International Journal of Scientific Research and Engineering Development-– Volume 4 Issue 2, Mar- Apr 2021

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

ASSESSMENT OF GROUNDWATER CONTAMINATION IN PORTHARCOURT AREAS

Monday.E. Ossai*,Ibrahim O. Bazambo*,Titilola T. Falese* and Nurein O. Falade*,Adekunle A. Adefemiwa*

**Bioresources Development centre, National Biotechnology Development agency, Ogbomosho, Oyo State, Nigeria.*

--************************----------------------------------

Abstract:

Heavy metal concentrations of hand dug wells from eight locations within Portharcourt metropolis was studied. About sixteen hand dug well water samples were analysed. The samples were analysed for the following physicochemical parameters such as Temperature, pH value, total dissolved solid and conductivity within 24 hours of sampling using Standard methods. The metal cations were determined using the A.A.S method, Hardness, Chloride and Bicarbonate concentrations were determined using Titrimetric method, Sulphate was determined by spectrophotometric method while Nitrate was determined as Nitrogen content using the Kjedhal method. From the obtained results, most physicochemical parameters were found to be within the WHO acceptable limits for drinking water in all sample location.

Rumagbo and Elewere has the highest (108.5mg/L) and lowest (36.08mg/L) concentrations of HCO^{3-} respectively, the highest concentration of SO_4^{2-} was recorded in Waterline (72mg/L). Cl^- (91.5mg/L) and NO^{3-} (0.05mg/L) have their highest concentrations observed at Eligolo, the highest concentration for F^- (6.85mg/L) was obtained in Rumuola.

Mn, Cd, Fe and Pb ions concentration were found to be highest in water samples from Eligolo, As ion concentration (0.75mg/L) was found to be highest in Rumuola, lowest in Elewere (0.38mg/L). All reported concentrations were above the WHO limits of heavy water concentrations in drinking water. The results obtained from this study suggest a significant risk to the population given the toxicity of these metals and the fact that for many, hand dug wells and bore holes are the only sources of their water supply in this environment.

Keywords —. Heavy metals, Toxicity, Hand dug well,

--************************---------------------------------

1.0 INTRODUCTION

Water is one of the most fundamental assets to human on earth without which life on earth will be unreasonable [1, 2]. Water covers over 70% of the earth surface, nonetheless; accessibility of consumable water for individuals is as yet a significant issue particularly in the developing nations [3],[4],[5],[6] because of the way that water sources are regularly polluted. Pollution of water sources can emerge from leaching of rocks, industrial and agrochemical releases that are washed into them [7], particularly during the wet season[8]. Bresline in 2007, [9] and National Academy of Science NAS in 2009 [10] detailed that more than one billion individuals do not get clean safe water. The amount of freshwater accessible to man is not really 0.3 - 0.5% of the total water on the earth and its wise usage is important [11].Many people in the world especially majority of which live in rural areas among the poorest and most vulnerable do not have access to safe clean drinking water [12]. A recent survey found that an estimated 65 million Nigerians had no access to safe water [13]. Provision of clean, reliable and portable water in rural areas and urban slums remains a huge task to governments throughout the world especially considering the fact that larger fraction of the population lives in the urban areas [14].

As a result of this gross absence of potable water, the vast majority rely upon groundwater for utilization, homegrown, agrarian and industrial uses all around the world[15], [16]. According to UNESCO in 2012 over 2.5 billion people world-wide rely predominantly upon groundwater to cater for their essential day to day water needs, and hundreds of millions of farmers depends on it to earn their livelihoods and contribute to national security of others. It is reported that only 58% of Nigerians living in the urban and semi-urban areas and 39% of the rural dwellers have access to potable water supply; others largely rely on ground and surface water for their domestic water supply [18]. The quality of ground water sources is affected by the features of the media through which the water passes on its way to the ground water zone of saturation [19], thus, the heavy metals discharged by industries, traffic, municipal wastes, hazardous waste sites as well as from fertilizers for agricultural purposes and accidental oil spillages from tankers can result in a steady rise in pollution of ground water [20], [21].

Groundwater quality differs from place to place and this may therefore affect its suitability for consumption [22]. For instance, land-use has been found to influence the quality of groundwater [23]. Water breaks down most substances than any other solvent thus; a lot of toxic substances which can cause malfunctioning of human body and chronic ailments are present in it [24], [25]. Among the chemical dissolved in groundwater are heavy metals. Drinking groundwater and surface water contaminated by heavy metal ions can be detrimental to health [26], especially at concentrations above certain minimum.

