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Review

Heavy metal pollution in drinking water - a global risk for human health: A review

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Water resources in the world have been profoundly influenced over the last years by human activities, whereby the world is currently facing critical water supply and drinking water quality problems. In many parts of the world heavy metal (HM) concentrations in drinking water are higher than some international guideline values. Discussing about the HM pollution in drinking water, the incorporation of them into the food chain, and their implications as a global risk for the human health, are the objectives of this review. It is known that there are million people with chronic HM poisoning which has become a worldwide public health issue, while 1.6 million children die each year from diseases for which contaminated drinking water is a leading cause. There is also evidence of HM in drinking water that are responsible for causing adverse effect on human health through food chain contamination. A global effort to offering affordable and healthy drinking water most to be launched throughout the world, while various laws and regulations to protect and improve the utilization of drinking water resources should be updated or created throughout the world, including the low income countries; otherwise, the problem of HM-polluted drinking water will be growing because demand for drinking water is still growing such as this problem will become even more pressing in the future. Finally, notwithstanding, additional researches are necessaries about the correlation between HM concentration in drinking water and human diseases, while the development of robust, cheap and sustainable technologies to improve the drinking water quality is necessary.

Key words: Groundwater, aquifer, water quality, water pollution, microorganism, water supply, microbial communities, food chain, disease.

INTRODUCTION

Although, there is no clear definition of what a heavy metal (HM) is; density is in most cases taken to be the defining factor. HM are thus commonly defined as those elements having a specific density of more than 5 g cm^{-3}. The main threats to human health from HM are associated with exposure to cadmium, lead, mercury and arsenic (arsenic is a metalloid, but is usually classified as a HM), but additionally, there are others 19 elements

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known as HM: antimony, bismuth, cerium, chromium, cobalt, copper, gallium, gold, iron, manganese, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc. Interestingly, small amounts of HM are common in our environment and diet, even some of them are necessary for good health, for example, living organisms require varying amounts of HM such as iron, cobalt, copper, manganese, molybdenum and zinc, which are required by humans too. However, large amounts of any of them may cause acute or chronic toxicity (poisoning) (Kabata-Pendias and Mukherjee, 2007). Soils represents a major sink for HM ions, which can then enter the food chain via water, plants or leaching into groundwater. HM toxicity can result in brain damage or the reduction of mental processes (Gaza et al., 2005) and central nervous function (Bouchard et al., 2011), lower energy levels (Holmstrup et al., 2011), damage to DNA (Jomova et al., 2011), alterations on the gene expression (Salgado-Bustamante et al., 2010), skin (Burger et al., 2007), muscle (Visnjic-Jeftic et al., 2010), blood composition (Di Gioacchino et al., 2008), lungs (Thomas et al., 2009), kidneys (Johri et al., 2010), liver (Burger et al., 2007), heart (Otles and Cagindi, 2010), and other vital organs for humans and other living organisms.

Long-term exposure to HM may result in slowly progressing physical, muscular and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, multiple sclerosis (Jones and Miller, 2008), gangrene, diabetes mellitus, hypertension and ischemic heart disease (Otles and Cagindi, 2010). Allergies are commons and repeated long-term contact with some HM or their compounds may even cause cancer (Dietert and Piepenbrink, 2006). For some HM, toxic levels can be just above the background concentrations naturally found in nature. However, HM have been excessively released into the environment due to rapid industrialization, manufacture of fertilizers and to the high production of industrial waste (Katsou et al., 2011) originated from metal plating, mining activities, smelting, battery manufacture, tanneries, petroleum refining, paint manufacture, pesticides, pigment manufacture, printing or photographic industries (Aguilera et al., 2010). This has created a major global concern because they are non-biodegradable and can be accumulated in living tissues, causing various diseases and disorders within the food chain. It is well known that groundwater supplies most drinking water throughout the world, which the global population is 7 billions of people (UNFPA, 2011), and whereas about 1.1 billion of them worldwide lack access to improved drinking water supplies and use unsafe surface and groundwater sources. Even people who have access to “improved” water supplies such as household connections, public standpipes, and wells may not have safe water (Sobsey et al., 2008) because it is well known that drinking water could be polluted with microorganisms (Lugoli et al., 2011), arsenic (Akter and Ali, 2011), polycyclic aromatic hydrocarbons (PAHs) (Bruzzoniti et al., 2010), organic pollutants (Wu et al., 2010), nitrate and nitrite (Manassaram et al., 2010) and HM (Bourdineaud, 2010).

At our knowledge, there are not reviews summarizing the global risk for the human health by the HM pollution in drinking water. The objective of this review is to discuss about the HM pollution in drinking water and their implications as a global risk for the human health.

HEAVY METAL POLLUTION IN DRINKING WATER THROUGHOUT THE WORLD

Pollution is defined as the introduction of elements, compounds or energy into the environment at concentrations that impair its biological functioning or that present an unacceptable risk to humans or other targets that use or are linked to the environment, while HM are common pollutants which might be found in drinking water throughout the seven continents arising scientific and public concern on human health. The continents identified by convention rather than any strict criteria are (from largest in size to smallest): Asia, Africa, North America, South America, Antarctica, Europe and Oceania.

The Asian continent

Asia is the largest continent on Earth in which China, Bangladesh, Vietnam, Taiwan, Thailand, Nepal and India are located, seven countries where environmental concerns are arising because large amounts of HM have been found in drinking water. In these countries, arsenic is found at high concentration in groundwater, drinking water and surface soil (Chen, 2006). Roychowdhury et al. (2003) reported that in India, the arsenic concentration (107 µg L^{-1}) in drinking water was approximately 11 times higher than the World Health Organization (WHO) guideline value (WHO, 2008) (Table 1), while concentrations of copper, nickel, manganese, zinc and selenium were lower than the WHO guideline values (Table 1). Furthermore, Chatterjee et al. (1995), found as, in ground water above the maximum permissible limit in six districts of West Bengal, India, covering an area of 34000 km^2 with a population of 30 millions. Ten years later, on the same area, Von Ehrenstein et al. (2005) revealed that consumption of arsenic-contaminated water was associated with respiratory symptoms and reduce lung function in men, especially among those people with arsenic-related skin lesions (Table 2), while Borah et al. (2010) stated that the drinking water sources in Assam, India, are heavily polluted with lead. Additionally, Borah et al. (2010) reported that iron content in the drinking water sources in that area exceeds the WHO guideline value of 0.3 µg L^{-1} (Table 1). Chaudhary and Kumar (2009) revealed that in the villages

Table 1. Current drinking water quality guidelines (µg L^{-1}) for heavy metals (HM), published by several organizations, committees or agencies throughout the world. There are no drinking water quality guidelines for bismuth, cerium, cobalt, gallium, gold, platinum, tellurium, tin and vanadium.

