

Drinking water contamination by chromium and lead in industrial lands of Karachi

Nadeem-ul-Haq,¹ Mubashir Aslam Arain,² Zeba Haque,³ Nasira Badar,⁴ Noman Mughal,⁵

Department of Biochemistry, Dow International Medical College, Dow University of Health Sciences,^{1-3,5}

Department of Community Health Sciences, Aga Khan University,⁴ Karachi, Pakistan.

Abstract

Objectives: To identify and quantify chromium and lead as contaminant in water sources of Karachi.

Methods: This water assessment survey was conducted from June 2007 to February 2008 in all the 18 towns of Karachi. In total 216 water samples were collected from ground (n=108) and surface water sources (n=108). Water samples were collected in a liter polyethylene acid resistant bottle with extreme care to prevent contamination and concentrations of heavy metals (chromium and lead). Metallic ion contents were estimated by Atomic Absorption Spectrophotometer. Statistical analysis was done by applying T-test and chi-square for continuous and categorical variables respectively at 95% confidence level; Pearson correlation was also determined between chromium and lead concentrations.

Results: A total of 187 water samples had lead concentration higher than the maximum acceptable concentration (MAC) in drinking water, established by WHO (10 PPB) and lead contaminated sources were in significantly higher proportion than chromium contaminated water samples (n=49) [$\chi^2=128$; $P<0.001$]. Mean chromium concentration in ground water was ($\mu=49$; $SE=3.8$) was significantly higher than mean chromium concentration ($\mu=33$, $SE=3.5$) in surface water ($P=0.003$). There was a significant and positive correlation between chromium and lead concentrations in ground water ($P=0.04$) however Pearson correlation was not significant for surface water ($P=0.6$). Industrial towns (Korangi, Landhi and SITE) had significantly higher concentration of chromium ($\mu=82.4$; $SE=8.9$) in their ground and tap water as compared to the mean chromium concentration ($\mu=33$; $SE=2.2$) in the water samples of rest of the towns of Karachi ($P<0.001$).

Conclusion: Chromium and Lead levels are high in almost all ground water sources, however extremely high concentrations were found in industrial areas. Presence of any one of the heavy metal contamination necessitate the need for the estimation of other heavy metals as significant positive correlation was found between chromium and lead concentration, indicating the possibility of similar contamination sources in Karachi (JPMA 59:270; 2009).

Introduction

Maintenance of drinking water quality is considered to be a matter of extreme importance for the overall health of a community as several health related problems can be prevented by providing water that is pure and free of contaminants such as heavy metallic ions, minerals and bacteria. Safe drinking water, as defined by the World Health Organization (WHO) Guidelines,¹ does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Those at greatest risk of waterborne diseases are infants and young children, people who are debilitated and the elderly.

Several water sources in developing countries are unhealthy because they contain harmful physical characteristics such as foul smell, color, chemical

impurities like heavy metal ions, and biological agents including bacteria, virus, and protozoa. Even though most of the mortality and morbidity associated with water-related disease in developing countries is directly due to infectious agents, yet toxic substances as Arsenic, Fluoride, Lead, Manganese, Chromium, Copper, Iron, and Zinc can also lead to several water-borne diseases. Increasingly, agriculture, chemical, fertilizer and industrial wastes are being found contaminating freshwater supplies. Such chemicals, even in small concentration, can build up over time and, eventually, can cause chronic diseases as cancers among the users.² The increasing volume of human excreta as well as toxins and solid wastes from industries in urban areas is leading to a severe deterioration of water quality.³

