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Role of Heavy Metals and Anthropogenic Activities in Water Contamination

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Abstract

Water is a fundamental requirement for all living beings and it is considered as the most diverse solvent. It has a unique polarity and a distinctive set of properties due to hydrogen bonding. Water, being a universal solvent, can easily be polluted by absorption, adsorption and suspension of a lot of materials into it. Major sources of water contamination include the disposal of untreated garbage, milling, industrialization, and urbanization. Water is easily polluted by substantial metals including Lead (Pb), Arsenic (As), Copper (Cu), and Chromium (Cr). Water contamination can lead to serious illnesses and sometimes it is so hazardous that it can cause the death of a living organism.

Keywords: death, metals, Pakistan, untreated garbage, water contamination

Introduction

Water is the medium of survival for all plants and animals [1]. Surface and groundwater reservoirs are two principle sources of water [2]. Water is a universal solvent which has the ability to absorb, adsorb and suspend the materials present in it due to its polarity and its unique hydrogen bonding [3]. Water may not be available in its pure form owing to the impurities and contamination by animals as well as due to anthropogenic and industrial activities [4,5,6]. The increased concentration of heavy metals in the environment is considered as environmental contamination [7]. Excessive concentration of heavy metals including Ti, Cr, Mn, Fe, Ni, Zn, Cd, Cu and Pb may have adverse effects on the growth of plants [8]. Heavy metals with a high

density and atomic weight are referred to as carcinogenic. They are poisonous in nature even at very low concentrations and they have substantial adverse health related effects on living cells. Substantial metals are characteristic components of the earth's covering. To some extent, they enter into our bodies /during nourishment, by drinking water and breathing air [9]. Anthropogenic activities including transport, industrialization, and dumping destinations of waste are responsible for the accumulation of pollutants into crops and other organisms through food chain [10].

2. Materials and Methods

Studies were made to overview the concentration of heavy metals in the environment. National Environmental Quality Standards for industrial effluents were reviewed [11]. Waste water in the various cities of Pakistan was examined [12,13]. Sources and health related impacts of heavy metals were discussed [14,15].

3. Results and Discussion

Untreated disposal of commercial and industrial wastes is a common practice in Pakistan. Industrial wastes are generally discarded into open pits and landfills. Due to the contamination of water, many waterborne diseases have become common in men, women and especially in children across the country. Table 1 displays National Environmental Quality Standards for industrial effluents [11].

Some heavy metals accumulate in the plants in higher concentrations through infected water and/or soil and then enter into the food chain [16]. Anthropogenic activities such as the use and manufacturing of fertilizers, the application of pesticides on crops, as well as the natural contamination of groundwater from arsenic dissolved salts, fluorides, and geothermal processes are the main reasons behind diffused pollution [17]. Heavy metals can migrate into shallow ground water and there are reports of various concentrations of heavyweight steel in waste waters [18]. They demonstrate a substantially harsh effect on soil fertility and on its macro and micro nutrients [19]. It is a well-known fact that these metals are important for plants and other organisms in low amounts but they are lethal at high concentrations. Many heavy metals (such as arsenic, beryllium, cadmium, nickel and hexavalent chromium) act as endocrine disruptors or metalloestrogens (small metalloids) and have a role in the

development of various kinds of malignant tumors [20]. Two classes of metalloestrogens have been identified: the first class includes metals such as antimony, oxyanions, arsenate, selenite, vanadate and nitrite, while the second class comprises bivalent-cations such as cadmium, copper, cobalt, nickel, calcium, mercury, tin, chromium and lead. Numerous studies have explained that exposure to cadmium (Cd) my lead to bosom disease [21].

