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REVIEW OF HEAVY METALS IN DRINKING WATER AND THEIR EFFECT ON HUMAN HEALTH

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Abstract: The levels of heavy metal contamination in various water sources as ground, surface, tap water etc. collected from various water origins (sources) of particular area in the research work (papers) of respective authors mentioned. The authors respective of their work determined the heavy metal concentration with the help of standard literature procedures. The methods in their research work were Atomic Absorption spectroscopy, Differential Pulse Anodic Stripping Voltammetry (DPASV), samples acidified to 1% with nitric acid and then stored in Double capped polyethylene bottles. The determination of the (concentration of) heavy metals found in their research work were as, Cd, Cr, Cu, Fe, Pb, Co, Mn, Hg, Ni, Zn. The concentrations determined were more than the maximum admissible and desirable limit when compared with the National and International organizations like WHO (2008), USEPA, EUC, EPA. On account of the concentrations of heavy metals determined by the authors in their research work, the authors detected the adverse effects on human health. On account of the concentrations of the heavy metals(determined) studied from their research papers , water samples are not suitable for drinking purposes unless it is treated with the water agencies. Thus the aim of this study is to review the research work on concentration of heavy metals in drinking water sources by respective authors in their research papers . If water from these origins (region of their respective areas) are taken for drinking purposes, the physiological effects (damages) to human health have been noted.

Keywords: Heavy Metals, Physiological parameters, Human Health.

I. INTRODUCTION

Toxic metals are usually present in industrial, municipal and urban runoff, which can be harmful to humans and biotic life. Increased urbanization and industrialization are to be blamed for an increased level of trace metals, especially heavy metals, in our waterways(Seema Singh et al.,2011[1].Many dangerous chemical elements if released into the environment , accumulate in the soil and sediments of water bodies (Abida Begum et al., 2009)[2]. There are over 50 elements that can be classified as heavy metals, 17 of which are considered to be very toxic and relatively accessible[1].Characteristically, also the anions have its important role in drinking water ; results also showed affecting the human health(S.Khanet al.,2012)[3] .Toxicity level depends on the type of metal, its biological role and the type of organisms that are exposed to it [1].Heavy metals have a marked effect on the aquatic flora &fauna which through bio-magnification enters the food chain and ultimately affect the human beings as well(Ram S Lokhande et al.,2011)[4]. The heavy metals in drinking water linked most often to human poisoning are lead, iron, cadmium copper, zinc, chromium etc .They are required by the body in small amounts , but can also be toxic in large doses. They constitute one important group of environmentally hazardous substances if present [1]. Heavy metals like copper are the essential trace elements but show toxicity if in excess amounts in drinking water. Cadmium is extremely toxic even in low concentrations, and will bio-accumulate in organisms and ecosystems and it has along biological half –life in the human body , ranging from 10 to 33years .Long term exposures to Cadmium also induces renal damage .So cadmium is considered as one of the priority pollutants form monitoring in most countries and international organizations. The contamination of water is directly related to the water pollution. There is need to continuously assess the quality of ground and surface water sources (Ehi-Eromosele C.O, OkieiW.O2012)[5].The known fatal effects of heavy metal toxicity in drinking water include damaged or reduced mental and central nervous function and lower energy level . They also cause irregularity in blood composition, badly effect vital organs such as kidneys and liver. (Sher Ali Khan et al., 2011[6]. The long term exposure of these metals result in physical ,muscular,neurological degenerative processes that cause Alzheimer's disease(brain disorder),Parkinson's disease(degenerative disease of the brain),muscular dystrophy (progressive skeletal muscle weakness),multiple sclerosis (a nervous system disease that affects brain and spinal cord), Also ,lead is one of the most common heavy metal in drinking water ,if occurred more than its permissible limit shows general metabolic poison and enzyme inhibitor(Gebrekidan etal.,2011) [7]. Lead has the ability to replace calcium in bone to form sites for long term replacements. Heavy metals like copper are the essential trace elements but show toxicity in excess. Toxicity can result from any of the heavy metals if they are present more or