Heavy metals are elements having atomic weights between 63.546 and 200.590 and a specific gravity greater than 4.0 i.e. at least 5 times that of water. They exist in water either as colloid, particle or dissolved [27] with their existence in water bodies being either of natural origin (e.g. eroded minerals within sediments, ore deposits leachate and products of volcanic eruption) or of anthropogenic origin (i.e. solid waste disposal, industrial or domestic effluents, harbour channel dredging) [28].

They derive their toxicity by binding with carboxylic acid (–COOH), amine (–NH2), and thiol (–SH) groups on proteins. When metals bind to these groups, they inactivate important enzyme systems or affect protein structure, which is linked to the catalytic properties of enzymes [29].

The Niger – delta region of Nigeria is blessed with abundant water resources, but as a result of the heavy mining and refining activities that are associated with crude oil exploration in the region, the water is not fit for consumption as it is highly contaminated. in the Niger – delta region, the level of contamination of ground water is continuously on the rise. this situation demands urgent attention, hence the need to assess the level of contamination of the groundwater being consumed by the people in this region, in order to determine the contamination source and ways of correcting this ugly trend

2.0. MATERIALS AND METHOD

Sixteen (16) water samples were collected from hand – dug wells from 8 different locations on 2 different occasions. The project area was divided into quadrant so that water collected is from each of the quadrant to represent the areas that falls within each section of the quadrant. After this has been done, the sampling location was studied before the commencement of the work.

Samples were collected in a 1.5lit. polyethylene bottles after rinsing with the water being sampled and were properly sealed. The moment the water sample was collected at the various point of sampling; it was wrapped with foil paper and then labelled accordingly with the name of the location where the sample was collected.

The information that were collected from the point of sampling are the sampling environment and activities that take place in the area.

2.1 Physicochemical Parameters Analysis

The samples were analyzed for the following physicochemical parameters such as Temperature, pH value, total dissolved solid and conductivity within 24 hours of sampling using Standard methods.

The samples were taken to the laboratory in Institute of Agricultural Research and Training (I. A. R & T) in Ibadan, Oyo State for analyses

2.2 Chemical parameters Analysis

The Samples were analysed quantitatively for metal ions, hardness, Chloride, Sulphate, Bicarbonate and Nitrate.

The metal cations were determined using the AAS method as described in APHA 3111B and ASTM D3651. Hardness, Chloride and Bicarbonate concentrations were determined using Titrimetric method, Sulphate was determined by spectrophotometric method while Nitrate was determined as Nitrogen content using the Kjedhal method.

2.3 Statistical Analysis

Data obtained were analysed using descriptive statistics for the mean and standard deviation, one-way ANOVA was used to test the significant differences in the concentrations of the metals in wells.

3.0 Result and Discussions

Table 1: Result of Physicochemical Parameters

parameters	pH	Ec (µS/cm)	TDS (mg/L)	T (°C)
RUMUKORO	4.20	182.50	77.50	30.75
ELEWERE	4.20	150.00	85.00	31.03
RUMAGBO	4.74	242.50	96.75	31.20
LAGOS STR	3.94	237.50	432.00	31.50

WATER LINE	4.03	247.50	450.00	30.65
MGBUOBA	4.26	227.50	297.00	31.28
RUMUOLA	3.97	175.00	468.75	31.05
ELIGOLO	4.64	207.00	342.50	31.35
WHO (2011)	6.5 – 8.5	150.75	1000	30 - 32
AVERAGE	4.25	208.69	281.19	31.10

The result of Physico-chemical and heavy metals analysis of Eight (8) locations shows that the temperature of the water ranged from 30 to 31.5°C (Table 1) which fall within the recommended standard for drinking water quality by [30].

The groundwater pH at all the sites were generally less than 6.0 indicating slight acidic condition The pH value of the water ranged from 3.90 to 4.75, thus, falling below the standard requirement limits (6.5-8.5) recommended by [30] and [31]. The pH values (Table 1) showed that the lowest value of 3.94 was recorded in Lagos street, which may be attributable to the discharge of acidic materials in to the ground water through industrial and domestic activities, while Rumagbo has the highest pH value of 4.74, which can be attributed to municipal waste disposal into the ground

water in the study area. This may pose a risk for consumption due to metal toxicity. Under a high acidic (low pH) condition, metals become more water soluble, thereby making it readily available for exposure.

