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Review Article

Physico-chemical and heavy metals analysis of drinking water and their effect on human health: A Review

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Abstract

Water is the vital source for life and if it is contaminated by heavy metals can pose perilous repercussions on living beings. Therefore, this review is framed in which the concentrations of different heavy metals were quantitatively analyzed in different water bodies by different authors. The main elements under their observations were sodium, potassium, arsenic, cadmium, chromium, nickel, mercury, zinc, iron, magnesium, copper, manganese, cobalt and lead. Some studies revealed the detection of sodium and potassium through flame photometer while the concentrations of other aforementioned metals were detected by using Atomic Absorption Spectrometer (AAS). And their levels were compared with some of the most reputable environmental agencies of the world like WHO (2008), EUC (2001) and EPA (2007). The researchers also analyzed the physical parameters for water quantitatively like electrical conductivity, temperature, pH, TDS, hardness, turbidity, alkalinity and salinity with the help of Digital Electronic Kits. Most of the water bodies present in the vicinity of industrial and municipal wastes were found highly polluted whereas the water bodies farther from these sources were aesthetically good in quality. In this study, the impacts of heavy elements on life have also been elaborated by quoting different research works.

Keywords: Human health; Heavy metals; Physico-chemical parameters; Pollution

Introduction

Sustaining of life without water is altogether impossible. Clean water is the key indicator for the development of any country. Naturally, water has most of the micronutrients with most balanced levels. But these levels have been highly disturbed by natural as well as to a greater extent by anthropogenic activities. Water related diseases are becoming the major problems in the world. In order to avoid any contamination of drinking water safe sources for the supply purpose are being used [1]. It has been reported that microbiological activities of water in vessels is lower than sources. Some researchers also suggest that contamination is widespread during storage and drawing of water supplies have a noteworthy activity to maintain the human stability on earth. Human being uses this supply as wellspring of irrigation, domestic water [2]. The increased rate of urbanization and industrialization has been threatened the

quality of water available for living organisms [3].

Water Quality Index is a tool which tells the standard and level of drinking water [1]. Contaminated water causes hazardous effects to the health of the organism. Human health is at greater risk when confront in any form with heavy metals. They adversely affect the function of heart, brain, lungs and kidney while some of them such as mercury and arsenic are carcinogenic in nature. Groundwater which is one of the huge sources of fresh water contains most of the important minerals [4]. There are about 50 heavy metals among which 18 are highly toxic in nature. Vegetation is an important part of food chain can also be highly affected by heavy metals.

Arsenic (As)

Arsenic is the member of group VA in the periodic table with atomic number 33, mass number 74.92 and density 5.72. Arsenic is the main constituent of most of the agrochemical. Sources of arsenic contaminations are fungicides, pesticides, sedimentary rocks, mining and metallurgy. It causes skin, lungs, kidney and bladder cancer, diabetes, reproductive toxicity and hearing loss [5]. Arsenic is found as organic complex e.g., dimethyl arsenic acid which is highly carcinogenic. According to WHO (2000), the acceptable limit of arsenic in drinking water is 0.01 mg/L. Public Health Engineering Department of Pakistan (PHEDP) reviewed the concentration of arsenic with the collaboration of United Nations Children Emergency Fund (UNICEF) and conducted a survey of drinking water supply from wells in 2001. It was observed that Muzaffargarh District was one of the most arsenic polluted district (Table 1).

Table 1. Arsenic contamination in potable water

Method	Permissible limit	Calibration range	Detection limit	Ref.
Anodic striping–linear sweep voltammetry	0.01mg/L	0.01-0.3 µM	10 nM	[6]
Atomic absorption spectroscopy	0.01ppm	0.001-0.0044 ppm	0.014 ppb	[7]
Atomic absorption spectroscopy, Flame Emission	0.01ppm (WHO)	0.006-0.007 ppm	0.08 ppm	[8]
ICP-MS	--	0.021-0.092 ppm		[9]
Flame atomic absorption spectroscopy	0.01 ppm	0.00	0.08 ppm	[10]

Copper (Cu)

Copper is the member of group IB in periodic table with atomic number 29, mass number 63.54 and density 8.96. Copper has huge industrial applications in the modern world. It is also considered one of the most toxic elements which altogether change the water quality. Sources of contaminations are pesticides, mining, metal piping, paper industries. Thus, affecting health by increasing blood pressure, muscular cramp, skin irritation, stomach nausea, vomiting, anemia [3]. It is always present in our food and inside the animal liver. Copper acts as reductant in enzyme activities. The recommended dietary allowance (RDA) for children is 0.9 mg/day. The concentration of coppers in different water samples were determined having range between 0.002mg/L-0.075mg/L [11]. High level of copper may lead to cause vomiting, abdominal pain, nausea, diarrhea and research have shown that copper leaches to drinking water from copper pipes [2] (Table 2).