HM	**WHO**[a]	**USEPA**[b]	**ECE**[c]	**FTP-CDW**[d]	**PCRWR**[e]	**ADWG**[f]	**NOM-127**[g]
Antimony	20	6	5	6	5	3	---
Arsenic	10	10	10	10	50	10	25
Cadmium	3	5	5	5	10	2	5
Chromium	50	100	50	50	50	50	50
Copper	2000	1300	2000	1000	2000	2000	2000
Iron	---	300	200	300	---	300	300
Lead	10	15	10	10	50	10	10
Manganese	100	50	50	50	500	500	150
Mercury	6	2	1	1	1	1	1
Nickel	70	---	20	---	20	20	---
Silver	---	100	---	---	---	100	---
Thallium	---	2	---	---	---	---	---
Uranium	30	30	---	20	---	17	---
Zinc	---	500	---	5000	5000	3000	5000

[a], World Health Organization (WHO 2011); [b], United Stated Environmental Protection Agency (USEPA, 2011); [c], European Commission Environment (ECE, 1998); [d], Federal-Provincial-Territorial Committee on Drinking Water (CDW), Health Canada (FTP-CDW, 2010); [e], Pakistan Council of Research in Water (PCRWR, 2008); [f], Australian Drinking Water Guidelines (DDWG, 2011); [g], Norma Official Mexicana NOM-127-SSA1-1994 (DOF, 1994).

Table 2. Symptoms or diseases associated with humans exposed to high heavy metals (HM) concentrations.

HM	**Exposure route**	**Symptoms or diseases**	**Reference**
Arsenic	Water ingestion	Melanosis, leucomelanosis, keratosis, and cancer	Medeiros et al. (2012)
	Water ingestion	Effects on neuronal development	Camacho et al. (2011)
	Water ingestion	Damage to DNA, single-strand DNA and double strand DNA breaks, cerebrovascular diseases, diabetes mellitus and kidney diseases	Jomova et al. (2011) and Mo et al. (2009)
	Ingestion	Alterations on the gene expression	Salgado-Bustamante et al. (2010)
	Water ingestion	Lesions on skin and liver, hyperkeratosis or hyperpigmentation, respiratory complications, induces changes in the hormonal and mucosal immune responses.	Mosaferi et al. (2008)
	Water ingestion	Chronic renal failure, cytogenic damage	Bawaskar et al. (2010)
	Water and food ingestion	Lesions on heart, gangrene, diabetes mellitus, hypertension, and ischemic heart disease	Otles and Cagindi (2010)
	Water consumption	Lung function failure and skin lesions	Von Ehrenstein et al. (2005)
	Smoking cigarettes and water ingestion	Coughing, chest sounds in the lungs and shortness of breath	Arain et al. (2009)
Antimony	Inhalation,food and water ingestión, and occupational exposure	Respiratory irritation, pneumoconiosis, genotoxic and antimony spots on the skin	Lijima et al. (2010) and Wu et al. (2011)
Bismuth	Food consumption	Liver and kidney failure	Medeiros et al. (2012)

Table 2. Contd.

HM	Exposure route	Symptoms or diseases	Reference
Cadmium	Nanoparticles	Pneumoconiosis	Cassee et al. (2011)
	Nanoparticles	Myocardial infarction	Gómez-Aracena et al. (2006)
	Food consumption	Accumulation in liver, gills and muscles	Medeiros et al. (2012)
	Food consumption (lettuce and rice)	Accumulation in liver, gills and muscles	Pereira et al. (2011)
	Ingestion	Kidneys failure	Gobe and Crane (2010)
	Water ingestion	Chronic renal failure	Bawaskar et al. (2010)
	Water ingestion	It is absorbed via the alimentary tract, penetrates through placenta during pregnancy, risks of stillbirth, and damages membranes and DNA	Von Ehrenstein et al. (2006)
Cerium	Nanoparticles, ingestion and inhalation	Toxicity	Gaiser et al. (2009)
Chromium	Soil, inhalation, dermal contact	Cancer	Wang et al. (2011)
	Water ingestion, meat	Stomach cancer	Smith and Steinmaus (2009)
Cobalt	Water ingestion	Accumulation in muscle, liver and gills	Visnjic-Jeftic et al. (2010)
Copper	Ingestion and dermal contact	Alzheimer type II astrocytosis, Parkinsonism, cognitive dysfunction, and ataxia.	Butterworth (2010) and Mercer (2001)
Gallium	Occupational exposure, ingestion	Pulmonary toxicity	Chitambar (2010)
Gold	Mining	Pneumotitis, headache, gastro-intestinal bleeding	Castilhos et al. (2006)
	Inhalation, water ingestion	Toxicity	Bourdineaud (2010)
Iron	Water ingestion	Alzheimer type II astrocytosis, Parkinsonism, cognitive dysfunction, and ataxia.	Butterworth (2010)
	Water ingestion	Accumulation in muscle, liver and gills	Visnjic-Jeftic et al. (2010)
Lead	Food consumption	Brain damage and reduction of mental processes	Medeiros et al. (2012)
	Water Ingestion	Effects on brain and central nervous function	Struzynska (2009)
	Ingestion	Lower energy levels	Holmstrup et al. (2011)
	Ingestion and inhalation	Accumulation in lungs	Thomas et al. (2009)
	Ingestion	Blood composition	Di Gioacchino et al. (2008)
	Water ingestion	Chronic renal failure	Bawaskar et al. (2010)
	Ingestion	Parkinson disease, neurodegenerative disorders	Jones and Miller (2008)
Manganese	Ingestion	Alzheimer type II astrocytosis, Parkinsonism, cognitive dysfunction, liver diseases, and ataxia.	Butterworth (2010)
	Water ingestion	Effects on central nervous functions	Bouchard (2011)
Mercury	Water ingestion	Damage to DNA	Bucio et al. (1999)
	Water ingestion	Accumulation in muscle, liver and gills	Visnjic-Jeftic et al. (2010)
Nickel	Water ingestion	Accumulation in muscle, liver and gills	Visnjic-Jeftic et al. (2010)

Table 2. Contd.

HM	Exposure route	Symptoms or diseases	Reference
Nickel	Food and water ingestion	Allergies and cancer	Dietert and Piepenbrink (2006)
	Drinking water and food	Systemic toxicity	Duda-Chodak and Blaszczyk (2008)
	Ingestion and inhalation	Cancer of the lungs, throat, stomach, nose and sinuses	Duda-Chodak and Blaszczyk (2008)
Platinum	Water ingestion and vegetables	Accumulation in tissues	Dubiella-Jackowska et al. (2009)
Silver	Water ingestion	Decreases blood pressure, diarrheal, stomach irritation and decreased respiration	Drake and Hazelwood (2005)
	Food and water ingestion		Gaiser et al. (2009)
Tellurium	Inhalation, dermal contact	Cancer, apoptosis	Jamier et al. (2010)
Thallium	Food	Fetal demise	Hoffman (2000)
	Vegetables	Causes adverse health effects and degenerative changes in many organs.	Cvjetko et al. (2010)
Tin	Occupational exposure	Lung cancer	Jones et al. (2007)
Uranium	Inhalation, ingestion	Cancer and chronic kidney diseases	Prat et al. (2009)
	Water ingestion	Renal dysfunction	Chiba and Fukuda (2005)
Vanadium	Water Ingestion	Cirrhosis, renal stone disease, distal renal tubular acidosis, hypokalemic periodic paralysis, and cancer	AlSaleh (1996)
Zinc	Water ingestion	Accumulation in muscle, liver and gills	Visnjic-Jeftic et al. (2010)
	Food consumption	Accumulation in liver, gills and muscles	Pereira et al. (2011)