Electrical conductivity, which is a measure of dissolved salts in water, ranges between 150.00 and 247.50 µS/cm, which is within the standard requirement limits recommended by [32]. Electrical conductivity is observed to be highest in samples from Waterline area (247.50) and lowest in Elewere samples (150.00). this is higher than 12.73 µ S/cm - 32.46 µ S/cm reported by [16] from groundwater from Itu.
The result shows that the total dissolved solids, which signifies the presence of cations and anions in water, in the water samples from all the sampling sites are well below the [30] limit for drinking water. The highest mean value (468.75) was recorded in Rumuola, while the lowest value of 77.5 mg/L was observed in Rumukoro. The observed range 77.5 – 468.75mg/L is higher than the 61.33- 277.0mg/L reported in Borehole water samples from Warri by [34]

TABLE 2: MEAN CONCENTRATION OF ANIONS

Location	HCO_3^- mg/L	SO_4^{2-} mg/L	Cl^- mg/L	NO_3^- mg/L	F^- mg/L
RUMUKORO	72.23	47.5	38	0.01	1.75
ELEWERE	36.08	67.25	26.75	0.03	2.4
RUMAGBO	108.5	47.75	69	0.01	1.8
LAGOS STR	36.25	70.75	90	0.02	1.78
WATERLINE	36.18	72	35	0.03	3.05
MGBUOBA	36.18	48	30	0.03	4.7
RUMUOLA	72.18	57	40.5	0.03	6.85
ELIGOLO	108.2	60.25	91.5	0.05	2.35
WHO (2011)	-	200.00	250.00	10.00	-

The result of the concentrations of some Anions present in the water samples collected from 8 locations in Port Harcourt metropolis is as shown in Table 2 above. Rumagbo and Elewere has the highest and lowest concentrations of HCO_3^- respectively, the highest concentration of SO_4^{2-} was recorded in Waterline. **Cl^-** and **NO_3^-** both have their highest concentrations observed at Eligolo, while the highest concentration for **F^-** was obtained in Rumuola. The concentrations for all the anions were found to be below the permissible limits set by [30]. Nitrate concentration above the recommended value of 10 mg/L is dangerous to pregnant women, it also poses a serious health threat to infants less than three to six months of age because of its ability to cause blue baby syndrome in which blood loses its ability to carry sufficient oxygen [16].

TABLE 3. THE MEAN CONCENTRATION OF CATIONS.

Location	Na	K	Ca
RUMUKORO	113.4	137.25	92
ELEWERE	125.25	166	47.88
RUMAGBO	113.45	137.75	195.25
LAGOS STR	124.15	146.25	543.25
WATER LINE	126	168	575.75
MGBUOBA	122.4	180.5	354.5
RUMUOLA	158.35	174	674.5
ELIGOLO	135	157.75	304.25
WHO (2011)	200		75

Highest concentration was recorded for Sodium at Rumuola (158.35 mg/L) while the lowest concentration was recorded at Rumukoro. All concentrations of Sodium ions observed were found to be below the permissible limit set by [30].

Only Rumukoro and Elewere test sites have moderate concentrations of Calcium (92 and 47.88mg/L respectively), with only Elewere site being below the limit set by WHO (2011), all samples from other sites were well above the 75mg/L limit set by WHO.

The concentrations of Potassium were found to be lowest at Rumukoro and highest at Mgbuoba

TABLE 4: THE MEAN CONCENTRATION OF HEAVY METALS PRESENTS IN THE SAMPLES FROM 8 LOCATIONS IN PORT HARCOURT.

Location	Mn	Cd	Pb	Fe	As
RUMUKORO	0.81	7.3	7.08	1	0.61
ELEWERE	0.75	6.85	6.03	1.2	0.38
RUMAGBO	0.8	7.3	7.08	1	0.6
LAGOS STR	0.7	7.4	7.1	1	0.5

	2		3		8
WATER LINE	0.7	6.33	6.2	1.73	0.51
MAGBUOBA	0.84	7.73	7.53	1.18	0.7
RUMUOLA	0.84	8.3	7.8	1	0.75
ELIGOLO	0.88	8.1	7.78	1.2	0.62
WHO (2011)	0.1	0.003	0.01	0.3	0.01

