Drinking water: a major source of lead exposure in Karachi, Pakistan

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ماء الشرب: مصدر رئيسي للتعرُّض للرصاص في كراتشي في باكستان

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الخلاصـة: تُعَدُّ زيادة الرصاص في ماء الشرب مصدراً لا يُكتَرَثُ به للتسمم بالرصاص في باكستان. وقد أجرى الباحثون مسحاً مستعرضاً في عامَيْ 2007–2008 لعينات الماء المأخوذة من مصادر ماء الشرب في كراتشي، تلك المدينة الصناعية الكبرى. وتهدف هذه الدراسة إلى مقارنة مستويات الرصاص بين المياه الجوفية غير المعالَجة، وبين المياه السطحية المعالَجة (ماء الصنبور) في ثماني عشرة منطقة مختلفة. ومن بين 216 عينة تم جمعها من المياه الجوفيَّة والسطحية، احتَوَتْ 86٪ من هذه العينات على مستويات مرتفعة من الرصاص أعلى من أقصى تركيز تسمح به منظمة الصحة العالمية، وهو 10 أجزاء بالبليون. وكان متوسط تركيز الرصاص في المياه الجوفيَّة [146 (±119) جزءاً بالبليون] أعلى بدرجة يُعتدُّ بها إحصائياً من المياه السطحية [77.1 (±54) جزءاً بالبليون]. ولم يَقِلَّ متوسط مستوى الرصاص في المياه السطحية عن الحدّ الفيصل cut-off لمنظمة الصحة العالمية في أيٍّ من المناطق الثماني عشرة، في حين اتَّصَفَتْ مصادر المياه الجوفية في تسع مناطق بمستوى شديد من التلوث (> 150 جزء بالبليون)، مما يستدعي التدخُّل السريع للتخلص من مصادر التلوث.

ABSTRACT Excess lead in drinking water is a neglected source of lead toxicity in Pakistan. A cross-sectional survey in 2007/08 was made of water samples from drinking water sources in Karachi, a large industrial city. This study aimed to compare lead levels between untreated ground water and treated surface (tap) water in 18 different districts. Of 216 ground and surface water samples collected, 86% had lead levels higher than the World Health Organization maximum acceptable concentration of 10 ppb. Mean lead concentration in ground water [146 (SD 119) ppb] was significantly higher than in surface water [77.1 (SD 54) ppb]. None of the 18 districts had a mean lead level of ground or surface water below the WHO cut-off and ground water sources in 9 districts had a severe level of contamination (> 150 ppb). Urgent action is needed to eliminate sources of contamination.

Eau de boisson : une source majeure d'exposition au plomb à Karachi (Pakistan)

RÉSUMÉ Au Pakistan, une quantité excessive de plomb dans l'eau de boisson représente une source ignorée d'intoxication par ce métal. Une enquête transversale réalisée en 2007 et 2008 a analysé des échantillons d'eau provenant de sources d'eau de boisson à Karachi, une grande ville industrielle. Cette étude visait à comparer les taux de plomb des eaux souterraines non traitées et des eaux de surface traitées (robinet) dans 18 districts. Elle a révélé que 86 % des 216 échantillons d'eaux souterraines et de surface présentaient des taux de plomb supérieurs à 10 ppb, la concentration maximale acceptable selon l'Organisation mondiale de la Santé. La concentration moyenne de plomb dans les eaux souterraines [146 ppb (E.T. 119)] était significativement supérieure à celle des eaux de surface [77,1 ppb (E.T. 54)]. Dans aucun des 18 districts, le taux de plomb moyen pour les eaux souterraines ou de surface n'était inférieur au plafond de l'OMS. De plus, les sources d'eau souterraines de neuf districts présentaient un niveau de contamination très élevé (> 150 ppb). Une action urgente est requise pour supprimer les sources de contamination.

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Received: 21/12/09; accepted: 15/03/10

Introduction

Water contamination is as a major source of health problems, particularly in the developing world. Lead contamination of drinking water supplies can have deleterious effects on multiple organ systems, including the nervous, haematopoietic, renal, endocrine and reproductive systems, especially in children [1–5]. The principal routes of exposure and absorption of lead are through ingestion and inhalation, and around 35% to 50% of lead in drinking water gets absorbed in adults, a figure that can rise to 60% in children [6].