villages around Kali river (India), 22 samples exceeded the limit of iron (0.3 µg L^{-1}) and the possible sources of the high iron content in drinking water are various iron industries located close to Kali river. Therefore, it has been reported that uranium was found to be more than the safe limit in drinking water samples from India (Kumar et al., 2006) and Finland (Prat et al., 2009), while Frisbie et al. (2009) demonstrated that some tube wells from Bangladesh had concentrations exceeding WHO health-based drinking water guidelines were U, Mn, As, Pb, Ni and Cr. Additionally, Lodhi et al. (2003) reported that HM concentrations in drinking water from Skardu, Pakistan, followed the order Zn > Fe > Ni > Pb > Co > Cu > Cr but no survey regarding the potability of water has been conducted in the past. Furthermore, Nickson et al. (2005) revealed that drinking water sampled in Muzaffargarh, Pakistan, reached up to 906 µg L^{-1} As and that in 58% of samples > 10 µg L^{-1} As were found.

Moreover, Maharjan et al. (2005) argued that the tube wells are the only source for drinking water in Terai, Nepal, where As ranged from 3 to 1072 µg L^{-1} with a mean of 403 µg L^{-1}, therefore, arsenicosis victims counts up 6.9% of Nepalese population resides. Likewise, Buschmann et al. (2007) reported seasonal fluctuations in the arsenic concentration (from 1 to 1340 µg L^{-1}) in drinking water from wells in Cambodia. In addition, they stated that regions exhibiting low and elevated arsenic levels are co-incident with the present low relief topography featuring gently increasing elevation to the west and east of a shallow valley understood as a relict of pre-Holocene topography. In Vietnam, Buschmann et al. (2008) stated that groundwater contamination is of geogenic origin and caused by natural conditions in the aquifers.

In this area, chronic arsenic poisoning is the most serious health risk for the similar to 2 million people drinking this groundwater without treatment, followed by malfunction in children development through excessive manganese uptake. Additionally, high concentrations of Ba, Cd, Ni, Se, Pb and U were presents too. In Sri Lanka, cadmium is one of the most troublesome toxic HM which accumulates in the water reservoirs and agricultural soil as a result of intensive use of Cd contaminated phosphate fertilizers that causes chronic renal failure (Bandera et al., 2010) (Table 2). It is known that Cd is the heavy metal of most environmental concern in terms of adverse effects from long-term application of phosphate fertilizers.

Limbong et al. (2004) found concentrations of mercury in drinking water from Indonesia very close to values established by WHO (Table 1). Additionally, Cortes-Maramba et al. (2006) revealed that notwithstanding, in Philippines, levels of mercury in drinking water and sediments were within allowable, limits the frequency of gastrointestinal complaints, was significantly associated with elevated hair methylmercury levels. It is known that more than 60,000,000 Bangladeshis are drinking water with unsafe concentrations of one or more elements such as As, Mn, U, Pb, Ni and Cr (Frisbie et al., 2009) notwithstanding the WHO efforts to improve their water quality. Xu et al. (2006) reported that the mean concentrations of Cu, Zn and As in drinking water from Shangai, China were 10.8 µg L^{-1}, 0.29 mg L^{-1} and 0.91 µg L^{-1}, respectively; which were lower than United States Environmental Protection Agency (USEPA) and WHO guideline values (Table 1). Chiba and Fukuda (2005) found that uranium concentrations were high in the water samples of the Central Asian countries including east side of the Aral Sea, Kazakhstan, while a high prevalence of renal dysfunction was also reported by them.

The African continent

Africa is the second-largest of the world and second most-populous continent, after Asia. Africa suffers from many environmental problems including deforestation, degradation, desertification, air and water pollution, the loss of soil fertility, a dramatic decline and loss of biodiversity. Asante et al. (2007) reported contamination by As, Mn, Hg and Pb in drinking water from Tarkwa, Ghana. Several water samples showed As and Mn concentrations above the WHO guideline values for drinking water (Table 1), suggesting that human health risk is a great concern for those metals. Similar results were found by Buamah et al. (2008) in groundwater within the gold-belt zone of Ghana. They collected and analyzed 290 well water samples and stated that 5 to 12% of sampled wells had arsenic levels exceeding the WHO guideline value (Table 1). Eighty per cent of wells exceeded 0.3 mg L^{-1} Fe, the drinking water guideline value for iron and 42% exceeded 0.1 mg L^{-1} Mn, the WHO health-based guideline value for manganese (Table 1). Dzoma et al. (2010) stated that water samples from Koekemoerspruit, Africa have As and Cd levels of 12 and 10 µg L^{-1}, respectively, those levels are several magnitudes higher than the WHO maximum permissible levels for drinking water of 10 and 3 µg L^{-1}, respectively (Table 1).

The North American continent

In this continent, water pollution is becoming a bigger issue. Pollution from farms, factories and even the water conducts may contaminate drinking water. High concentrations of Cu (88 to 147 µg L^{-1}) and Ni (16-35 µg L^{-1}) were found in bottled drinking waters sold in Canada (Dabeka et al., 2002) while McGuigan et al. (2010) reported that in some provinces and territories from Canada that is, Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Quebec, and Saskatchewan have been found concentrations of As above 10 µg L^{-1}, the current guideline level of the Federal-Provincial-Territorial Committee on Drinking Water (Table 1). It is known that inorganic arsenic in naturally occurring in groundwater throughout the United States (Zierold et al., 2004), such as several national assessments have found that high arsenic concentrations (> 10 µg L^{-1}) are widespread in drinking water aquifers in the western United States, the Great Lakes region and New England (Ryker, 2003). Chemical data from more than 400 groundwater sites in the Middle Rio Grande Basin of central New Mexico indicate that arsenic concentrations exceed 10 µg L^{-1} across broad areas of the Santa Fe Group aquifer system, which is currently the most exclusive source of drinking water supply for residents of the basin (Bexfield and Plummer, 2003). Peters et al. (2006) pointed out the importance of quantifying arsenic exposure from private water supplies and reported that domestic bedrock wells supply water to 120,000 households, with a median arsenic concentration of 1.9 µg L^{-1}, domestic surficial wells provide water to approximately 40,000 households with a median arsenic concentration of 0.15 µg L^{-1}, and municipal water systems provide water to 265,000 households with a median arsenic concentration of 0.41 µg L^{-1}.

