion [34].

Along with arsenic, lead and cadmium concentrations were also found high in the samples of few districts of Karachi (Fig. 5). The range of lead and cadmium was observed as 0.201-1.817 mg/L and 0.0005-0.5012 mg/L respectively (Table.1), in which few samples violated the drinking water standards. These results were in contrast with a study where both lead and cadmium in the ground water were found in the acceptable limits [27] while another study simulate the current findings where both metals were found in excessive amount [35]. Literature suggested that plumbing is one of the common source of exceeding lead concentration in both surface or ground water resources [36]. Whereas lead toxicity may disturb stomach and kidney functions of human body [37]. Moreover, anxiety, dementia, stiffness in bones and muscles were also reported due to lead toxicity [38]. However, cadmium concentration may be induced due to intermixing of effluents of electro chemical industries because cadmium is widely used in electrical appliances [39]. According to the report of Agency for Toxic Substances and Disease Registry (ATSDR), cadmium caused lethal effects on human health in which hepatic, lungs, kidney and cardiac disorders were included [40].

Briefly, the overall picture of contamination (microbial and physicochemical) in the ground water resources of different districts of Karachi city was found as follows West > South > Central > Malir > Korangi > East (Fig. 6).

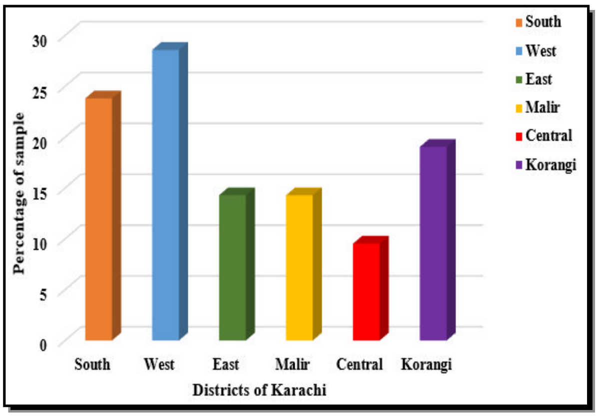


***Figure 3.*** **Percentage of violated samples by physical assessment of ground water**

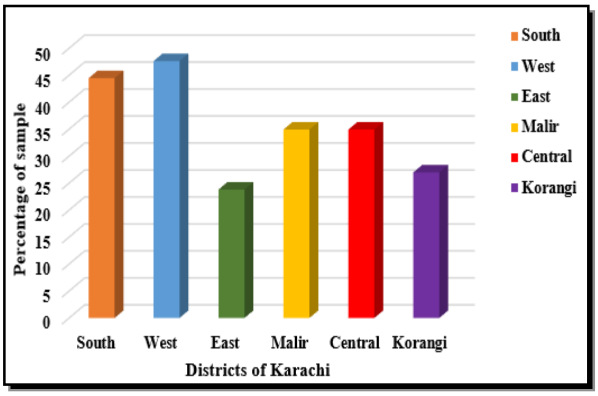


***Figure 4.*** **Percentage of violated samples by chemical assessment of ground water**

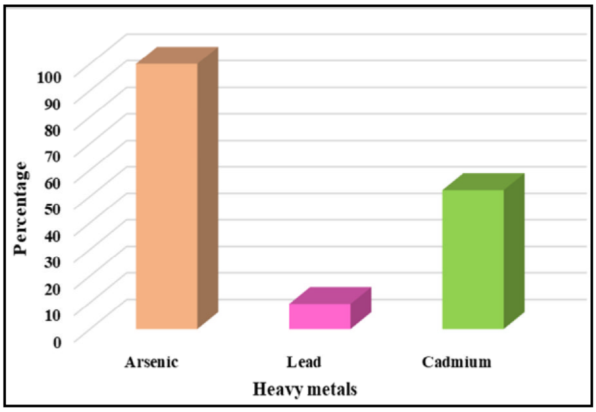


***Figure 5.*** **Percentage of heavy metals detected in the ground water samples**

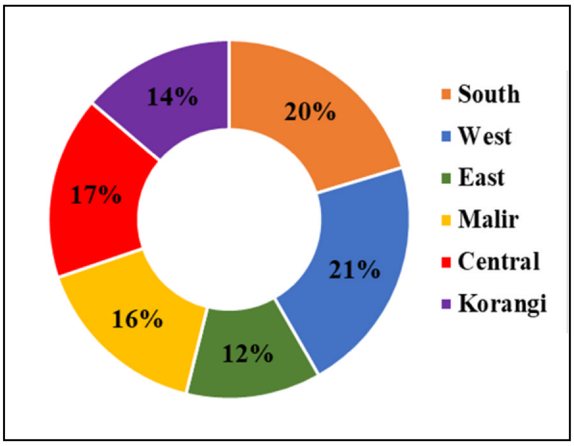


***Figure 6.*** **Percentage of heavy metals detected in the ground water samples**

## Conclusion

Physical assessment of the study area declared that taste of ground water was objectionable while pH and turbidity of the ground water samples exist in the standard prescribed limit. Among chemical contaminants, arsenic concentration was found extremely high, which is beyond the permissible limit. While other chemical parameters including TDS, hardness and chloride were also high and unfit the water quality. By microbiological assessment of the study, coliforms were detected in most of the ground water samples, whereas fecal coliforms were present in the samples of West, South, Central and Korangi districts of Karachi which also deteriorate the water quality. In short, this study stated that ground water quality of West and South district was highly contaminated followed by Central, Malir and Korangi districts whereas, contamination ratio in the East district was very low. There are many possible sources of ground water contamination including poor hygienic and sanitary conditions of these districts. Moreover, seepage of industrial effluents (from cottage industries) and household chemicals also induce chemical contaminants in the ground water. But this deteriorated ground water quality of Karachi can be improved by maintenance of good hygienic condition, repairing of leaked sewage pipelines and by spreading the awareness among the people about the hazards of water borne illnesses. Furthermore, implementation of water treatments like boiling, use of water softeners and chlorination can also reduce ground water contamination.

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