Chromium is one of the heavy metal which can contaminate drinking water sources, in addition it is found in a wide range of foods, including egg yolks, whole-grain

products, high-bran break-fast cereals, coffee, nuts, green beans, broccoli, meat and brewer's yeast.⁴ Chromium is considered as an essential element for humans, and daily ingestion of 0.5 g to 2 g is required for adults, though daily requirements for chromium is somewhat controversial.^{5,6} A diet lacking in chromium may result in the development of diabetes mellitus as it has been found to be an active component of glucose tolerance factor (GTF), which make the metabolic action of insulin more effective⁷ and it also enhances the action of insulin within the cells.⁸ On the other hand excessive chromium exposure can have serious ill effects through excessive ingestion or environmental exposure (inhalation etc). It can cause perforation of nasal septum, lung cancer, and skin ulceration. Occupational studies concluded that there is sufficient evidence for the carcinogenicity of certain forms of chromium in occupational exposure to workers.⁹ The international agency for Research on Cancer categorizes chromium as carcinogenic to human beings. The excess effects of chromium are growth depression, damage to kidney and liver and cancer.¹⁰ WHO has set maximum acceptable concentration of 50 PPB for chromium in drinking water, and amount exceeding the limit can result in chronic toxicity if continuous ingestion takes place.

Lead is also one of the heavy metals that contaminates drinking water through its multiple originating sources like industrial waste, vehicle smoke and household paint. Prolonged undue exposure to lead can have deleterious effects on multiple organ systems, including the nervous, haematopoietic, renal, endocrine, and reproductive systems.¹¹ In addition children of 1 to 6 years of age are particularly prone to suffer from excessive lead exposure as the nervous and circulatory systems in young children are not fully developed.¹² WHO has set 10 PPB¹ of lead in drinking water as a maximum acceptable concentration (MAC), however previous studies in limited areas of Karachi has shown high lead concentration in surface and ground water sources in Karachi.

This drinking water quality assessment survey for heavy metal (chromium and lead) contamination was conducted from June 2007 to February 2008 in Karachi by the departments of Biochemistry, Basic Medical Sciences Institute, Jinnah Postgraduate Medical Center, Karachi. We examined 216 water samples obtained from ground and surface drinking water sources of the end users drinking water sources including houses and apartments of various locations in 18 towns of city. Karachi was selected as it is the largest, urbanized and industrialized city hence it is facing all kinds of environmental pollution including contamination of drinking water with heavy metals. In 2001 a devolution plan was implemented by the Government of Pakistan according to which the earlier five Districts of Karachi were merged into one district which officially became a City District, now this city is divided in 18 towns.¹³ Although there are no estimates

available for the informal sector, 75% of the working population is employed here.¹⁴ In this context the World Bank identified Karachi as the most business-friendly city of Pakistan in February 2007. Type of residence in Karachi can be divided into planned or unplanned areas. The unplanned areas may be either squatter settlements (non-permanent settlements) or slums. According to unofficial estimates there are 702 squatter settlements in Karachi.¹⁴ Different sources reported that between 40 to 61 percent of the city's population is living in squatter settlements^{13,14} where there is lack of proper shelter, water supply and other utilities.

Karachi receives water from Hub dam and Indus River from piped municipal water, wells and through vendors. Water from the Indus is the main source of water for Karachi and is sent through pipelines from a distance of 150 miles.¹⁵ The process of rapid industrialization and urbanization has created problems of water pollution in Karachi. In addition, lack of rational water management practices and improved sanitation has deteriorated, both chemically and biologically, the quality of ground and surface waters in the country.¹⁶ Data is scarce regarding the heavy metal contamination (Chromium and Lead) of water sources and its concentration in different regions of Karachi and it is important to identify and quantify the lead and chromium contaminated water sources for the prevention of poor health consequences as a result of their toxicity. Therefore the purpose of this study was to estimate chromium and lead concentration in water sources and to compare their concentrations in industrial and non industrial towns of Karachi.

Methodology

Water samples were collected from all the 18 towns of Karachi¹³ including 1) Kemari 2) Baldia 3) SITE 4) Lyari 5) Saddar 6) Orangi 7) North-Nazimabad 8) Liaquatabad 9) Jamshed 10) New Karachi 11) Gulberg 12) Gulshan-e-Iqbal 13) Korangi 14) Shah Faisal 15) Landhi 16) Binqasim 17) Malir 18) Gadap.

From each of the town, 6 ground water and 6 surface water samples were collected. Samples were collected in 1 liter polyethylene acid resistant washed rinsed with de-ionized water and dried bottles. Bottles were completely filled with the water samples and 5ml of (conc.) HN0_3 were added as preservative to adjust the pH < 2.0 to maintain heavy metal concentrations. Samples were marked with unique numbers with dates.