Nevertheless, Erickson and Barnes (2005) stated that in the upper Midwest, USA, elevated arsenic concentrations in public drinking water systems are associated with the lateral extent of northwest provenance late Wisconsin-aged drift, where twelve percent of public water systems located within the footprint of this drift (212 of 1764) exceed 10 µg L^{-1} As, the USEPA drinking water guideline value (Table 1). This suggests that high-arsenic sediment is not necessary to cause arsenic-impacted ground water because leaches, bedrocks, depth and human activities are also important factors that increase the HM pollution in drinking water. Lytle et al. (2004) stated that it is well known that the use of iron solid surfaces to adsorb arsenic has become the basis for several drinking water treatment approaches that remove arsenic. It is reasonable to assume that iron-based solids such as corrosion deposits present in drinking water distribution systems have similar adsorptive properties and could therefore concentrate arsenic and potentially re-release it into the distribution system. They found in iron-based solids collected from drinking water distribution systems located in Ohio, Michigan and Indiana arsenic contents ranged from 10 to 13,650 µg g^{-1} solids. The concentrations of trace elements in water from Tuskegee Lake (Southeastern of United States) were investigate by Ikem et al. (2003), they found that the water quality characteristics were mostly below the recommended drinking water standards by the USEPA and the European Union (EU) except for aluminium, iron, manganese and thallium. In addition, the average values of Cr, As, Mn, Zn and Cl^{-} in the water samples analyzed were higher than the respective reference values for fresh water.

Recently, it has been reported that in Mexico, natural groundwater As contamination ranked 0.5 to 3.7 mg L^{-1} (Hossain, 2006). However, Wyatt et al. (1998) reported that drinking water samples of wells or storage tanks from Northern Mexico, that is, Sonora state, had 117 µg L^{-1}As, 50 to 120 µg L^{-1} Pb, and 1 to 25 µg L^{-1} Hg, which appears that As, Hg and Pb contamination in drinking water for this area is a major concern. Camacho et al. (2011) stated that in the states of Coahuila and Chihuahua, Mexico, high As concentrations were found mainly in groundwater, their source being mostly from natural origin related to volcanic processes with significant anthropogenic contributions near mining and smelting of ores containing arsenic (Figure 1). Some details of HM-polluted drinking water from Mexico can be found in Armienta and Segovia (2008), Camacho et al. (2011) and McClintock et al. (2012).

The South American continent

Marshall et al. (2007) found that drinking water in region II of Chile is supplied mainly by rivers that contain inorganic arsenic at very high concentrations. Before 1958, the arsenic concentration in the water supply in the main city of region II, Antofagasta, was approximately 90 µg L^{-1}, nearly twice the drinking water standard in much of the world (50 µg L^{-1}) until the recent lowering of the level in some countries to 10 µg L^{-1} in the mayor cases. Garcia-Sanchez et al. (2008) reported that in the Coyuni river basin (Venezuela), artisanal gold mining has caused significant mercury pollution due to the extensive use of Hg in the Au amalgamation processes. They recorded high Hg concentrations up to 4.6 µg L^{-1} in surface water samples which exceeds the USEPA recommended value of 2 µg L^{-1}. Madrakian and Ghazizadeh (2009) detected > 1.1 and < 2.4 µg L^{-1} Sn(IV) in water samples from Brazil. De Figueiredo et al. (2007) revealed that integrated studies on environmental and anthropogenic sources of As contamination have been carried out only in three areas from Brazil: 1) the Southeastern region known as the Iron Quadrangle, where As was released into the drainage systems, soils and atmosphere as a result of gold mining; 2) the Ribeira Valley, where As occurs in Pb-Zn mine wastes and naturally in As-rich rocks and soils; 3) the Amazon region, including the Santana area, where As is associated with manganese ores mined over the last 50 years. However, they argued that toxicological studies revealed that the populations were not exposed to elevated levels of As, with the As concentrations in surface water in these areas rarely exceeding 10 µg L^{-1}.

A possible reason is the deep weathering of bedrocks along with formation of Fe/Al-enriched soils and sediments function as a chemical barrier that prevents the release of As into water. In addition, the tropical climate results in high rates of precipitation in the northern and southeastern regions and, hence, the As contents in drinking water is diluted. Alonso et al. (2006) found concentrations of aluminium, arsenic, manganese and iron above the guideline values of WHO in drinking water from Bolivia. Recently, the arsenic exposure in Latin America has been reviewed by McClintock et al. (2012), they estimated that at least 4.5 million people in Latin America are chronically exposed to high level of As that is >50µg L^{-1}, and some as high as 2000 µg L^{-1} As.

The Antarctican continent

The Antarctica is a terrestrial continent covered in 98% by ice that averages at least 1.6 km in thickness and it has reached a temperature −89°C. It is considered a desert, with annual precipitation of only 200 mm along the coast and far less inland. Although, Antarctica does not have stream-river drainage systems, there are many sub-glacial and sub-aerial lakes, and the summer melting of snow banks or glacier ice may originate small seeps and ephemeral streams in coastal areas (Bargagli, 2008). Nevertheless, Antarctica is often considered as one of the last pristine regions, metals, organic compounds, invasive species and other contaminants enter the continent through air, water, bird, marine mammals and by anthropogenic activities (Hughes and Convey, 2012). Significant interannual variations in physical characteristics of the surface waters, such as sea-ice coverage and melt water percentage, can affect both the stability of the water column and the trace metal distribution and speciation. Heavy metals such as V, Cr, Mn, Cu, Zn, Co, Ag, Cd, Ba, Pb, Bi and U have been measured in a series of dated snow samples, covering the period from 1834 to 1990, collected at remote, low accumulation sites in Coats Land, Antarctica, but concentrations are found to be extremely low, down to 3 × 10^{-15} g g^{-1} for most metals, then confirming the high purity of Antarctic snow (Planchon et al., 2002; Rivaro et