Excess lead in drinking water is a threat for population health not only in developing countries but also in the developed world. However, it is considered an overlooked source of lead toxicity [7]. In Pakistan few studies have been carried out on the health effects of lead through multiple lead exposure sources [8], although excessively high lead levels in drinking water have been reported in some areas of Karachi [4,9]. One community-based study hypothesized that high lead levels in blood may be a factor associated with hypertension in the Pakistani population [10]. A systematic review in Pakistan reported that more than half of children had higher than normal blood lead levels. Several factors are responsible for high lead exposure in Pakistani children, including paint, cosmetics, drugs, industrial waste and drinking water; however atmospheric lead exposure has been reduced since the introduction of lead-free petroleum fuel in 2001 [11].

The drinking water supply in Karachi city is mostly obtained through the municipal tapwater and local ground water [12], yet data are scarce regarding lead contaminated sources and their concentration in the different regions of Karachi. The aim of this study was to determine the concentration of lead in the tapwater and ground water of different areas of Karachi in order to prioritize actions on contaminated water sources in these areas.

Methods

This community-based water quality assessment survey was conducted from June 2007 to February 2008 in Karachi by the Department of Biochemistry at the Basic Medical Sciences Institute, Jinnah Postgraduate Medical Centre, Karachi.

Sampling

We examined 216 water samples obtained from drinking water sources in residential areas. Samples were collected from the end-users' drinking water sources, including houses and apartments of various locations in 18 districts of the city [13].

From each district 6 ground water and 6 surface water samples were collected. Surface water was defined as tapwater coming from rivers, dams and other storage sources, supplied to the city after filtration. Ground water samples were from those sources where individual houses, industries or small communities obtained their own water through boring into the land. This water usually does not go through any filtration plant and is used by the households in the original form by considering it pure underground water.

Data collection

Samples were collected in 1 L polyethylene, acid-resistant bottles that had been washed, rinsed with deionized water and dried. Bottles were completely filled with water samples and 5 mL of concentrated $HN0_3$ was added as preservative to adjust the pH to < 2.0 to maintain heavy metal concentrations. Samples were marked with unique numbers with dates. Samples were collected manually by the authors and trained data collectors. Water samples were obtained from tap after 1 minute running of water out of the tap to prevent falsely excessive heavy metal concentration.

An atomic absorption spectrophotometer (AAnalyst 700, Perkin Elmer), at recommended wavelengths for metal ions, was used as per standard procedure published by the American Public Health Association for the examination of water and wastewater method. Further details are explained in another published paper [14].

On site measurement of pH was conducted using a digital pH meter (Hanna, HI 9024) with a temperature probe. The meters were calibrated at 2 points against standard buffer solutions of pH 7 and 9 prior to each measurement.

Conductivity and total dissolved solids of the spot samples was measured with microprocessor portable conductivity/TDS meter (Hanna H l-9835). The manufacturer's calibration procedure was followed to obtain the guaranteed precision and accuracy. The conductivity meters were calibrated before each measurement against a standard solution of potassium chloride of known conductivity.

Statistical analysis

The data were entered and analysed using *SPSS*, version 15. Chi-squared and Student *t*-test were applied for categorical and continuous variables respectively for individual district readings of lead concentration. In addition multiple district comparisons of ground water was done using Kruskall–Wallis test at the 95% level of significance. A median ranking was made for each district on the basis of ground water lead levels.

Results

A total of 216 ground (n = 108) and surface (n = 108) water samples were collected from 18 districts of Karachi (6 from each drinking water source).

A great majority of the water samples (88%, 190/216) had lead levels higher than the maximum acceptable concentration in drinking water established by WHO (10 parts per billion (ppb)] [15]. While 90% (97/108) of the groundwater samples had lead levels about the WHO cut-off compared with 86% (93/108) of surface water samples, the difference was not significant (χ^2 = 0.9; P = 0.2).

Overall, the mean lead quantity in ground water [146 (SD 119) ppb] was significantly higher than in surface water [77 (SD 54) ppb] (P < 0.001). When the concentrations of lead were compared in each of the 18 districts, 7 districts had significantly higher mean lead levels in ground water as compared to surface water of the same district (Table 1). No districts had a mean lead level of ground or surface water below the WHO recommended levels of 10 ppb.