Samples were collected manually, by authors and trained data collectors. Extreme care was taken during the sampling and only trained persons were entrusted the task of sampling. The tap water sample was collected after removing any external filling from tap, such as rubber tube and then turning the tap on full and allowing to run to waste for 1

minute. Atomic Absorption Spectrophotometer of Perkin Elmer model AAnalyst 700 2003, at recommended wavelengths for metal ion was used as per standard procedure published by the American Public Health Association for the examination of water and wastewater method.

Data was entered and analyzed in SPSS version 15; Chi-square and t-test were applied for categorical and continuous variable respectively for individual town readings of lead concentration. In addition Pearson correlation was determined between chromium and lead concentrations at 95% confidence level.

Results

A total of 216 ground (n=108) and surface (n=108)

ground water ($P < 0.04$) however Pearson correlation was not significant for surface water ($P = 0.6$). SITE area had extremely high concentration of chromium in surface water ($\mu = 150$; $SE = 9$) as well as in ground water samples ($\mu = 145$; $SE = 16$). In surface water estimation, only SITE and Baldia town had higher than recommended mean chromium concentration though in ground water samples revealed high chromium content in drinking water samples from Landhi, Korangi, Gulberg, Sadar and Gulshan Iqbal (Table). Mean lead concentration was found to be higher than WHO recommendation in almost all towns of Karachi (though 29 of the individual samples were in normal limits). Extremely high lead concentration (> 200 PPB) was found in Jamsheed town, Baldia, Kimari Orangi and Liyari.

Table: Distribution of lead in ground water and surface drinking water supply in 18 towns of Karachi (N=216).

Areas	Mean Lead levels in Tap water PPB (SE)	Mean Lead levels in ground water PPB (SE)	Mean Chromium levels in Tap water PPB (SE)	Mean Chromium levels in ground water PPB (SE)
Bin Qasim Town	12.8 (6)	14 (7.4)	20.7 (8)	28 (7)
Gidap Town	14.5 (7.6)	28 (11)	16 (5.6)	32 (8.7)
North Nazimabad Town	23 (17.4)	35 (17)	20 (6)	18 (4)
Gulshan Town	26 (5.7)	33 (7.5)	29 (6)	68 (18)*
Shah Faisal Town	20 (6.3)	65 (12)	43 (18)	37 (9.9)
Gulberg Town	98 (15.8)	100 (37.6)	31.6 (9)	55 (17)*
New Karachi Town	95 (7.6)	93 (12.3)	15 (2)	33 (11)
Saddar Town	75 (8.5)	135 (24)	13 (2.6)	55 (32)*
Site Town	110 (22.6)	151 (22)	150 (9)*	145 (16)*
Liaqatabad Town	71.6 (14)	188 (71)	33 (8)	38.8 (8)
Landhi Town	100 (31)	160 (30.4)	36.6 (7)	61 (8)*
Malir Town	135 (24.6)	168 (32.5)	15 (2)	46.7 (11)
Korangi Town	105 (19.9)	185 (16)	34 (9)	66.6 (8)*
Jamshed Town	130 (23.6)	207 (43)	30 (10)	40 (7)
Baldia Town	75 (6.7)	207 (44)	55 (20)*	48 (12)
Kemari Town	120 (21)	270 (56)	18 (5)	45 (7.6)
Orangi Town	85 (11)	320 (71)	16.7 (3)	38 (8)
Liyari Town	91.6 (10)	270 (19)	19 (5.6)	26 (6.8)

* Chromium levels above WHO recommended cut off (> 50 PPB)

Person correlation was found significant between lead and chromium concentration in ground water (P -value=0.04).