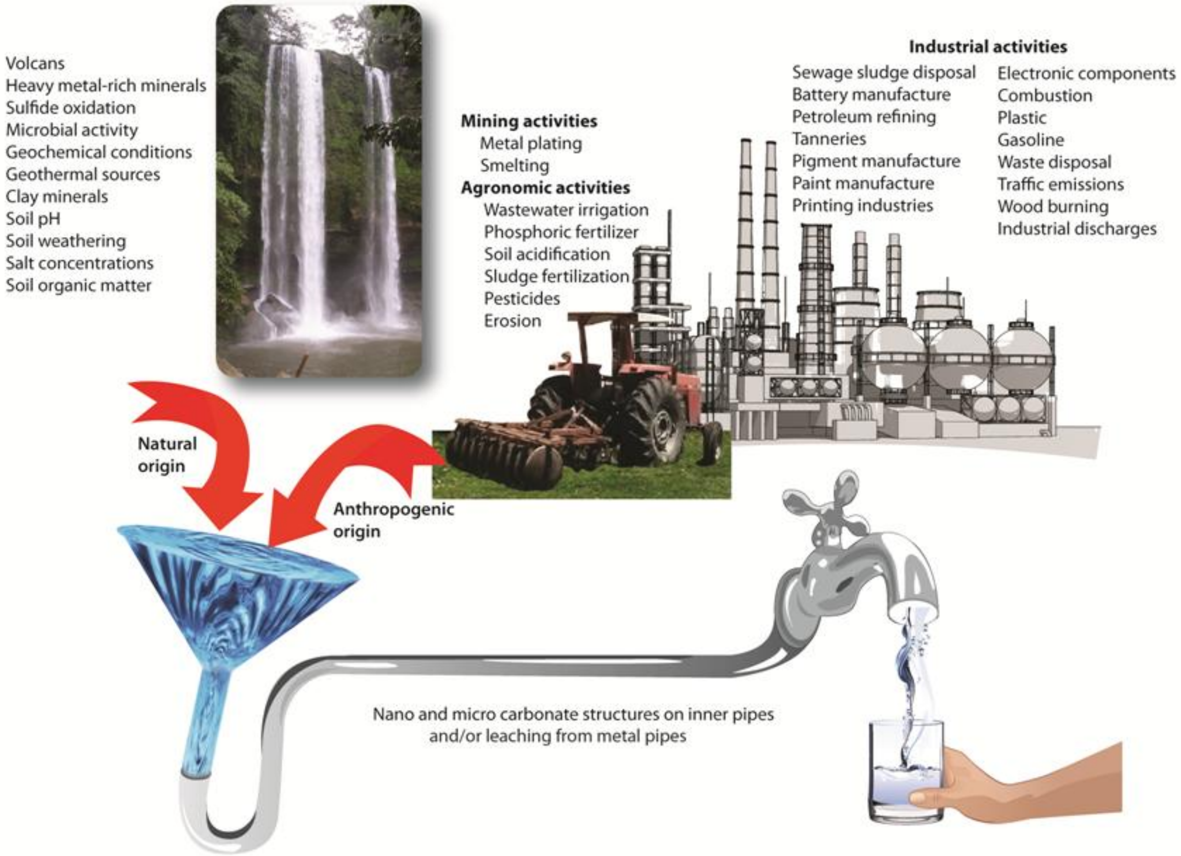

Figure 1. Natural or anthropogenic heavy metals sources polluting groundwater and drinking water systems throughout the world.

al., 2011).

Natural processes such as volcanic activity, hydrothermal processes and sediment transport are more important than anthropogenic inputs in accounting for the metal concentrations measured in sediments at different places. Findings show that human activities in the study areas may contribute to negligible levels of trace metals associated with anthropogenic inputs (for example, Cr and Zn) in sediments (Guerra et al., 2011). Eolian deposition from strong winds contributes in an important way to the trace metallic elements content onto Antarctic dry valley glacier snow and glacier melt ecosystems, including supra and proglacial streams. It is known that lithogenic material is the dominant source of As, Cd, Cu, Mo, Pb, Sn and Sb to snow (for example, Taylor Valley). Comparisons of distributions of As, Mo, Cu and Pb between snow and supra and proglacial melt streams suggest that eolian deposition is a major source of these elements to Antarctic dry valley aquatic ecosystems (Fortner et al., 2011). Mercury is a globally dispersed toxic metal that affects even remote polar areas, for example, during seasonal atmospheric mercury depletion events in polar areas, mercury is removed from the atmosphere and subsequently deposited in the surface snows, mainly coldest climatic stages (Jitaru et al., 2009).

The European continent

Kelepertsis et al. (2006) found elevated concentrations of As (125 µg L^{-1}) and Sb (21 µg L^{-1}) in the drinking water of Eastern Thessaly, Greece, where more than 5,000 people drink water containing As and Sb above the USEPA guidelines, while recently, Jovanovic et al. (2011) found that 63% of all water samples exceeded Serbian and European standards for arsenic in drinking water and Cavar et al. (2005) reported that in three villages from eastern Croatia, the mean arsenic concentrations in drinking water samples were 38, 172 and 619 µg L^{-1} which could present a serious health threat to around 3% of Croatian population. Tamasi and Cini (2004) found in South Tuscany, Italy, that As concentrations were relatively high in drinking water sampled from the ends of the distribution lines when compared to values at sources, showing that the quality of drinking water in town is somewhat worse than that at one of the main sources, probably due to leaching from metal pipes. Similar results were found by Etxabe et al.

(2010) in Spain and Haider et al. (2002) in Austria, they concluded that lead concentration in drinking water increased as it is released from piping. Tsoumbaris et al. (2009) and Doulgeris et al. (2007) revealed that in several samples of drinking water from north-eastern Greece, manganese and iron concentrations exceeded the acceptable limits for potable water set by the Hellenic Joint Ministerial Act Y2/2600/2001 'quality of the water intended for human consumption'. Additionally, Rajkovic et al. (2008) reported the presence of radioactive elements of uranium and strontium of anthropogenic origin in drinking water-samples of the water-supply network from Belgrade, Serbia.

Nielsen (2009) reported that in Denmark, nickel was detected in 3,362 wells and in 221 wells; the local current drinking water limit at 20 µg L^{-1} was exceeded. However, it has to be remembered that the current WHO drinking water guideline is 70 µg L^{-1} Ni (Table 1). A total of 908 bottled water samples and 164 tap water samples were analyzed for HM and their results showed that 4.63% (42 samples) of all bottled water samples exceed the limits for one or more of the following elements: arsenic (9 samples), manganese (eight samples), nickel (1 sample) and barium (1 sample). Moreover, ten of the samples exhibited uranium concentrations above 10 µg L^{-1} and 127 samples yielded > 2.0 µg L^{-1} U (Birke et al., 2010). They also analyzed the Te concentrations in bottled water which varies between < 0.005 and 0.21 µg L^{-1}, while in the tap water between < 0.005 and 0.025 µg L^{-1}. The maximum Te concentration measured in surface water in Germany was 0.073 µg L^{-1}. Other authors have observed values between 0.00017 and 0.073 µg L^{-1} Te in surface water (Sugimura and Suzuki, 1981) and ranged values between 0.00051 and 0.0033 µg L^{-1} Te in rain water (Andreae, 1984). Although, in Germany, < 0.6% of all households are estimated to receive drinking water exceeding the threshold level of 10 µg L^{-1} U, up to 75 µg L^{-1} U have been measured in Bavaria (Friedmann and Lindenthal, 2009). Prat et al. (2009) reported that elevated concentrations of uranium have been measured in water samples from private wells in residential communities in different countries throughout the world (Greece, Australia, U.S. and Germany).

Moreover, they found exceptionally high natural concentrations in drinking water originating from drilled wells in Southern Finland (from 37 to 3,410 µg L^{-1}, that is, reach more than 100 times those given in the current WHO guideline of 30 µg L^{-1}), but no clear clinical symptoms have been observed among the exposed population.