less from its original limits in drinking water. Drinking water is obtained from a variety of sources like wells, rivers , lakes ,reservoirs ,ponds etc. The various sources of water poses the greatest risk to human health due to contamination of these sources .Water pollutants mainly consists of heavy metals , microorganisms , fertilizers and thousands of toxic organic compounds . Heavy metals in water occur only in trace levels but are more toxic to the human body. Keeping in view the hazardous nature of heavy metals contamination in water, it was imperative to initiate this study to assess the problem and suggest ways and means to decrease the risk of toxic heavy metals contamination of drinking water[5].Drinking water has been discussed centre stage as a commodity to be priced or paid for by the user, following the observation of the United Nations International drinking Water Supply and Sanitation Decade (IDWSSD) during 1981-91,(sinceJune1991) the initiation of a new era of economic reforms and liberalization. Constitutional rights and responsibilities related to water are blurred within the federal framework, as all three namely the central Government , State Government , Local bodies at the Village(Panchayat) and city(Nagarpalika) level dealing with water(Keshab das and Neha Panchal)(2006)[7]. For winding up the toxicity of heavy metals in drinking water and also for the protection of human health , guidelines for the presence of heavy metals in drinking water have been set by different International organizations such as USEPA, WHO, EPA and the European Union Commission .

II. MATERIALS AND METHODS

The determination of heavy metals concentration in drinking water were determined by the authors with the help of standard literarure procedures in their research work . The methods consists of Atomic Absorption Spectroscopy by N.H Zarel et al., and Javid Hussain et al., while Ehi Eromosole C.O1 et al. applied the method of the Differential pulse anodic stripping Voltammetry (DPASV) in their research work . Gebrekidan Mebrahtu *et al., in his work took all samples from chlorine treated ground water sources.The drinking water samples were collected in prewashed (with detergent , dilute HNO3 , doubly diionised distilled water respectively).Double capped polyethylene bottles collected from the month of Feb to May 2010. Most of the water samples were obtained directly from tap after allowing the water to run for at least 5 minutes so as to stabilise the variation in EC and Temperature(Reimann et al., 1996).Then the samples were acidified to 1% with Nitric Acid and stored in 500 mL in double capped polyethylene bottles (Gebrekidan and Samuel) .

The determination of concentration for heavy metals in their research papers (particular) were Pb ,Cd, Cr, Cu, Fe, As, Ni, Hg , Co , Zn, Mn . The concentrations of resulting heavy metals were compared with the national and International organizations. (WHO-2008, USEPA, EPA, EUC). The effects of heavy metals found more/less than the maximum admissible limits were noted.

Thus the aim of this study is to review the research work on heavy metals done by respective authors on heavy metals in drinking water sources from their origin. If population of these areas have happened the intake of amount of such water samples its physiological (effects) damages to human health have been noted. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

III. RESULTS AND DISCUSSIONS

Work done on heavy metals in drinking water by(various) respective authors with their respective work have been (discussed) studied. The quantity of heavy metals found in their research have stated with their maximum admissible limit. The resulting trace elements resulting with their concentration in drinking water were compared with several International Organizations such as WHO, USEPA, EPA EUC, MAC etc. The mean concentrations of all investigated metals in the waters tested were well not, prominent in their desirable limits (WHO-2008) and several health related risks were resulted (Gebrekidan M and Samuel Z (MEJS)2011)[6]. The Heavy metals in drinking water samples resulted in respective authors were Pb, Cd, Cu, Zn, As, Mn, Cr, Ni, Co, Fe with their respective concentrations in their work. Heavy metals in drinking water samples are related with chronic diseases. Heavy metals drinking water have been set up by different authors and also listed their adverse effects on the human health. As the source of drinking water sample mentioned surface; ground and tap waters collected in some part of Lagos Metropolis. The samples showed the presence of lead, copper and cadmium and their concentrations resulted were also compared with WHO (2008) specified contaminant levels for drinking water. The results obtained showed that all the well water and bore whole water samples investigated contain high concentrations of these heavy metals. Lead and cadmium concentrations were found to be above the WHO maximum acceptable concentration (MAC).None of the samples showed the copper concentrations above the WHO (MAC) for copper. On the whole samples analyzed, only the sample collected from Odo-lyaalaro stream, Ojota showed no pollution of lead. Other samples showed pollution of all of the metals analyzed.