Table 1. National Environmental Quality Standards for Modern Effluents

Parameter	Standard (mg/L)	Parameter	Standard (mg/L)
pH value (basicity / acidity)	6-10 pH	Temperature (T)	40°C
Total Suspended Solids (TSS)	150.0	Total Dissolved Solids	3500
Biochemical Oxygen Demand	80.0	Chemical Oxygen Demand	150
Phenolic Compounds	0.1	Oil and Grease	10.0
Chloride	1000	Fluoride	20.0
An-ionic detergents	20.0	Cyanide	2.0
Cadmium	0.10	Sulphide	1.0
Chromium	1.0	Sulphate	600
Nickel (Ni)	1.0	Silver (Ag)	1.0
Selenium (Se)	0.50	Mercury (Hg)	0.01
Fungicides, Herbicides, Pesticides and Insecticides	0.15	Ammonia (NH_3)	40.0
Copper	1.0	Lead (Pb)	0.05

Urban soil may contain many pollutants depending upon its uses [22]. Many human activities result in the accumulation of heavy metal ions in the soil. This is the reason that the soil of all urban areas is generally contaminated with copper, cadmium, zinc and lead emanated from vehicles [22, 23]. Heavy metal pollution in soil is extremely dangerous as these metals enter into plants and ultimately, into human beings through the food chain [24]. The application of crop protecting pesticides and fertilizers has greatly enhanced pollution in the agricultural land [25]. Unfortunately, the use of these chemicals may

serve as an index of modernization; however, they cause serious health and environmental issues [26]. On the banks of natural streams diverse industries were built in Pakistan which led to an unexpected discharge of untreated effluents [27]. This problem is common especially in the big cities of Pakistan including Faisalabad. Moreover, the cities located near the rivers use water for irrigation and drain their effluents into rivers [28]. So, it is necessary to provide social consciousness to the inhabitants and implement the environmental legal guidelines [29].

Tables 2 and 3 display the region wise waste water production in various sectors of Pakistan [12, 13]. Table 4 shows the amount of toxic / trace / essential metals in samples (mg/L) [13,30].

Table 2. Waste Water Production in Different Sectors of Pakistan

Serial No.	Resource / Origin	Volume 10^6 m^3/year	Volume
1	Industrial	395.0	6.0%
2	Commercial	266.0	5.0%
3	Urban uptown	1628.0	25.0%
4	Rural uptown	3059.0	48.0%
5	Cultivation	1036.0	16.0%
Total		6414.0	100%

Statistical Analysis						
Source of Variation	SS	df	MS	F	P-value	F crit
Rows	10686602.48	6.00	1781100.41	1.05	0.44	3.00
Columns	15333069.24	2.00	7666534.62	4.52	0.03	3.89
Error	20366128.10	12.00	1697177.34			
Total	46385799.81	20.00				

3.1. Sewage's Source

Sewage is produced through various activities in industries, institutes, and residential areas. Waste water is generated from showers, baths, kitchens, loops, and basins that have outlets in the drains. It can also contain contaminants from trade and enterprise in a few areas. It may be recycled to be used in lavatories [31].

Table 3. Waste Water Produced Yearly by Cities (WB-CWRAS Paper 3, 2005)

Urban	Town inhabitants (1998 survey)	Percentage of all water formed	Total squander water delivered (10^6 m^3/year)	Percentage of canned aquatic waste	Receiving water frame
Gujranwala	1132.509	3.1	71.0	-	Vegetable farms, SCARP drains
Rawalpindi	1409768	1.8	40.0	-	Vegetables farms, River Soan
Lahore	5143495	12.5	287.0	0.01	Vegetable farms, River Ravi, Irrigation canals
Faisalabad	2008861	5.6	129.0	25.6	River Chenab, Vegetable farms and River Ravi
Multan	1197384	2.9	66.0	-	Irrigation canals, vegetables farms and River Chenab
Sheikhopura	870110	0.7	15.0	-	SCARP drains
Karachi	9339023	26.3	604.0	15.9	Arabian sea
Sialkot	713552	0.8	19.0	-	Irrigation canals, vegetables Farms and River Ravi

Statistical Analysis						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	1.5×10^{13}	8.0	1.9×10^{12}	1.0	0.45	2.2
Columns	3.8×10^{13}	4.0	9.5×10^{12}	5.1	0.0028	2.7
Error	6.0×10^{13}	32	1.910^{12}			
Total	1.1×10^{14}	44				

Table 4. Amount of Toxic / Trace / Essential Metals in Samples (mg/L)