We classifies the districts into 3 zones of mild, moderate and severe lead contamination according to their mean lead levels in drinking water: < 50 ppb (the WHO cut-off until 1993) [15], from 50–150 ppb and > 150 ppb respectively. Only ground water sources were compared in Table 2 and significant differences were found between lead levels in the drinking water of 18 districts (χ^2 = 65.3, P < 0.001). The median ranking ground water sources of all districts revealed that Bin Qasim had the lowest lead concentration in drinking water, with median levels of 8 ppb and at the other extreme Jamsheed, Badia, Kimari, Liyari and Orangi ranked highest with median lead levels above 200 ppb (Table 2).

The pH in groundwater samples was in the acceptable range and no significant difference was found between the pH readings of ground and surface water samples [mean 7.3 (SD 0.4) versus mean 7.4 (SD 0.4)] (P = 0.8).

Mean total dissolved solids in ground water samples was 1084 (SD 913) mg/dL, which was significantly higher than in surface water samples [291 (SD 37) mg/dL] (P < 0.001). Kamari, Orangi, Lyari, Gulshan, Baldia, Site, Jamshed and Malir towns had total dissolved solids level > 1000 ppm and in other towns they were between 500 and 1000 ppm.

Discussion

The process of rapid industrialization and urbanization has created problems of water pollution in megacities such as Karachi. Despite generally improved sanitation, a lack of rational water management practices has led to a deterioration, both chemically and biologically, in the quality of ground and surface water sources [16]. The results of this study revealed that most of the sources of tap (surface) water and ground water were contaminated with unacceptably high levels of lead. The situation was worse in ground water which is becoming the most dangerous source of lead ingestion in the city.

Several studies have established a positive association of high blood lead

Table 1 Distribution of lead concentrations in drinking water supplies in 18 districts of Karachi: comparison of treated surface water and untreated ground water supplies (n = 6 samples in each district)

District	Lead levels in surface water (ppb)	Lead levels in ground water (ppb)	*t*-value	*P*-value
	Mean (SD)	Mean (SD)		
Bin Qasim	13 (15)	14 (18)	–0.07	0.9
Gidap	16 (19)	28 (27)	–0.1	0.3
Gulshan	26 (14)	33 (18)	–0.67	0.5
North Nazimabad	23 (43)	35 (41)	–0.47	0.6
Shah Faisal	20 (15)	65 (30)	–3.25	0.01
New Karachi	95 (19)	93 (30)	0.12	0.9
Gulberg	98 (39)	100 (92)	–2.5	0.9
Sadar	75 (21)	135 (59)	–2.4	0.04
Site	110 (55)	140 (44)	–0.4	0.6
Landhi	100 (76)	160 (74)	–1.4	0.2
Malir	135 (60)	168 (79)	–0.81	0.43
Korangi	105 (49)	185 (39)	–3.1	0.01
Liaqatabad	72 (34)	188 (174)	–1.6	0.1
Jamsheed	130 (58)	207 (105)	–1.5	0.1
Baldia	75 (16)	207 (108)	–2.9	0.02
Kimari	120 (51)	270 (1370	–2.5	0.03
Liyari	92 (26)	270 (47)	–0.82	< 0.001
Orangi	85 (27)	320 (174)	–3.2	0.02

ppb = parts per billion; SD = standard deviation.

Table 2 **Kruskall–Wallis test for differences in lead levels of untreated ground water drinking water supplies in 18 districts of Karachi grouped by level of contamination (*n* = 6 samples in each district)**

Level of contamination/District	Median lead levels ppb	Median rank
Mild (mean lead < 50 ppb)		
Bin Qasim	8	10.0
Gidap	20	17.8
North Nazimabad	20	19.5
Gulshan	25	21.4
Moderate (mean lead 50–150 ppb)		
Shah Faisal	65	34.6
Gulberg	70	44.3
New Karachi	110	45.5
Sadar	115	58.4
Site	155	61.6
Severe (mean lead > 150 ppb)		
Liaqatabad	150	61.8
Landhi	200	63.9
Malir	200	64.5
Korangi	195	70.3
Jamsheed	200	72.0
Baldia	185	74.6
Kimari	325	83.3
Orangi	365	87.2
Liyari	285	89.7