Thus, result showed an indication of pollution hazards encompassing high emission of lead (Pb) in drinking waters from the combustion of ships and boat that use the way. The concentration of Pb found in drinking water samples found in the range of 0.020 mg/L to 0.215 mg/L. The maximum acceptable concentration results are of concern as lead is a poisonous metal that can damage nervous connections (especially in young children's) and cause blood and brain disorders. One of the most important and serious biochemical effects of lead is its interference with haemo synthesis, which leads to haematological damage [5]. The presence of elevated levels of Pb & Cd in almost argons is a serious

matter of concern & the potential for human exposure to heavy metals from eating fish caught in the lakes(Ram S. Lokhande et al.,2011)[4]. Also a potent neurotoxin that accumulates in soft tissues and bone over time. It is a cumulative poison and a possible human carcinogen[5]. The inadequate and irregular supply of water through piped water system has forced the population to use whatever quality of water available in the nearby water sources .This leads to water borne diseases and other health hazards (Mangesh. V. Kadu)[9]. Copper has the maximum acceptable concentration of (0.l mg/L) (WHO-2008). Little copper is essential for good health too much can be harmful. Ingesting large amounts of copper compounds can cause death by nervous system, liver and kidney failure. Minimum concentrations of copper detected for tap, surface and ground waters was 0.020 mg/L with maximum concentration being 0.120 mg/L from the result obtained from its analysis. None of the water samples contained copper above the specified maximum acceptable concentration (1.5 mg/L). However, copper was detected in all the water samples and since toxicity is associated with continuous low level exposure, this can eventually lead to serious health effects. High levels of copper in drinking water can cause vomiting, abdominal pain, nausea, diarrhoea and has been reported that copper leached into drinking water from copper pipes (Ehi-Eromosele C. O.et al.,2012)[5]. Method of preventing heavy metal contamination is simply by removing plumbing materials that contain lead, copper, or galvanized steel (Erin James Ling et al.,2011)[10].

Contamination of drinking water with high level of copper may lead to chronic anaemia. Studies have shown that ingesting copper may also implicated in coronary heart diseases and high blood pressures although coronary heart diseases have also been linked to copper deficiency. All the samples showed detectable levels of Cadmium and with all the samples having concentrations above the Maximum acceptable concentration for drinking water (0.003 mg/L) for surface water (0.01 mg/L)from the result) obtained from the DPASV analysis for Cadmium. Cadmium in drinking water samples resulted in the range of 0.010 mg/L to 0.110 mg/L. There are a few recorded instances of Cd poisoning found in human beings if the consumption of contaminated fishes. The maximum acceptable limit for Cd is 0.005 mg/L (WHO-2008). Thus, the whole samples analyzed only, surface water sample 8, showed no pollution of Pb and no water sample had Cu pollution all the other samples showed pollution of Pb and Cd. (Thus there water sample is not Suitable for drinking purposes).

Similarly, as Ehi-Eromosele C. O. et al.,2012 [5] have worked on drinking water sample from various locations, the author Javid Hussain et al.,2012 also collected water samples from Mardan District KPK, Pakistan, to determine the concentrations of trace elements like Ni, Pb, Cr, Cd, Zn, Cu. They also determined the concentrations of cations as Na, K, Mg, Ca in the drinking water sample of Mardan district KPK Pakistan. The analysis of date gave normal concentration of heavy metals water of Mardan tube well is fit for drinking only after Mg is removed by boiling. The concentration of heavy metals found in drinking water samples were ranged between 0.01–0.10 mg/L, 0.00–0.03 mg/L, 0.01–0.02 mg/L, 0.00 mg/L, 0.01–0.16 mg/L, 0.00– 0.01 mg/L respectively. Whereas, the normal concentration of each present heavy metal according to the International organizations like (WHO-2008) showed Ni -, 0.05 mg/L, 0.05mg/L, 0.005 mg/L, Zn – 5.0 mg/L, 0.05 mg/L respectively. Also the concentration of found some cations like Na+, K+, Mg2+, Ca2+ resulted were 24.5–140 ppm, 3.5–5.9 ppm, 62.4–144 mg/L, 144–292.8 mg/L respectively. Thus, the Mardan districts drinking water showed hardness & hardness causes cardiovascular disease mortality in human body.