Table 2. Copper contamination in drinking water

Methods	WHO limit	Calibration range	Detection limit	Ref.
Atomic absorption spectroscopy (AAS)	0.05 ppm	0.002 ppm-0.075 ppm	0.005 µg/L	[11]
AAS, Flame Emission	--	0.04-0.06 ppm	0.007 µg/L	[8]
ICP-MS	0.05 ppm	0.031-0.192 ppm		[9]
DPASV	0.05 ppm	2-120 µg/L	0.34 µg/L	[12]
Flame atomic absorption spectroscopy	0.05 ppm	0.01-0.21 ppm	0.001 µg/L	[10]

CL: confidence level

Antimony (Sb)

Antimony is member of group VA in periodic table with atomic number (51), atomic mass (121.5) and density (6.68). Antimony is found in the form of Antimony trioxide and potassium antimony tartrate. Antimony (V) is found in water which is not more harmful. It causes heart diseases and lungs impairment. The individuals are affected with this element by breathing defiled air, drinking sullied water or by eating sustenance's. Khan et al. (2017) have reported the concentration of antimony in drinking water from different areas of Quetta district, which ranged between 0.028 mg/L - 0.03mg/L (Table 3).

Table 3. Antimony contamination in water

Method	Permissible limit	Calibration range	Detection limit	Ref.
Voltammetry	0.006 mg/L	Up to 0.3335 mg/L	1.8×10^{-4} mg/L	[13]
Atomic Absorption Spectroscopy	0.006 ppm (EPA)	0.2774 ppm-1.0214 ppm	0.0000008mg/L	[7]
AAS, Flame Emission	0.006 ppm (EPA)	0.028-0.03 ppm	0.0000008mg/L	[8]
HPLC/ ICP-DRC-MS	0.006	Up to 0.045	--	[14]

Lead (Pb)

Lead is member of group IVA in periodic table with atomic number (82), atomic mass (207) and density (11.35). Lead is another highly toxic element which is found in earth crust in the form of galena (PbS) widely used in paint, pesticides, smoking, automobile emissions, mining etc., and potential toxic effects are anemia, cancer, kidney failure, nervous system damage, mental retardation, vomiting, severe diarrhea [5]. EPA (Bangladesh, 2014) groups suggests that lead has high carcinogenic effects. Lead can cause many diseases like renal failure, coma and death. Lead originates from air, lead polluted soil or drinking water. Lead tainting is basic in more established water channels [10]. The work of different researchers may be summarized as below (Table 4).

Table 4. Lead contamination in water

Method	WHO limit	Calibration range	LOD	Ref.
Atomic absorption spectroscopy	0.015 ppm WHO	0.03 mg/L-0.06 mg/L	0.01 mg/L	[7]
AAS	0.015 ppm	0.0097-0.00987 ppm	0.01 mg/L	[7]
ICP-MS	------	0.011-0.064 ppm	0.002 mg/L	[9]
Square wave anodic sweep voltammetry (SWASV)	0.015 ppm	1-20 µg/L	0.0001mg/L	[6]
AAS	---	0.08-0.24	0.01 mg/L	[10]

Cadmium (Cd)

Cadmium is member of group IIB transition metals in periodic table with atomic number (48), atomic mass (112.4) and density (8.65). Sources of cadmium pollution are steel and plastic industries, electroplating, Nickle-cadmium batteries, welding etc. and its potential toxic effects are damage to kidney, cancer, bronchiolitis, fibrosis, skeletal damage [5]. Number of studies suggested that cadmium is a ubiquitous element which is mainly found in waste water. Its highest concentration was reported in Korangi industrial area of Karachi (5.35mg/L), which altogether exceeded by the WHO standard (0.1mg/L). Moreover, north and east zones of Lahore district were also having more concentration of cadmium. DPASV (Differential pulse Anodic stripping voltammetry) analysis the concentration of cadmium was above the standard levels such as ranging from 0.01ppm to 0.11ppm. The acceptable limit for Cd in drinking water is 0.005ppm [12]. Only 8 samples taken from potable water, showed no pollution of Pb and water samples had copper pollution all the other samples showed the pollution of lead (Pb) and cadmium (Cd). Author suggested that these water samples were not suitable for drinking [6]. Bajraktari et al. (2019) reported the concentration of cadmium in different water sample taken from river Drini I Bardhe. The concentration of cadmium was ranged between 0.002 mg/L - 0.005 mg/L. An another report on the concentrations of some heavy metals in water of Mainefhi also Toker reservoirs present in Asmara city, Eritrea by utilizing flame photometric method [2]. They found cadmium in higher concentration in all samples (0.0035 mg/L) (Table 5).