MANGANESE: The minimum and maximum concentration of Manganese metal ions obtained from the hand-dug wells at the eight different sampling sites in Portharcourt as shown in fig), range from 0.7 mg/L in sample from Water line and 0.88mg/L in the sample from Eligolo. The maximum permissible limit by WHO is 0.1mg/L. Decomposition and subsequent leaching of industrial effluents are probable sources of groundwater enrichment with manganese. It is an essential element for plants and animals, and it is used in products such as batteries, glass and fireworks [35]. Potassium permanganate is used as an oxidant for cleaning, bleaching and disinfection purposes. Other manganese compounds are used in fertilizers, fungicides and as livestock feeding supplements [36], [37]

CADMIUM: The maximum concentrations of cadmium metal ions was obtained in the sample from Rumuola (8.3) and the minimum concentration was observed in the sample from Waterline (6.33mg/L). The maximum Level by WHO is (0.003 mg/L). Cadmium metal ion in all the samples were observed to be above the maximum permissible limit set by WHO for drinking water. Chronic cadmium exposures result in kidney damage, bone deformities, and cardiovascular problems [38]

LEAD**:** Lead finds extensive use in storage batteries, solders, bearings, cable covers, ammunition, plumbing, pigments, caulking, sound vibration absorbers (Hardy *et al.,* 2008). The highest concentration of Lead was recorded in the sample from Rumuola (7.8) and the lowest in the sample from Elewere (6.03mg/L). The two routes of exposure to lead are from inhalation and ingestion and the effects from both are the same. Lead metal ion concentrations in all the samples were observed to be above the maximum permissible limit set by WHO for drinking water. Source of lead in the water samples analysed in this study could be from runoff from indiscriminately disposed lead-acid batteries, lead-based solder; metallic alloy, lead-based paints, used oil, waste incineration, scrap and junk auto part.

IRON: There is always some level of Iron in most groundwater, this is due to the fact that it is common in many aquifers and it is found in trace amounts in practically all sediments and rock formations. The maximum concentration of iron was obtained in the sample from Waterline, while the recorded minimum concentration (1.00mg/L) was recorded in Samples from four sites (Rumukoro, Rumagbo, Lagos street and Rumuola). The maximum limit by WHO is 0.3mg/L for iron, all the samples were observed to be above the maximum permissible limit set by WHO for drinking water. This indicates that the local mineral deposit in the studied area may have high levels of iron.

ARSENIC: In its gaseous form, Arsenic is a common by product in the production of pesticides. It is also a component in paints, rat poisoning, Fungicides and wood preservatives. The water samples analysed were all found tocontain Arsenic in more than the desirable concentration stipulated by the World Health Organization (0.01mg/L). The lowest mean concentration was recorded at Elewere, while the highest was observed at Rumuola. It causes damage to blood, kidney, skin, central nervous and digestive systems [39].

Generally speaking, the quality of the water samples collected from wells in Portharcourt were found to be largely contaminated when compared with the standards set by the World Health Organization (W.H.O). the concentrations of the various metals and anions analysed for in the samples were observed to be mostly above the limits set by W.H.O., the mean concentration of Al was found to be 0.38±0.01 which is above the 0.2 mg/L limit set by W.H.O. The mean concentration of Cd was found to be 7.41±0.14 mg/L which is way much higher than the 0.01 mg/L limit set by W.H.O.

The mean value of the pH of 4.25 and is found to be below the range (6.0 – 8.5) that is desirable for groundwater quality, and at a lower pH, the water tends to become Acidic. This acidic nature of the water result into Leaching of more metals present in rock formation into the groundwater. It therefore follows that water with a low pH will likely have elevated levels of toxic metals. This partly explain the unusual high levels of metals observed in groundwater from this region.

CONCLUSION

The result obtained from the analysis carried out on the water samples from Portharcourt, one the commercial and economic nerve center of the Niger – Delta region shows that there is a high rate of contamination of the groundwater in the studied area.

REFERENCES

[1] World Health Organization (WHO). Guideline for drinking water quality – 2nd Edition. 2004. Geneva, pp. 231 – 233.

[2]S. S.Yadav, and R. Kumar. Monitoring water quality of Kosi River in Rampur District, Uttar Pradesh, India. *Advances in Applied Science Research*, 2 (2): pp 197 – 201, 2011.