So Javid Hussain et al.,2012[11] from their works, stated that the heavy metals concentration in Mardan districts drinking water and also the level of sodium (cations), potassium, calcium magnesium but the water of mardan division was free from any heavy metal pollution and all the analysis were found to be within the permissible limit except the Mg level.,2012.The research work done by Gebrekidan Mebrahtu and Samuel Zerabruk 2011) on heavy metals in drinking water, their work showed that the concentration of heavy metals in the drinking water samples which they collected from the urban areas of the Tigray region, Northern Ethiopia, have some of the physico-chemical parameters values higher than the WHO (2008) recommended maximum admissible limits. The total 106 drinking water samples were collected from 16 densely populated urban areas. They in their work analyzed total six physicochemical parameters as temperature, conductivity, total dissolved solids (TDS), salinity, pH and turbidity and ten heavy metals viz, As, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb and Zn using standard Procedures. The results were compared with other national and international standards. Gebrekidan Mebrahtu and Samuel Zerabruk.,2011[7] Among the analyzed samples, regarding physicochemical parameters 84.01% for electrical conductivity, 47.17% for TDS and 31.13% for turbidity shows concentration higher than 93.4% of the samples were within the United States Environmental Protection Agency (USEPA) admissible pH limit (6.5-8.5) and all the samples analyzed were within the Eu(1998) admissible pH limit (6.5-9.5). All samples showed Manganese and Copper within the WHO(2008) maximum admissible limit, but Arsenic (40.3%), Cadmium (7.46%), Chromium (64.18%), Iron (37.31%), Nickel 7% and Lead (29.85%) crossed the maximum admissible and desirable limits recommended by WHO (2008). The maximum admissible limit of Cobalt in drinking water is not mentioned by WHO, but all the samples analyzed were found to comply the New Zealand (1000 µg/L) and USEPA (100 µg/L) maximum admissible limits. Although no guideline is set by WHO (2008) for Zinc level in drinking water, of the samples analyzed, 94.02% comply the New Zealand standard and 97.01% comply all the maximum admissible limits referred in their study. The result is an indication of pollution hazards and weak drinking water treatment practices in the areas, which in turn have important human health implications. Their research therefore, recommends the government and other responsible authorities to take appropriate corrective measures[6]. As same N. H.-Zarel, N. Saadati1, M. Hassonizade1, P. Barati1, M. Ahmadi1, Z.

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Nazari2 collected the 52 grab water samples from the Karun river at the Ahvaz city during 2003-2007. Their study aimed to determine the levels of heavy metals as Chromium, Copper, Lead, Cadmium, Zinc, Manganese and Iron in the water of the Karun river at Ahvaz city.

The maximum and minimum concentrations of Cr, Cu, Pb, Cd, Zn, Mn and Fe in samples were determined in the range of (150.86-3.22), (69-8), (36.71-3.18), (51.4-0.02), (1578.5-19.3), (365-1.97) and (8295-815) respectively. The least and highest mean concentrations belonged to Cd is 2.42 and Fe in 2940.33 ppb respectively. Thus, the mean concentrations of all investigated metals in the waters tested were well below the maximum contaminant levels established by the WHO and EPA for levels in drinking water (N. H.-Zarel et al.(2007)[12].

The hazardous effects of heavy metals such as nickel shows the carcinogenic action on rat reported by sunderman. Ni accumulates in aquatic life, but its magnification along in food chain is not confirmed (Keshab das and Neha Panchal2006)[8] .Similarly ,Zinc is an essential requirement for a healthy body, excess zinc can be harmful and cause Zinc toxicity. Cobalt is beneficial for humans because it is part of vit B12 , essential for human health .It is used to treat anaemia with pregnant woman as it stimulates the production of red blood cells.Too high concentration of Co may damage human health.[3].

At the risk of the water being contaminated, Local institutions should be geared towards protecting, creating and improving water bodies .At this stage , reference must be made to the existence and operation of para-statal agencies in different rural areas of the country. Such efforts, though sporadic and often at a micro-level, by NGOs/CBOs or even philanthropic individuals are important in their own right [8].