Region / Zone	Sample No.	Potassium	Sodium	Arsenic	Lead	Calcium	Iron	Zinc	Copper
Standard of WHO	_		12	200	0.05	0.1	200	0.3	3	1.5
PIES	S1	9	11	0.643	0.309	260	2.2207	6.013	0.5915
GIES	S2	14	9	0.475	0.35	450	2.0345	9.0058	0.6197
HIES	S3	18	18	0.942	0.275	360	3.8001	8.0027	0.408
Sardar Colony	S4	22	37	0.2694	0.096	240	0.096	2.0079	0.3662
Latifabad	S5	15	17	0.0457	0.12	210	0.0414	2.0014	0.5352

Region / Zone	Sample No.	Potassium	Sodium	Arsenic	Lead	Calcium	Iron	Zinc	Copper
Shinwaari Town	S6	26	30	0.3694	0.21	290	0.1241	2.0029	0.3239
Ghazi Rahim Abad	S7	23	25	0.42	0.256	280	0.269	2.0037	0.3944
Pakha Ghulam	S8	12	14	0.38	0.28	290	0.2414	2.0137	0.3803

Statistical Analysis

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	14976.68	9.00	1664.08	0.88	0.55	2.01
Columns	568304.37	8.00	71038.05	37.52	0.00	2.07
Error	136315.38	72.00	1893.27			
Total	719596.43	89.00				

3.2. Mixing of Sewage with Rainwater

Sewage commonly includes city runoff and hurricane water runoff. Sewage structures able to handle typhoon water are known as blended sewer structures and are commonplace in urban areas [32]. They are considered more expensive in comparison to sanitary sewers [33]. Sewage water may contain oil, animal and plant wastes, heavy metals, natural compounds, and dust [34].

3.3. Sources and Health Related Impacts of Heavy Metals

There are many toxic metals released from different sources in our environment. Their main sources are industry effluents, burning of organic matter, power generation plants and vehicles[14]. Metals reach people and the environment through environmental booths and pathways depending upon their density and mobility. All known parts of the world's covering are also understood to contain heavy metals which cannot be eradicated or eliminated. They are accessible to living bodies via tap water, food and to some extent by air [15].

3.3.1. Arsenic. The compounds of arsenic are carcinogenic to human beings. Arsenic (As) is poisonous and its organic composites such as diethyl arsenic acid are very threatening to individuals [35,36]. It may enter into the food chain through food and vegetables and via contaminated ground water. Human beings are directly exposed to arsenic due to the use of arsenic contaminated water [37]. There are more than 200 naturally occurring mineral forms of arsenic, out of which 20% are sulfides and sulfosalts, 60% are arsenate and the remaining 20% are arsenates, arsenide, oxides and silicates [38]. Arsenic poisoning may result in lung cancer, and malignancies of bladder, kidney, colon and skin, [39, 40]. As indicated by WHO and EPA, the drinking water standard of arsenic is 10 milligram per liter, whereas the solubility and mobility of arsenic increases at pH more than 8.5 [41]. Various procedures are under investigation for the successful removal of arsenic from contaminated water [42].

3.3.2. Cadmium. Cadmium (Cd) is reported to have many poisonous and toxic properties and it is considered responsible for liver and kidney cancer and may other health related issues. It demonstrates strong health related impacts in human beings. It is found in soil at about 0.1 ppm [43]. Its concentration varied from 0.001 to 0.21 mg/liter

in groundwater samples obtained from the numerous regions of Pakistan. A concentration of 0.21 milligram per liter was reported in tube water collected from Hayatabad Industrial Estate [44, 45]. Its presence in environment is attributed to agricultural and industrial emissions. Exposure to cadmium is associated with fracture risks and osteoporosis in women and elderly people. There were multiple studies conducted on urinary cadmium excretion and bone demineralization. It causes liver disease (hepatotoxicity) through binding with cysteine rich protein such as metallothionein. It also has a tendency to join with glutamate, histamine and aspartate ligands resulting in iron deficiency [46]. Cadmimum toxicity induced by contaminated vegetables, soil and water may cause severe health related effects in human beings.