The Oceania continent

In countries such as Australia and New Zealand, the presence of HM in water systems is of local significance. In these countries, strict quality guidelines have been developed, particularly for protection of aquatic ecosystems (Hart et al., 1999). Presence of HM in the Oceania continent is due to both natural and anthropogenic origin. It has been found the presence of various naturally-occurring radium isotopes in water samples from saline seepages from Australia (Dickson, 1985). The distribution of Cu, Pb and Zn have been studied in aquatic systems draining Mount Isa Mine in arid northern Queensland, Australia, the delivery of HM to riverbanks and dust entrainment in arid zones may concentrate HM and ultimately ingested and absorbed by biota (Taylor and Hudson-Edwards, 2008). Other important source of contaminations has been detected in Lake Burragorang, where high concentration of Cu, Pb and Zn (204, 332 and 2460 µg g^{-1}, respectively) were found in fluvial sediment, this issue was associated to sewage treatment plant. Additionally, coal-based power stations contribute considerable to Cu, Ni, Co and Cr pollution (562, 157, 113 and 490 µg g^{-1}, respectively) in fluvial sediments (Birch et al., 2001). In Australia, rainwater harvesting is typically used to supplement tap water in Auckland, New Zealand, a cross-sectional survey was realized to determine HM concentration and microbiological content, it was found that 17.6% of the examined collection points exceeded one or more of the maximum guideline values for HM of the New Zealand Drinking Water Standards (NZDWS), and 56.0% points exceeded the microbiological criteria of <1 FC/100 ml. 14.4% exceeded the NZDWS for lead and copper.

It is known that in Australia, a principal source of drinking water is the rainwater, however, it has been found that there exist some health risks linked to HM if untreated rainwater is consumed (Lye, 2002; Chang et al., 2004).

HEAVY METAL-POLLUTED DRINKING WATER AND ITS IMPLICATIONS IN THE HUMAN HEALTH

There are numerous epidemiological studies in humans that have demonstrated the carcinogenic effects of As from drinking water (Table 2). The most common sign of exposure to As is hyperpigmentation, especially on the trunk and keratosis on the palms and soles of the feet. These skin lesions generally develop five to ten years after exposure commences, although, shorter latencies are possible. Many other signs and symptoms have also been reported in Bangladesh, that is, chronic cough, crepitating on the lungs, diabetes mellitus, hypertension and weakness (Milton et al., 2004). Exposure to arsenic concentrations in drinking water in excess of 300 µg L^{-1} is associated with diseases of the circulatory and respiratory system, several types of cancer (Jarup, 2003), and diabetes while the health consequences of exposure to low-to-moderate levels of arsenic (10 to 100 µg L^{-1}) are also known that is, elevated mortality rates were observed for both males and females for all diseases of the circulatory system, cerebrovascular diseases, diabetes mellitus and kidney diseases (Meliker et al., 2007). Additionally, Ghosh et al. (2006) found in West Bengal, India that cytogenic damage and genetic variants in individuals are susceptible to arsenic-induced cancer through drinking water. It is known that concentration of some HM in drinking water is linked to the bedrock geology (Birke et al., 2010) (Figure 1).

The skin is quite sensitive to arsenic, and skin lesions are some of the most common and earliest nonmalignant effects related to chronic As exposure. The increase of prevalence in the skin lesions has been observed even at the exposure levels in the range of 0.005 to 0.01 mg L^{-1} As in drinking waters (Yoshida et al., 2004). Groundwater arsenic contamination and illnesses of people have been reported in half of 18 districts in West Bengal, India (Chowdhury et al., 2001). Mosaferi et al. (2008) showed that people which drank arsenic-polluted water in Iran suffered hyperkeratosis or hyperpigmentation (Table 2). It is known that since 1990, a large number of people have been experiencing various health problems from drinking arsenic contaminated water (50 to 1,860 μg L^{-1}) in 13 countries of Inner Mongolia, China, where 411,000 people are currently at risk from arsenic poisoning (Guo et al., 2007a). Wang et al. (2007) reported that in Bangladesh, the growth and the intelligence quotient scores of children exposure to arsenic were affected, and Camacho et al. (2011) found that cognitive development in children can be affected by arsenic contamination. Marshall et al. (2007) found a clear latency pattern for lung and bladder cancer mortality for both men and women that are consistent with the effects of a large increase in population exposure to arsenic-polluted drinking water starting in 1958. Arsenic is known to generate reactive oxygen species such as hydrogen peroxide, hydroxyl radical and superoxide anion, which induce a variety of oxidative DNA adducts and DNA protein cross-links and single-strand DNA and double strand DNA breaks (Mo et al., 2009). Chronic exposure of As via drinking water causes various types of skin lesions such as melanosis, leucomelanosis and keratosis. Other manifestations include neurological effects, obstetric problems, high blood pressure, diabetes mellitus, diseases of the respiratory system and of blood vessels including cardiovascular, and cancers typically involving the skin, lung and bladder. The skin seems to be quite susceptible to the effects of As. Arsenic-induced skin lesions seem to be the most common and initial symptoms of arsenicosis (Rahman et al., 2009).

Arsenic is a multiorgan human carcinogen. The best-known example of this effect occurred in subgroups of the Taiwanese population who were chronically exposed to high levels of naturally occurring arsenic in drinking water and developed cancers of the skin, lung, urinary bladder and potentially the kidney (IARC, 2004). Additionally, blackfoot disease in Taiwanese is attributed to intake of groundwater contaminated with arsenic from pesticides (Chen et al., 1992) (Table 2). Additionally, studies have shown that exposure to high concentration of arsenic (≥ 200 μg L^{-1}) during pregnancy increases the risks of stillbirth, but there was no indication that arsenic increases rates of spontaneous abortion and infant mortality (Von Ehrenstein et al., 2006). Although, Christian et al. (2006) demonstrated that in pregnant women exposed to arsenic in drinking water, Se intake may be correlated with urinary As excretion, and Se may alter As methylation and thereafter, dimethylarsinic acid is formed, a pentavalent metabolite of inorganic arsenic which is known as a multiorgan tumor promoter (Hughes, 2009). Likewise, Bouchard et al. (2011) revealed that exposure to manganese at common levels (the median was 34 μg L^{-1}) in groundwater is associated with intellectual impairment in children, while Cortes-Maramba et al. (2006) reported that the incidence of elevated diastolic blood pressure increases with elevated hair total mercury levels. The kidney is the main organ affected by chronic Cd exposure and toxicity (Johri et al., 2010). Shirai et al. (2010) found that even a low-level Cd body burden of general population has slight but significant negative effect on birthweight of newborns from 78 pregnant women in Tokio.

The exact mechanisms by which HM causes cancer are still questionable and needs further investigation. It is well known that approximately, 35 million people in the US obtain drinking water from domestic wells; however, few studies have investigated the risk of arsenic exposure from this source. Kumar et al. (2010) indicated that domestic well users accounted for 12% of the US population, but 23% of overall arsenic exposure from drinking water. Additionally, they found that domestic wells and public wells in the western US have the highest arsenic levels with excess fatality risks estimated to be in the range of 1 per 9,300 to 1 per 6,600 in these regions. However, Meliker et al. (2010) did not find evidence of an association between high-level arsenic exposure and bladder cancer in Southeastern Michigan, USA, while neither significant association were found between exposure to arsenic-polluted drinking water and risk for cancers of the lung, bladder, liver, kidney, prostate, colorectum or melanoma skin cancer (Baastrup et al., 2008). Notwithstanding that Cheng et al. (2010) reported that chronic arsenic exposure from drinking water is associated with cancer, diabetes, peripheral vascular diseases and increases risks of cerebrovascular diseases (Table 2). Likewise, Lisabeth et al. (2010) reported that exposure to even low levels of arsenic in drinking water (1.01 μg L^{-1}) may be associated with a higher risk of incident stroke. Samadder (2010) reported that in an area of the district Murshidabad of West Bengal, India, where 1.25 million people are exposed to arsenic pollution, more than 26% of the study area is severely affected as life expectancy of the people living in this area may reduce considerably by the impact of arsenic in groundwater if they experience life-long exposure.