Table 5. Cadmium contamination in water

Method	WHO limit	Calibration range	LOD	Ref.
AAS	0.005 ppm (WHO)	0.002 ppm-0.005 ppm	0.003 mg/L	[11]
SWASV (Square wave anodic sweep voltammetry)	0.005 ppm	0.00001-0.00015 mg/L	7.4×10^{2} mg/L	[6]
AAS	0.005 ppm	0.01-0.1 ppm	0.001 mg/L	[2]
ICP-MS	--	0.001-0.0.22 ppm	0.000008 mg/L	[9]

Sodium (Na)

Sodium is member of group IA with atomic number (11), atomic mass (23) and density (5.3). Sodium is an essential nutrient for human body which controls some of the important metabolic activities and transport system in plants and animals. It is found in water as NaCl, and free ions. Yadav et al, (2012) reported that concentration of sodium was above the WHO limit in water samples of Agra city, India. Calibration range was between126.5ppm-1254ppm. Its permissible limit was 250mg/L (Table 6).

Potassium (K)

Potassium is member of group IA with atomic number (19), atomic mass (39) and density (5.9). Potassium is found in water due to weathering of rocks, it has more concentration in polluted water [4]. It causes several diseases if increased from the permissible limit of WHO i.e. 50mg/L. Grachev et al. (2018) reported the concentration of potassium in water samples in Russia with value of 57mg/L. Yadav et al. (2012) reported the concentration of potassium in fresh water samples as varied between 1.9mg/L - 60.2mg/L (Table 7).

Table 6. Contamination of sodium in water

Method	WHO	Calibration range	LOD	Ref.
Flame AAS	250 mg/L	17.5 mg/L-37 mg/L	0.1 mg/L	[10]
Wavelength-dispersive X-ray fluorescence Spectroscopy (WD-XRF)	250 mg/L	1000 mg/L-20000 mg/L	74.1 mg/L	[5]
EDAX (Energy Dispersive X-ray analysis	250 ppm	5.83 mg/L-11.4 mg/L		[15]
Analytic Hierarchy process (AHP), Fuzzy water quality index (FWQI)	250 mg/L	2-5.7 mg/L	0.1mg/L	[16]
Gas chromatography- Mass spectrometry (GC-MS)	250 mg/L	68.84 mg/L-68.94 mg/L	--	[17]
Titration and Flame photometry (model PFP7/C)	250 mg/L	190 mg/L-320 mg/L	-----	[10]

Table 7. Contamination of potassium in water

Method	WHO	Calibration range	LOD	Ref.
Wavelength dispersive X-ray fluorescence Spectroscopy (WD-XRF)	50 mg/L	200 mg/L-1000 mg/L	12.1mg/L	[5]
Gas chromatography- Mass spectrometry (GC-MS)	50 mg/L	11.48 mg/L-11.69 mg/L	------	[17]
EDAX (Energy Dispersive X-ray analysis	50 ppm	0.12 mg/L-1.8 mg/L		[15]
Analytic Hierarchy process(AHP), Fuzzy water quality index(FWQI)	50 mg/L	0.4 mg/L 2.6 mg/L	0.2 mg/L	[16]
Spectroscopic methods	50 mg/L	33-35 mg/L	5mg/L	[18]
Titration and Flam photometry (model PFP7/C)	50 mg/L	2 mg/L-30 mg/L	------	[10]

Iron (Fe)

Iron is member of group VIIIB in periodic table with atomic number (26), atomic mass (62) and density (7.67). Iron is an essential element for human health. It is the main component of protein, enzymes and hemoglobin. It acts as catalyst in metabolism and used for transport of gases in an out of the body. The tolerable upper intake level for adult is 45mg per day [12]. The concentration of iron was identified in water samples in Oban Massif, Nigeria with range from 0.07mg/L-0.3mg/L [3]. Various studies showed that the iron range was 0.01-11.3ppm in water; the highest value was reported from Kasur city, Pakistan [19]. All the results of concentrations of iron in water samples were compared with international reputed organization (WHO 2000) (Table 8).