$\chi^2 = 65.3$, $df = 17$, $P < 0.001$.

levels with consumption of lead contaminated drinking water [17,18]. The health hazards from consuming such contaminated water are obvious [19]. Signs of chronic lead toxicity, including tiredness, sleeplessness, irritability, headaches, joint pains and gastrointestinal symptoms, may appear in adults at blood lead levels of 50–80 µg/dL. After 1–2 years of exposure, muscle weakness, gastrointestinal symptoms, disturbances in mood and symptoms of peripheral neuropathy were observed in occupationally exposed populations at blood lead levels of 40–60 µg/dL. Renal disease has long been associated with lead poisoning; however, chronic nephropathy in adults and children has not been detected below blood lead levels of 40 µg/dL.

In our study 86% of water samples had lead levels above the levels recommended by WHO, i.e. 10 ppb [15]. Our results are consistent with the results of other water assessment studies in Pakistan [9]. On the other hand, one study from a developed country reported that only 3.7% of water samples from household drinking water were above the WHO recommended lead levels. In our study we also calculated mean lead levels in each district and found no district with a mean lead level of drinking water below the WHO recommended levels. According to our classification, although ground water sources in 9 districts were in the category of severe lead contamination.

In both water sources, our results of lead concentration were compatible with the results of Jaleel et al. in different districts of Karachi [9]. Lead is used in the production of lead acid batteries, solder, alloys, cable sheathing pigments, rust inhibitors, glazes and plastic stabilizers. Most of these industrial wastes are dumped into the rivers and soil without treatment. This is probably the major source of the high rates of lead contamination of drinking water in Karachi. Leaching from lead supply pipes is also a well known source of lead in tapwater [20] and corrosion of water and sewage pipelines, which may lead to release of heavy metals into drinking water, is a common occurrence, particularly in the older areas of Karachi.

In our study water pH was measured as lower pH can enhance corrosion of waterpipes [21,22]. However, we found all water samples from both surface and groundwater within the WHO recommended pH range of 6.5–9.5 [21] in all districts of Karachi. Although no health-based guidelines are proposed for pH, eye irritation and other skin disorders are associated with pH values > 11.

Total dissolved solids may also lead to increased corrosion of water pipes. On the other hand few studies have shown that high total dissolved solids in water may have a protective effect on cardiovascular disease [23]. Total dissolved solids < 500 ppm are considered as normal, although levels up to 1000 ppm may be acceptable concentrations [24]. In present study the mean concentration of total dissolved solids of tap water was below the 500 ppm level [291 (SD 37) mg/dL], but the mean surface water concentration was higher than the WHO cut-off [1084 (SD 913) mg/dL].

Prospective studies with large sample sizes can determine the health effects of high lead contamination in the drinking water of Karachi. Children are at particularly high risk from lead contaminated water, and the long-term health problems need to be documented as most of the existing studies in Pakistan have been conducted on small samples [11]. Appropriate interventions are required to minimize lead levels in water. In addition there is a need to investigate the reasons for extreme differences in lead levels among different districts of the city so that the further sources of contamination can be eliminated.

Conclusions

Lead levels are extremely high in several drinking water sources in the industrial city of Karachi. This is particularly alarming in ground water sources, almost all of which had higher lead concentrations that the WHO acceptable limit of 10 ppb. Underground drinking water can be a source of heavy metal toxicity and needs thorough testing for unseen toxic substances such as lead. Mean lead quantity was > 150 ppb in the ground water sources in half of the districts of Karachi. There is a need for further investigation of sources of lead in drinking water supplies in the city and for detailed inspection of water samples to be carried out in every area. In the worse affected districts there may be a need for cessation of some of the water sources to prevent the adverse consequences of lead toxicity in the public.

Acknowledgements

We acknowledge the support of Professor Zahida-T-Maqsood, Department of Chemistry, University of Karachi, for providing laboratory test facilities for the water samples.

We also acknowledge the academic support of Professor Khemomal A. Karara, Head of the Department of Biochemistry, Basic Medical Sciences Institute, Jinnah Postgraduate Medical Centre, Karachi, Pakistan.

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