Table I: Concentration of Heavy Metals in Drinking Water in Examined Water Samples of Respective Authors with their Respective Papers

Sr. No.	As µg /L	Cd mg/L	Cr mg/L	Cu mg/L	Fe	Pb mg/L	Co	Mn mg/ L	Hg** Nd	Ni mg/L	Zn mg/L	WHO maximum permissible (mg/L) limit 2008.	Papers by various authors (Research work on heavy metals in drinking water)
1	-	0.010 - 0.100	-	0.020 - 0.120	-	0.020 - 0.215		-	-	-	-	Ar=0.05 Cd=0.005	Ehi-Eromosele C.o et al.(2012)
2		0.00	0.00-0.02	0.00 - 0.01	-	0.00 - 0.03			-	0.00 - 0.10	0.00 - 0.16	Cr = 0.05 Cu = 0.05 Fe = 0.3 Pb=0.05	Javid Hussain et al.(2012)
3	320 - 1060	14µg/L - 21µg/L	92µg/L - 158 µg/L	-	97 µg/L - 1872 µg/L	5 µg/L - 1347 µg/L	6 µg/L - 36 µg/L	21 µg/L - 215 µg/L	-	31 µg/L - 459 µg/L	45 µg/L - 5055 µg/L	Mn=0.1 Hg=0.01 Ni = -	Gebre kidan M and Samuel Z (MEJS)(2011)
4		51.4 ppb - 0.02 ppb	150.86 ppb- 3.22 ppb	69 ppb - 8ppb	8295 ppb - 815 ppb	36.71 ppb - 3.18 ppb	-	365 ppb - 1.97 ppb			1578.5 ppb - 19.3 ppb	Zn = 5.0	N.H-Zarel et al.(2003-2007)

**Nd - The maximum permissible limit mg/L for (Mercury)Hg not determined by WHO -2008

IV. CONCLUSION

On account of the research of authors, the drinking water samples contain metal concentration more than the admissible and desirable levels (WHO, EUC, EPA, USEPA). Most of the water samples were at populace level, which are not possible for drinking purposes. The authors in their paper concluded from their work that the water samples need constant monitoring of various water sources as the results showed levels of pollution signalling a major proportion of the populace are at a significant risk given the toxicity of these metals (Ehi et al., N. H-Zarel et al., Javid Hussain et al., Gebrekidan et al.). There is a need that the drinking water of the areas should be filtered by the quality control agencies. The water can be used for drinking purposes unless it is passed through special water treatment.

People may suffer through disease on drinking water with higher concentration of heavy metals. They may have physiological effects as on kidney, digestive system, circulatory system, nervous system etc. various other organs and various systems of the body.