3.3.3. Mercury and lead. Mercury (Hg) contaminates various ecological compartments such as water, soil, and atmosphere. Its increased concentration in a water system results in bio-accumulation and bio-magnification among carnivorous fish [47]. Mercury (Hg) and lead (Pb) have toxic effects on fetuses, breastfeeding mothers and pregnant mothers. Exposure to them among infants is mainly influenced by mother diet, metal specification, and nutritional value. They have adverse effects on sensory system and fetal growth. Mercury is primarily found in the protein of animal flesh (particularly fish and shellfish). Lead is also found in osseous structures. Both of these elements are found in breast milk and maternal blood and are provided to the hatchling during development [48].

Lead is poisonous to human beings and severely affects excretory, reproductive and nervous systems [49]. Children are affected by drinking juices or eating foods whose preparation involved lead contaminated water [50]. Lead poisoning in adults is caused by exposure through inward breath in the work environment. In pediatric, lead harming occurs due to the ingestion of ecological media including paint chips, soil, dust, earthenware production, drinking water and drugs. Growing erythrocytes, nervous system and kidneys are affected by lead poisoning through drinking water [51].

3.3.4. Nickel. Nickel (Ni) is widely distributed in soil, water, air and other natural environs. Its contact may result in numerous side effects on human health, including nasal and lung cancer, lung fibrosis, kidney and cardiovascular diseases, and allergy [35,52]. Nickel amalgam is not only cancer producing but its alloy also affects the

respiratory system and nostril sinuses [35]. There were investigations carried out regarding heavy metal contamination in the irrigation water of Hayatabad (Peshawar, Pakistan) and Gadoon (Swabi, Pakistan). Water samples were collected from various industrial outlets. The results showed the presence of 0.019-0.074 ppm Ni, 0.090-0.165 ppm Zn, 0.053-0.234 ppm Mn, 0.024-0.121 ppm Cr, 0.117-0.330 ppm Pb, 0.191-0.330 ppm Fe, 0.021-0.195 ppm Co and 0.102-0.260 ppm Cu [53,54].

3.3.5. Copper. Copper (Cu) is also an essential element found in many enzymatic systems, vitamin E, and vitamin C, while zinc acts against Cu toxicity. Many antioxidants including beta-carotene, alpha-carotene and polyphenols also reduce copper induced oxidative damage [55]. Its higher intake has toxic effects [56]. Copper and cholesterol are very important in nutrition, brain functioning and also in the etiology of Alzheimer's disease. A minute amount of copper in drinking water has a significant effect on individual learning and memory [57]. This metal is also utilized by living organisms as a micronutrient but its oxide, hydroxyl, nascent oxygen, and metal chelates cause adverse impacts on living bodies [58,59].

3.3.6. Chromium. Chromium (Cr) has considerable significance specifically in metallurgical / metallic processes. Chromium in its +3 and +6 oxidation state is utilized largely in shades, metal finishing and wood additives [60]. Cr (VI) affects adversely nostril and nasal sinuses [35]. High concentrations of chromium affect and damage liver function, respiratory system, excretory system, digestive system, and the immune system. It also causes ulcer, skin diseases and disturbs the blood pressure [61]. Plant growth, photosynthesis, water quality, mineral nutrition and development, such as the germination process, growth of leaves, stems, and roots are also affected by the presence of Chromium [62].

3.3.7. Aluminum. Aluminum (Al) has toxic effects on several body organs such as brain and kidneys and also on bones and blood. It is well known that aluminum plays a role in some neurodegenerative diseases, disturbs various enzymes and biomolecules and causes Alzheimer's disease [63].

3.3.8. Zinc. Zinc (Zn) may become harmful when its concentration exceeds the physiological requirements [64]. Its excessive utilization

may result in immense gastrointestinal disorders and changes in the levels of cholesterol and lipoprotein [65].

Many waste material treatment techniques including physical and chemical techniques, activated sludge process, adsorption, and anaerobic digestion are applied to rid the pollutants present in water [66].

4. Conclusion

Untreated industrial waste water mostly contains heavy metals such as As, Zn, Cr and Cu. In Pakistan, the most common source of water for agricultural work are canals. Groundwater is utilized in housing, cultivation and manufacturing processes. Waste water from the outlets of factories and drains contains varying amounts of heavy metals. Common pollution sources in waste water include halogenated organic compounds, significant metals, dyes, pesticides, and herbicides. This water contamination can lead to serious illnesses and sometimes it is so hazardous that it can cause the death of an organism.

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