water samples were collected from 18 towns of Karachi (6 from each drinking water source). Many water samples ($n = 49$) had chromium concentration higher than the maximum acceptable limit (MAC) in drinking water, established by WHO (50 PPB). In addition lead contamination was present in several ($n = 187$) water sources (> 10 PPB), which was in significantly higher proportion than chromium contaminated water samples ($\chi^2 = 128$; P -value < 0.001). Mean chromium concentration in ground water ($\mu = 49$; $SE = 3.8$) was significantly higher than mean chromium concentration ($\mu = 33$; $SE = 3.5$) in surface water (t -statistics = -3; $P = < 0.003$). Likewise lead was also present in significantly higher concentration in ground water ($\mu = 146$ $SE = 11$) as compared to surface water ($\mu = 81$; $SE = 6$) [t -stat = -5; $P = < 0.001$]. There was a significant correlation between chromium and lead concentrations of

Industrial towns (Korangi, Landhi and SITE) had significantly higher concentration of chromium ($\mu = 82.4$; $SE = 8.9$) in their ground and tap water as compared to the mean chromium concentration ($\mu = 33$; $SE = 2.2$) in the water samples of rest of the towns of Karachi ($P = < 0.001$). In addition, lead concentration was also found to be higher in industrial town ($\mu = 140$; $SE = 10$) as compared to the other towns ($\mu = 107.9$; $SE = 8$) of Karachi ($P = < 0.02$).

Discussion

The results of this study revealed that most of the city sources of tap (surface) and ground water were contaminated with unacceptably high levels of lead though situation is worse for ground water and particularly in industrial areas of the city. Almost all ground water sources

were found to have above WHO recommended lead concentration (10 PPB) and such water consumption is becoming the most dangerous source of lead ingestion in the city. Previous studies¹⁷ have also reported high lead concentration in certain water sources though no intervention has been done for the improvement of water quality.

Similarly chromium contamination was also found in several water sources in Karachi. Though epidemiological studies do not support direct effects of drinking water chromium content for toxicity, however continuous consumption of water with chromium concentration of greater than 25 PPB has been found to cause significant risk for toxicity.¹⁸ In industrial town including Korangi, Landhi and SITE, chromium concentration was significantly higher than mean concentration of other towns and such concentrations can certainly be dangerous for the water consumers. There are several factors for this high concentration as chromium is used in leather industry, pigments and glass industries. More than 7000 different industries are working in three industrial zones of Karachi region discharging their effluents up to 75-100 thousand m³ daily through Lyari River and Malir River across the city to the Arabian Sea damaging the quality of underground water of the city and the coastal area. Although there are few small treatment plants for industrial water, but they are totally insufficient.^{7,19}

The waste effluent contains high levels of chromium so the concentration of chromium in sub surface water of industrial areas becomes high. In Pakistan, mostly wastewater gets discharged untreated into surrounding surface waters including rivers, lakes, and coastal areas and for most of the cities, industrial zones and agriculture areas situated near the banks of the River Indus are using fresh water from River Indus and discharging the waste water back in to it without any treatment making the pollution load high.¹⁹ In addition, Saddar town, Gulberg town and Gulshan Iqbal town also showed higher chromium content in their ground water sources. Saddar town is particularly known to have high environmental pollution because it is the center of the city and large vehicle pollution as well as industrial waste originates in this region. High chromium content in Gulberg and Gulshan town is particularly worrisome and needs further investigation.

Prospective studies with large sample size can determine health affects of these high toxic substances in drinking water of Karachi. Children are particularly at high risk due to lead contaminated water and long-term health problems need to be investigated. Appropriate interventions are required to minimize heavy metal contamination

particularly in industrial zones where extremely high lead and chromium content was seen. In addition it can be concluded by the results of this study, that ground water sources are not safe in an industrial land like Karachi and extreme caution is required to use such water for drinking and food making purposes.

Conclusion

Chromium and Lead levels are high in several drinking water sources in Karachi. This is particularly alarming for ground water sources as almost all water sources are lead contaminated according to WHO acceptable limit 10 PPB and six towns had mean chromium concentration in water samples above acceptable limit of WHO (50 PPB). Presence of any one of the heavy metal contamination necessitate the need for other heavy metal estimations as significant correlation was found between chromium and lead concentration, indicating the possibility of similar contamination sources in Karachi. Immediate cessation of contaminated ground water sources is required specially those with high content of both lead and chromium.

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Conflict of interest:

Authors declare no conflict of interest with any institute or funding agency.

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