Physico-chemical parameters

Physico properties were studied by Ugbaja & Ephraim, (2019) which include EC, pH, COD, DO, TDS, TSS, Turbidity, alkalinity, etc. They reported the results having different ranges, temperature from 25.3ºC – 26.6ºC, pH from 4.35-6.20, EC from 16.6 µs/cm - 26.4 µs/cm, TDS (10.3mg/L to 38.9mg/L), TSS (0.02mg/L to 1.5mg/L), DO (3.09mg/L to 9.88mg/L). Researchers have reported the Physico-chemical analysis of some water samples from Agra city, India [4]. They recommended and reported that the nature of drinking water of Agra city is not the point of confinement of WHO, and this city requires prudent

measurements before utilizing water. Consequence of certain examples were as under (samples pH 7, TDS 1335mg/L, turbidity 6.5 NTU, Ca^{+2} 123ppm, Na 313ppm etc.). Researchers investigated and reported the bacteriological and Physico-chemical parameters of surface and tap water quality in certain areas of Oban Massif, Nigeria [3]. They used Atomic absorption spectroscopic (AAS) techniques. They Checked and reported the Physico-chemical properties of wet and dry sessions, the values were in satisfactory level of NSDWQ for wet session while if there should be an occurrence of dry session. TDS, turbidity, concentration of Fe, Mn, NO^{3-} and so forth were below as far as possible (temperature 25.4°C wet, 22 C0 dry, pH 4.58, wet pH 5.93, Fe 0.07ppm wet, 0.115ppm dry, Mn 0.003ppm wet and 0.01ppm dry) (Table 9).

Table 8. Contamination of iron in water

Method	WHO limit	Calibration range	LOD	Ref.
Flame atomic absorption spectroscopy	1.0mg/L (WHO 2011)	ND-0.64mg/L	5µg/L	[10]
ICP-MS & Iron K-edge X-ray absorption Spectroscopy	0.3mg/L	1 mg/L-37 mg/L	150 µg/L	[9]
Spectroscopic methods	0.3mg/L	0.01-0.050mg/L	0.001	[20]
EDAX(Energy Dispersive X-ray analysis	0.3ppm	0ppm-1.73ppm		[15]

Table 9. Physical parameters with references

S. No.	pH	BOD (By Respirometric method) and by Lovibond meter	COD (By Open reflux method, Back titration)	TDS (mg/L)	EC	Ref.
1	7.71-8.39			181-338	412.2-8056.5	[11]
		80 mg/L-500 mg/L	118 mg/L-957 mg/L			[17]
2	4.58-6.31			9.5-15.4	16.6-23.5	[3]
3	7.2-7.7			1020-3635	1580-5200 µs/cm	[4]
		1.37mg/L-1.43mg/L	3.39 mg/L-3.45 mg/L			[17]
4	5.9-6.7			240-450	47-97	[10]

Water samples were collected from different areas tube wells located at district Pishin, province Balochistan, Pakistan by respective authors [7]. As, Pb, Al and Sb metals were analyzed by using Atomic spectrometry. Physical parameters like pH, conductivity, colors, transparency etc. were also checked. Antimony and aluminum concentrations were 0.2774ppm-1.0214ppm and 0.7304ppm-1.7211ppm respectively. Authors suggested that as depth of the well increases as the amount of aluminum decreases. Local institutions should be gathered toward safe and quality water creations, as water is at risk of being contaminated. Water agencies should play a key role to establish awareness to clean the water of high quality. Tareen *et al.* [7] collected samples from Mardan district KPK Pakistan. They determined the concentration of following trace metals like Ni, Zn, Cu, Cd, Cr, Pb and some cations like Na, Mg, K and Ca. They concluded that the concentration levels of heavy metals were with in limit as said by WHO. Concentration ranges were as follow; Ni

(0.01ppm-0.1ppm), Pb (0.00ppm-0.03ppm), Cr (0.01ppm-0.02ppm), Cd (0.00ppm), Zn (0.01ppm-0.16ppm), Cu (0.00ppm-0.01ppm). Author suggested that the water samples result shows that water in Mardan district KPK Pakistan are suitable for drinking.

Conclusion

From the above review the authors concluded that samples which were examined were not suitable for drinking purposes, as they were having metals concentration more than permissible level allowed by (WHO, EPA, USEPA and EUC). Respective authors suggested that the drinking water needs constant care and monitoring as most of the human population is at significant risk. Higher content of heavy toxic metals cause kidney problem, digestive system problems, nervous disorders, etc. Potable drinking water should be filtered and cleaned before used by quality water agencies and modern desalination techniques. Most of diseases are associated with drinking water, if human use clean water and free from toxic metals, most of diseases will be controlled.

Authors' contributions

Conceived and designed the idea: AU Rehman, Samiullah, N Khan, Hayatullah & A Baqi, Wrote the paper: A Basheer,

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