Hayes and Skubala (2009) estimated that about 25%

of EU household will have a lead pipe, meaning that around 120 million people are potentially exposed to health risks such as interference with heme biosynthesis, interference with calcium and vitamin D metabolism, gastrointestinal irritation, dullness, restlessness, irritability, poor attention span, headaches, muscle tremor, abdominal cramps, kidney damage, hallucination, loss of memory, encephalopathy, hearing impairment, gonad dysfunction and violent behaviours, but the greatest health concern associated with lead is the reduced IQ in infants. Additionally, haemorrhagic diarrhea and reproductive failure in bonsmara cattle has been reported in South Africa when they drink water with high lead concentrations (Elsenbroek et al., 2003). The use of medicinal products derived from plants (phytomedicines) has been increasing dramatically in the past years; such plants may contain HM from their presence in soil, water and air. Additionally, some of them do not tolerate higher levels of HM but hyper-accumulate Cd, Pb or Cu (Diaconu et al., 2009). In addition, it has been revealed that there is a close correlation between the average lead concentration in the tap water from Germany and blood lead concentrations (n = 142 value pairs, Spearman's rho 0.43, $p \leq 0.0001$) (Fertmann et al., 2004). The solubility of Cr is strongly dependent upon its oxidation state. In addition, to redox conditions, the effect of water chemistry (pH, competing ions, complexing agents) and of natural solids (adsorbents) can also be quite significant (Richard and Bourg, 1991). It is known that hexavalent chromium contaminates drinking water in Liaoning Province, China, where Beaumont et al. (2008) demonstrated that human ingestion of Cr^{6+} may increase the risk of stomach cancer.

Similar results were reported by Smith and Steinmaus (2009) in animals, which showed carcinogenic effects when ingested drinking water polluted with Cr^{6+}. The toxicity of cobalt is low and it is considered as an essential element, which is required in the normal human diet in the form of vitamin B12, cyanocobalamin (Gil et al., 2008). However, the ingestion or inhalation of large doses of this analyte may lead to toxic effects but, notwithstanding that rocks are associated with Co which is slowly weathered and dissolute (Meck et al., 2010) (Table 2). Although, copper is an essential metal as cobalt for the human diet, in some cases, the ingestion of copper and long-term overexposure can generate acute and chronic health effects including gastrointestinal diseases and liver damage (Nor, 1987), but notwithstanding that the WHO recommends 2 mg L^{-1} as a maximum concentration value for drinking water, there is no confirmed indication of a liver malfunction in infants whose food had been prepared using tap water with an elevated copper concentration that could be found (Zietz et al., 2003) and, therefore, no indication of a hazard due to copper pipes connected to public water supplies could be detected. Additionally, Fewtrell et al. (2002) found in England and Wales that population exposed to elevated Cu level in drinking water that is, 3 mg L^{-1}, are likely to become ill. It has been observed that theorical and practical experiences suggest that higher Cu levels in drinking tap water samples are typically associated with newer plumbing systems, and levels decrease with increasing plumbing age.

Similar results were found by Turek et al. (2011); they found that copper levels in water decreased with plumbing age in 16 buildings with plumbing ages ranging from less than 1 to 44 years. However, it is also known that detachment of nano and micro copper carbonate hydroxide structures formed on the inner surface of copper pipes, induced by the shear stress produced by the fluid flow, which increases the concentration of dissolved copper in water (Vargas et al., 2010). Nowadays, gallium, indium, arsenic and another HM are widely used semiconductor manufacturing elements, and doubt has been expressed that groundwater is contaminated via industrial effluents because contaminated water may be a health risk to people living nearby. Chen (2007) revealed that in Taiwan gallium, indium and arsenic were introduced into groundwater via industrial effluents and their concentration into drinking water were Ga, 19.34 µg L^{-1}; In, 9.25 µg L^{-1} and As, 34.19 µg L^{-1}. As concentration in drinking water is approximately 3.5 times higher than the WHO guideline values, but there are no criteria or standards for Ga and In (WHO, 2008). Ikem et al. (2003) reported that notwithstanding, average values of aluminium, iron, manganese, and thallium of samples from Tuskegee Lake were mostly above the recommended drinking water standards by the USEPA and the EU, the human health risks for heavy metals in fish caught from Tuskegee Lake are low for now, and irrespective of the source of fish, concentrations of metals in muscle tissues were all below the recommended Food and Agriculture Organization (FAO) maximum limits in fish. It has to be remembered that Thallium is more toxic to humans than mercury, cadmium, lead, copper or zinc.

Additionally, thallium is readily transported through aqueous routes into the environment (Peter and Viraraghavan, 2005). Duda-Chodak and Blaszczyk (2008) reported that inhalation of nickel can cause cancer of the lungs, throat, stomach, nose and sinuses, but there are no information about nickel in drinking water and its effect on the human health. It is well known that uranium has been measured in drinking water from different countries throughout the world (Prat et al., 2009). According to the recent Human Alimentary Tract model produced by the International Commission on Radiological Protection (ICRP, 2004), at least 98% of the uranium ingested in soluble form is discharged in faeces. Consequently, only a very small part of ingested soluble uranium (0.1 to 2%) is transferred to the blood because of the very low level of absorption of uranium by the gastro-intestinal tract (Prat et al., 2009). They conducted some studies to identify biological parameters linked to an uranium-induced chemotoxicity, nevertheless, none significant clinical effects on health could be found. HM in living species have been detected throughout the world. The highest heavy metal concentrations obtained in fish are as follows: Cd in liver, the mean value was 1.36 ± 0.19 mg kg^{-1} dry weight (dwt); Pb and Zn in spleen, the mean values were 3.33 ± 0.86 and 143.97 ± 16.17 mg kg^{-1} dwt, respectively; Cu in gills, 3.76 ± 1.16 $mgkg^{-1}$ dwt; and Mn in scales, 14.80 ± 4.77 $mgkg^{-1}$ dwt (Beltcheva et al., 2011).

Concentrations of Al, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Cd and Pb were determined in feathers of penguin collected in the Antarctic Peninsula. The highest levels of several elements were found in samples from King George Island (8.08, 20.29 and 1.76 µg g^{-1} dwt for Cr, Cu and Pb, respectively) and Deception Island (203.13, 3.26 and 164.26 µg g^{-1} dwt for Al, Mn and Fe, respectively), where probably human activities and large-scale transport of pollutants contribute to increase HM levels. Concentrations of Cr, Mn, Cu, Se or Pb, which are similar to others, found in different regions of the world, show that some areas in Antarctica are not utterly pristine (Runcie and Riddle, 2004; Jerez et al., 2011).