REFERENCES

[1] Seema Sing1,Swati Lal[1] ,Jeena Harjit[1*],Sulbha Amlathe[2] and H.C.Kataria[3], Vol.3,2011,no.5,239-246 33-40.
[2] Abida Begum 1*,Harikrishna S2,Irfanullah Khan3 International Journal of Chem Tech Research.CODEN(USA):IJCRGG ISSN :0974-4290. Vol .1,NO.2,pp245-249,April-June 2009.
[3] Sardar Khana,b,* ,Maria Shahnaz a,Noor Jahana,Shafiqur Rehmana,M.Tahir Shahc,Islamud Dind Journal of cleaner Production xxx (2012)1-9.
[4] Ram S .Lokhande1 ,Pravin. U.Singare2,*,Deepali S.Pimple3 Resources and Environment .(2011);1(1):13-19 DOI:10.5923/j.re.20110101.02
[5] Ehi-Eromosele C.O1,*,Okiei W.O2 Resources and Environment 2012,2(3):82-86 DOI :10.5923/j.re.20120203.01
[6] 1Sher Ali Khan,1Zahoor Ud Din, 2Ihsanullah &1Ahmad Zubair I.J.S.N., Vol.2(3)2011:648-652 ISSN 2229-6441
[7] Gebrekidan Mebrahtu*and Samuel Zerabruk Volume 3(1):105-121,2011
[8] Keshab Das and Neha Panchal, Gujrat Institute of Development Research, Ahemadbad, September (2006)
[9] Mangesh .V.Kadu , Current World Environment, Vol.6 ,295-297(2011)
[10] Erin James Ling ,Brian Benham , Scott Forrester Communications and Marketing , College of Agricultureand Life Sciences,Virginia Polytechnic Institute and State University ,2011.
[11] Javid Hussain ,Jehangir Shah ,Iktiar Khan ,Wilson Araujo Lopes, Rosemario Cerqueira Souza, Jose Domingos Santos da Silva,Edvaldo Pereira Queiroz Junior and Iracema Andrade Nascimento American-Eurasian J.Agri.&Environ.Sci.,12(8):1091-1094,2012 ISSN 1818-6769IDOSI publications,2012.
[12] N.H-Zarel, N. Saadati 1,H.Hassonizade1,P.Barati1,M.Ahmadi 1,Z.Nazari2.1.Water,Soil &Sediment Laboratory of Khouzestan Water &Power Authority;2.Department of Toxicology &Pharmacology, Pharmacy School,Ahvaz Jondishapour, University of medical Sciences(2003-2007)
[13] Yee Ling, T. and L. Nyanti (2012). Spatial and Temporal variation of heavy metals in a tropical river. World Applied Science Journal, 16(04): 550-559.
[14] Serife, T., S. Kartal and E. Latif (2000). Determination of heavy metals and their atomic absorption spectrometry after a four stage sequential extraction procedure. Analytical Chimica Acta, 413: 33-40.
[15] Ehi-Eromosele C. O., Okiei W. O. Department of Chemistry, Covenant University, P. M. B. 1023 Otta Nigeria, Department of Chemistry, University of Lagos, Nigeria.
[16] R. M. C. Suttan, S. J. Hill, P. Jones, J. Chromatogr. A739 (1996) 81.
[17] B. Mohammad, A. M. Ure, D. Littlejohn, J. Anal. At. Spectrom, 7 (1992) 695.
[18] M. Vircaus, V. Rone, A. Palne, D. Vircava. Anal. Chim. Acta., 299 (1994) 291.
[19] ATSDR (1992). The agency for toxic substances and disease registry. A Public Health Assessment Guidance Manual. U. S. Deptt. Of Health and Human Services, Atlanta, Georgia.
[20] IOSHIC (1999). International occupational safety and health information centre. Metals in basics of chemical safety, chapter 7, Sep. geneva: International Labour Organization.
[21] Mohapatra U. K., Singh B. C. (1999). Trace metal in drinking water from different sources in the old city of Cuttack. Indian Jour. of Environ. Health, 41(2): 115-120.
[22] WHO (1996). Health criteria and other supporting information. In: (2nd ed.), Guidelines for drinking water quality 2, WHO, Geneva, pp. 940-949.
[23] WHO (2003). International year of fresh water. General assembly resolution A/RES/55/196. Official Website: www.wateryear2003.org.
[24] WHO (2008). Guidelines for drinking water quality. World Health Organization, Geneva.
[25] WHO (1998). European standard for drinking water, World Health Organization, Geneva.
[26] Sanayei, Y., Ismail, N. and Talebi, S. M. (2009). Determination of heavy metals in Zayandeh rood, Isfahan-Iran. World Applied Sciences Journal, 6(9): 1209-1214.
[27] Sing, S. and Mosely, L. M. (2003). Trace metal levels in drinking water on Viti Levu, Fiji Islands. S. Pac. J. Nat. Sci., 21: 31-34.
[28] Atalay, A., Pao, S., James, M., Whitehead, B. and Allen A. (2008). Drinking water assessment at underserved farms in Virginia's coastal plain. Journal of Environmental Monitoring and Restoration, 4: 53-64.
[29] London, L., Dalvie, M. A., Nowicki, A. and Cairncross, E. (2005). Approaches for regulating water in South Africa for the presence of pesticides. Water SA, 31(1): 53-60.
[30] USEPA
[31] EPA (2002). Environmental protection agency safe drinking water facts sheets, Islamabad, Pakistan.
[32] European Union Commission (EUC) Guidelines.
[33] WHO-Guidelines for drinking water quality 3rd edn. Incorporating the first and second agenda volume recommendations (World Health Organizations, Geneva, 2008).