[3] A. Y. Faremi and O. B. Oloyede. 2010. Biochemical assessment of the effect of soap and detergent industrial effluents on some enzymes in the stomach of albino rats. *Research Journal of Environmental Toxicology*,vol 4 (3),pp 127 – 133.

[4] S. S. D, Foster. The interdependence of groundwater and urbanization in rapidly developing cities.*Urban Water,*vol 3, pp 209 – 215,2001.

[5] Lashkaripour, G. R. Contamination of groundwater resources in Zaheden City due to rapid development. *Pakistan Journal of Applied Science*, vol3 (5): pp 341 – 345, 2003

[6] M. W. Pasquini, and M. J. Alexander. Chemical properties of urban waste ash produced by open burning on the Jos Plateau: Implication for agriculture. *Science of the Total Environment*, vol. 319 (1-3), pp 225 – 240, 2004

[7] R. A Lawal and Y.N Lohdip. Physicochemical and microbial analysis of water from Mimyak River in Kanke LGA of Plateau state, Nigeria. *Afr. J. Nat. Sci*. vol. 14, pp5-7,2011.

[8] I.O Obaroh, U Abubakar, M.A Haruna and M.C Elinge. Evaluation of some heavy metals concentration in River Argungu. *J. Fish. Aquat. Sci*. vol. 10(6), pp581-586, 2015.

[9] Bresline E (2007) Sustainable water supply in developing countries. *GeolgclSocty of Amer*., 2007 Paper 1,p. 194

[10] National Academy of Science NAS (2009) National Academy of Science: Overview-Safe Drinking Water is Essential. *The National Academies* Press, Washington, D.C
[11] K.Ganesh and K.Y.S Hedge (1995) Quality of lenetic waters of Dharwad district in North Karnataka. *J Environ Health.* Vol.7(1), pp 52–56, 1995
[12] MacDonald A M, and Calow R.C (2009) Developing groundwater for secure rural water supplies in Africa. Desalination. doi:10.1016/j.desal.2008.05.100
[13] B.Majuru, M.M Michael, P.Jagals, and P.R Hunter. Health impact of small-community water supply reliability. *Internl J HygiEnvironl Health.*vol. 214(2), pp162–166, 2011.
[14] I.E Ahaneku, and P.A Adeoye. Impact of pit latrines on groundwater quality of Fokoslum, Ibadan, Southwestern Nigeria. *Brit J of Appl Sci and Tech.*vol. 4(3): pp 440–449, 2014.
[15] T.Hvitved-Jacobson, and Y. A. Yousef. Highways run off quality, environmental impacts and Control. In Highway Pollution, Elsevier, 1991. London. pp. 165 – 208.
[16] G. A Ebongand H.S. Etuk. Portability of Groundwater in Itu Local Government Area, South-South of Nigeria. *International Journal of Materials Science and Applications*. Vol. 6 (3):pp. 126-135, 2017
[17] UNESCO (2012). "United Nations Educational, Scientific and Cultural Organization". World's groundwater resources are suffering from poor governance. UNESCO Natural Sciences Sector News. Paris, UNESCO, 2012.
[18] FGN (Federal Government of Nigeria). A report of water resources in Nigeria in the world water day. The Nation Newspaper, 2012. Abuja. Ferrier, C. 2001. Bottled water. Understanding a social phenomenon. *Journal of Human Environment*, 30 (2): 15 – 24.
[19] O.Adeyemi, O.B. Oloyede and A.T. Oladiji. Physicochemical and microbial characteristics of Leachate contaminated ground water. *Asian J. Biochem.,*vol. 2(5), pp. 343-348, 2007.
[20] I.O.Igwilo, O.J. Afonne, U.J. Maduabuchi, and O.E.Orisakwe. Toxicological study of the Anam River in Otuocha, Anambra State, Nigeria. *Arch. Environ. Occup. Health,*vol. 61(5), pp. 205-208, 2006.
[21] M.A. Momodu, and C.A. Anyakora. Heavy Metal Contamination of Ground Water: The Surulere Case Study. *Res. J. Environ. Earth Sci*., vol. 2(1), pp. 39-43, 2010.
[22] A.M Taiwo, A.T Towolawi,A.A Olanigan,O.O Olujimi, and T.A Arowolo2015. Comparative Assessment of Groundwater Quality in Rural and Urban Areas of Nigeria. In Research and Practices in Water Quality.
[23] E. O Orebiyi, J.A.Awomeso,O.A.Idowu, O.Martins, O.Oguntoke, and A.M. Taiwo, Assessment of pollution hazards of shallow well water in Abeokuta and Environs, Southwest, Nigeria. *American Journal of Environmental Sciences*. Vol. 6(1), pp. 50-56, 2010.
[24] A. Ikem, S. Odueyungbo, N. O. Egiebor and K. Nyavor. "Chemical quality of bottled water from three cities in Eastern Alabama". *The Science of the Total Environment,*vol. 285: pp. 165 – 175, 2002.
[25] E. I Adeyeye. "Bio-concentration of macro and trace elements in prawns living in Lagos Lagoon". *Pakistan Journal of Scientific and Industrial Research*, vol. 43, pp.367 – 373, 2000.
[26] A.O.Ohwoghere. Heavy metals distribution in degraded land forms in Delta State of the Niger Delta. *J Geology Min Res*vol. 4(3), pp. 43–50, 2012.
[27] A. A., Adepoju-Bello, O. O.Ojomolade, G. A.Ayoola, and H. A. B Coker. Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis. *The Nig. J. Pharm*. Vol. 42 (1), pp. 57-60, 2009.
[28] J. E.Marcovecchio, S. E. Botte and R. H. Freije2007. Heavy Metals, Major Metals, Trace Elements. In: Handbook of Water Analysis. L.M. Nollet, (Ed.). 2nd. LondonEdn: *CRC Press*; pp. 275-311.
[29] M.A.Momodu andC.A Anyakora. Heavy Metal Contamination of Ground Water: The Surulere Case Study. *Res. J. Environ. Earth Sci.,* vol. 2(1), pp. 39-43, 2010.
[30] WHO. "Guidelines for drinking water quality". World Health Organization, Geneva, Volume 1, 4th Edition. 2011.
[31] NIS (Nigerian Industrial Standard) (2007). Nigerian Standard for Drinking Water Quality. Available at: http://www.unicef.org/nigeria/ng_publications_Nigerian_Standard_for_Drinking_Water_Quality.pdf Accessed 02 Nov 2016.
[32] WHO (2007). Water for Pharmaceuticals Use, In: Quality Assurance of Pharmaceutical: A Compendium of Guidelines and Related Materials. 2nd updated Edn. World Health organization, Geneva, 2: 170-187
[33] D. H Hardy, J. Myers and C.Stokes 2008: Heavy Metals in North Carolina Soils, Occurrence & Significance, N.C: Department of Agriculture and Consumer Services, pp. 1-2.