DISCUSSION

Water is an essential substance for life. Freshwater comprises 3% of the total water on earth, but only a small percentage (0.01%) of this freshwater is available for human use (Hinrichsen and Tacio, 2002). Unfortunately, even this small proportion of freshwater is under immense stress due to rapid population growth, urbanization and unsustainable consumption of water in industry and agriculture (Azizullah et al., 2011). According to United Nations report, the world population is increasing exponentially while the availability of freshwater is declining. Additionally, the most problematic challenge of current water research is dealing with elevated arsenic concentration in drinking water (Smedley and Kinniburgh, 2002); currently, the most serious problem globally is the intoxication of millions of people with drinking water containing too much As (Hirner and Hippler, 2011), while many countries in Africa, Middle East and South Asia will have serious threats of water shortage in the next two decades, while in developing countries the problem is further aggravated due to the lack of proper management, unavailability of professionals and financial constraint (PCRWR, 2005). It is known that 1.6 million children die every year from diseases associated with contaminated drinking water. Water resources in the world have been profoundly influenced over the last years by human activities, including the construction of dams and canals, large irrigation and drainage systems, changes of land cover in most watersheds, high inputs of chemicals from industry and agriculture into surface and groundwater, and depletion of aquifers. As a result, problems of overuse, depletion and pollution have become evident and more and more conflicts are developing between various uses and users (GEO, 2000, 2011). Although, the drinking water demand is increasing throughout the world, the capacity of local drinking water resource is not, which is even decreasing in many areas of the world. Additionally, pollution with HM is a serious concern, due to these elements entering in to the soil, where they can be present for a long time, HM are potential contamination-source of drinking water.

In Pakistan, as well as in the whole world, drinking water comes from ground and surface water including rivers, lakes and reservoirs. The present free style way of disposing agricultural, industrial and domestic effluents into natural water-bodies results in serious surface and groundwater contamination. Run-off from agricultural land and saline seeps subject the most vulnerable water bodies to pollution and increased salinity, so the freshwater lakes are highly impacted (Bekiroglu and Eker, 2011). Environmental exposure to heavy metals in terms of public health is receiving increasing attention worldwide following cases of massive contamination in different parts of the world. This problem exists all over South America due to the lack of laws and restrictions made and enforced by the governments in these countries. In some places, sewage treatment plants are almost non-existent and the ones that do exist are outdated and not in working condition, whereby the water is delivered in natural water bodies or soils polluting the environment and the drinking water sources. Although, difficult to implement, a centralized and standardized source of drinking water quality data is urgently needed to determine the effects of HM and other contaminants on human health. In some cases, people have been exposed for years to water that did not meet those guidelines. The real problem is how to get pure drinking water safely and inexpensively. Independent studies suggest that millions of people throughout the world become sick every year by drinking contaminated water, with maladies from upset stomachs to cancer and birth defects. Additionally, in some regions, like the drought-affected areas throughout the world, people already have no fresh water for drinking and are compelled to drink brackish water (Ullah et al., 2009).

The latest implies that the HM-exposed population may be larger than that already identified. Arsenic is a toxic metalloid of global concern. It usually originates geogenically but can be intensified by human activities such as applications of pesticides and wood preservatives, mining and smelting operations, and coal combustion. Arsenic-contaminated food is a widespread problem worldwide (Otles and Cagindi, 2010). Chronic arsenic toxicity due to drinking of arsenic contaminated water causes significant morbidity in children in different parts of the world (Mazumder, 2007), whereby social conscience about health risks and consequences of environmental pollution may be developed and the actual situation must be taken into account by authorities to achieve a definite solution to the problem. Although, the carcinogenicity of arsenic in humans has been known for more than 100 years, there is no definitive understanding of the mechanism of action for this effect (Hughes, 2009). Nowadays, there are some questions about how some HM can cause cancer? Do they act as arsenic? How spread is the HM pollution in drinking water? How many places with high HM concentration in drinking water have been not identified yet? How many countries or cities have serious problems with their water quality but according to political or economic convenience the results are changed or hidden? The answers to these questions are not so clear whereby additional researches are necessaries. Moreover, in order to reach water-quality standards, water-quality policies, new technologies, water management strategies and human resources are necessaries in many countries and cities throughout the world.

Water pollution is most often due to human activities (Hammer, 1986). However, the sources of these contaminants are unclear and merit further investigation. The major ones are indiscriminate disposal of industrial, municipal and domestic wastes in water channels, rivers, streams and lakes (Kahlown and Majeed, 2003), for example, an estimated 2 million tons of sewage and other effluents are discharged into the world-waters every day (Azizullah et al., 2011). The World is currently facing critical water supply and drinking water quality problems, whereby, in many parts of the world, water supplies are threatened by contamination and future water supplies are uncertain. High arsenic levels are often used to indicate improper well construction or the location or overuse of chemical fertilizers or herbicides (Borah et al., 2010). Thus, suitable protective measures for drinking water sources in the area are recommended. Arsenic contamination of drinking water has been a worldwide challenge (An et al., 2005), because arsenic has been associated with skin, lung, bladder and kidney cancers (NRC, 2001). It was reported that from 45 to 57 million people in Bangladesh and 13 million in the United States have been exposed to unsafe levels of arsenic (WHO, 2006). There is a need for new recommendations about HM maximum values, and sometimes also for HM minimum values for essential HM elements.

CONCLUSIONS

There are millions of people with chronic HM poisoning which has become a worldwide public health issue. The existence of hazardous metal ions (released or not by anthropogenic activities) in the environment is a potential problem to water and soil quality due to their high toxicity to plant, animal and human life. Special attention should consequently be given to drinking water because it is, besides oxygen, the most important requirement for physiological and hygienic needs. Monitoring all drinking water sources for HM should be considered throughout the world, but good test methods must to be established, whereby measurement quality should include both sampling and analysis. The needed measurement quality can be achieved by validation that the test method is fit for the intended purpose and by establishing traceability of the results to stated references and an estimate of the uncertainly of measurement; however, to reach the requirements described earlier, technical knowledge, infrastructure, and analytical technologies are needed, which are not easy to get in low economic development areas or countries. The World is currently facing critical water supply and drinking water quality problems, whereby drinking water quality policies, technologies, drinking water management strategies and human resources to satisfy water-quality standards are necessaries in many countries and cities throughout the world. Additional work to understand how to combine interventions and transition to greater level of service as incomes rise remain an important area of police-relevant work between governments, healthcare services, industries and drinking water-wells owners.

A global effort to offering affordable and healthy drinking water most to be launched around the globe, while various laws and regulations to protect and improve the utilization of drinking water resources should be updated or created throughout the world, including the low income countries; otherwise, the problem of HM-polluted drinking water will be growing because demand for drinking water is still growing such as this problem will become even more pressing in the future. Politic, industrial and public education programs are required on awareness of health risks associated with HM-polluted drinking water. Finally, the development of robust, cheap and sustainable technologies to improve the drinking water quality is necessary, especially for rural or low-income households.

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