[34] O. D.Fovwe, O.Solomon, andO. F Ebhodaghe, An appraisal of groundwater quality in selected areas in Warri Metropolis. *Journal of Water Resources and Ocean Science*. Vol. 3 (5), pp. 55 – 60, 2014.

[35] S.J. Aboud, and N.Nandini. "Heavy Metal Analysis and Sediment Quality Values in Urban Lakes". *American Journal of Environmental Science*. Vol. 5(6),pp. 678 – 687, 2009.

[36] A.N.Amadi, P.I. Olasehinde, J. Yisa, E.A. Okosun, H.O. Nwankwoala, and Y.B. Alkali. "Geostatistical Assessment of Groundwater Quality from Coastal Aquifers of Eastern Niger Delta, Nigeria". *Geosciences*. Vol. 2(3),pp.51–59,2012.doi: 10.5923/j.geo.20120203.03.

[37] A.N. Amadi, B.O. Udoh, T.M. Ozoji, W.G. Akande, I. Shaibu, M.A. Dan-Hassan, S.U. Hussaini, and A.S. Oguntade.Quality Assessment of Groundwater in Parts of Niger Delta, Southern Nigeria using Metal Pollution Index and Factor Analysis. *Pacific Journal of Science and Technology*. Vol. 21(1), pp. 280-289, 2020.

[38] Goyer RA, Clarkson TW (2001). Toxic Effects of Metals. In, Casarett and Doullis Toxicology: *The Basic Science of Poisons, Sixth Edition (C.D. Klaassen, ed.) Mc-Graw-Hill, New York*, pp. 811-867.

[39] G.K.Khadse, P.M. Patni, P. Kelkar, and S. Devotta. Qualitative Evaluation of Kanhan River and its Tributaries Flowing over Central Indian Plateau. *Environmental Monitoring and Assessment*. Vol. 147(1-3): pp. 83-92, 2008.