Assessment of Polycyclic Aromatic Hydrocarbon Levels in Surface Water and Sediment from Mini-Welele River in Mgbuosimini Community of Rivers State, Nigeria

[1]Ideriah T. J. K., [2]Sunday V., [2]Kalagbor A., [2]Awolo S. N

[1]Institute of Pollution Studies, Rivers State University Nkpolu Oroworukwo, Port Harcourt

[2]Department of Chemistry, Rivers State University Nkpolu Oroworukwo, Port Harcourt

DOI: https://doi.org/10.51584/IJRIAS.2025.10060047

Received: 15 June 2025; Accepted: 20 June 2025; Published: 04 July 2025

ABSTRACT

Levels of Polycyclic Aromatic Hydrocarbons (PAHs) in surface water and sediment samples in mini-Welele river in Mgbuosimini community, Rivers State, were assessed in this study using Gas Chromatography-Mass Spectrophotometer. The results for surface water showed highest level of Naphthalene (0.366 ppm) followed by pyrene (0.252 ppm). The results for sediment samples showed highest level of Acenaphthene (12.15 ppm) followed by pyrene (10.48 ppm). These values are higher than their recommended standard limits and were attributed to effluents and spillages from marine transport and artisanal petroleum activities in addition to atmospheric deposition. It was recommended that regular monitoring of activities around the rivers and strict environmental laws governing waste disposal should be enacted and enforced.

Keywords; Polycyclic Aromatic Hydrocarbon, Surface Water and Sediment, Mini-Welele, Nigeria

INTRODUCTION

Mini-Welele River is exceptionally important to the inhabitants of Mgbuosimini community in Rumueme, Port-Harcourt, as it serves as a drainage system, important ecological function, provides coastal protection, recreation, resources as sea food, energy, tourism and economic development.

The increase in water body pollution due to the numerous human activities such as dredging, drainage constructions, waste disposal and burning, building construction, and agriculture etc. can lead to increase in water temperatures, elevated nutrients levels, low dissolved oxygen concentrations, elevated pH, potential ammonia toxicity, increased incidence of fish disease, an abundance of aquatic plant growth, high chlorophyll levels (both planktonic and periphytic algae), high concentration of potential toxic elements and high concentration of toxicogenic blue-green algae. The presence of these pollutants at elevated levels has protracted destructive effects on aquatic biota and also ends self-purification processes of water and the behaviour of plants and animals present in the receiving aquatic medium and other beneficial uses to which water may be applied (Isaiah *et al*., 2019). When there is interference of pollutants or contaminants with water, there is a resultant decrease in its quality and this can be made known when different water assessment parameters have gone beyond the permissible limits for consumption, through laboratory measurements and evaluation (Kalagbor *et al*., 2021).

Researchers in different parts of the world have reported health problems associated with prolonged use of polluted surface water which range from dysentery, diarrhoea, abortion, premature birth, viral hepatitis and gastric and duodenal ulcers among others (Ali *et al.,* 2021; Pal *et al.,* 2018).

"Surface water are self-sustaining ecosystems that, without any human interference and natural disasters, could be able to indefinitely support both themselves and all forms of life within them. The declining quality of water in these systems threatens their sustainability and is therefore a cause for concern. Since most rural communities around the world traditionally take their water supply from rivers, dams, spring, lakes, ponds or from shallow

dug wells (Sun *et al.,* 2010; Aneck-Hahn *et al*., 2009; WHO and UNICEF 2006), increasing pollution from urban, industrial and agricultural sources is making available resources unusable and dangerous to health, (Contaminated surface water, 2008). Globally, about 1.6 billion children under the age of 5 years die annually due to unsafe drinking water coupled with lack of basic sanitation (WHO and UNICEF, 2006). In developing world alone, almost 5 million deaths annually are due to water related disease, as water quality problems are affecting virtually all the developing world's major rivers (Contaminated surface water, 2008). Even where pollution levels in the main stream of river are in acceptable levels, serious problems are often seen in the tributaries; usually local streams that have become urban drains. Unfortunately, these urban drains are also the main source of water for drinking and daily use for downstream poor communities along their banks (Contaminated surface water, 2008). Compared with pristine conditions, rivers and systems worldwide have doubled their content of nitrogen and phosphorus as a consequence of human activities (Camargo *et al*., 2004). Sever pollution levels can cause rivers to become biologically dead and poisonous to drink from. Cause of surface water pollution is diverse, though anthropogenic activities are the major contributors to fresh water pollution. For example, continued discharge of nutrient-rich waste water effluent into surface water resource, leads to eutrophication problems. While statistics show Cambodia, Indonesia, the Philippines and Vietnam all have abundant internal fresh water resource per capita, they nevertheless suffer from significant fresh water pollution from human activities (Hutton *et al*., 2007). In Vietnam, for example, $13^0/_0$ of households dispose of solid waste to water course (Hutton *et al*., 2007). In agriculture, while the application of organic manure and or inorganic fertilizers will boost the production of good crops and so make food affordable to even the low socio-economic class, nutrient application in excess of plant needs has a potential to pollute surface water as well as groundwater (Bhumbla, 2011). Apart from waste water effluents and agriculture, storm water run – off from the built –up environment is another source of nutrient enrichment in rivers (Bhumbla, 2011).

Surface water pollution also has economic consequence. A serious problem impacting on communities relying on polluted water sources for the production of potable water is the eventual cost of potable water. Treatment cost may become so excessive that water becomes available only to those who can afford it (Hutton *et al.,* 2007). Pollution of surface water by agricultural run–offs like sediment, nutrients, pesticides, salts and pathogens can impose costs on water users (Water Quality Impacts of Agricultural, 2012). Pesticides are especially difficult to remove from fresh water and thus can be found in municipals or bottled water, even after conventional treatment (Maria, 2003). Eutrophication of surface waters may accelerate alga production, resulting in clogged pipelines, fish kills, which may result in loss of revenue, and reduced recreational opportunities (USEPA, 1998). Sediment is the largest contaminant of surface water by weight and volume (Koltun *et al.,* 1997). Besides increasing the cost of water treatment for municipal and industrial water uses, sediment can also destroy or degrade aquatic wildlife habitat, reducing diversity and damaging commercial and recreational fisheries. In addition, many toxic materials can be bound to silt and clay particles that are carried into water bodies, including nutrients, pesticides, industrial wastes metals (Oster *et al*., 1998).

The imbalance between the construction of settlement (formal and informal) and sanitary infrastructure to carter for such increase in population growth, poses a serious threat to the existing water resources, both through increased demand in terms of increased abstraction and storage, and through pollution by disposal, dilution and transportation of effluents. Hence, the need for a better understanding of the qualities of water resources and sediment becomes imperative in the management and mitigation of problems that may arise, such as pollution.

MATERIALS AND METHODS

The Study Area

The Mini-Welele River is basically a very busy environment when it comes to fishing and transportation activities. The river is situated at Lat. 4.41939° N and Long 7.02001° E, in Obio/Akpor Local Government Area of Rivers State (Fig. 1).

Collection of Surface Water Samples

Surface water samples were collected using 1liter plastic containers. Glass bottles with aluminum cover were used to collect samples for the determination of PAH.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

Collection of Sediment Samples

Sediment samples were collected using 1liter plastic containers. Specifically, sterile plastic vial s were used to collect sediment samples.

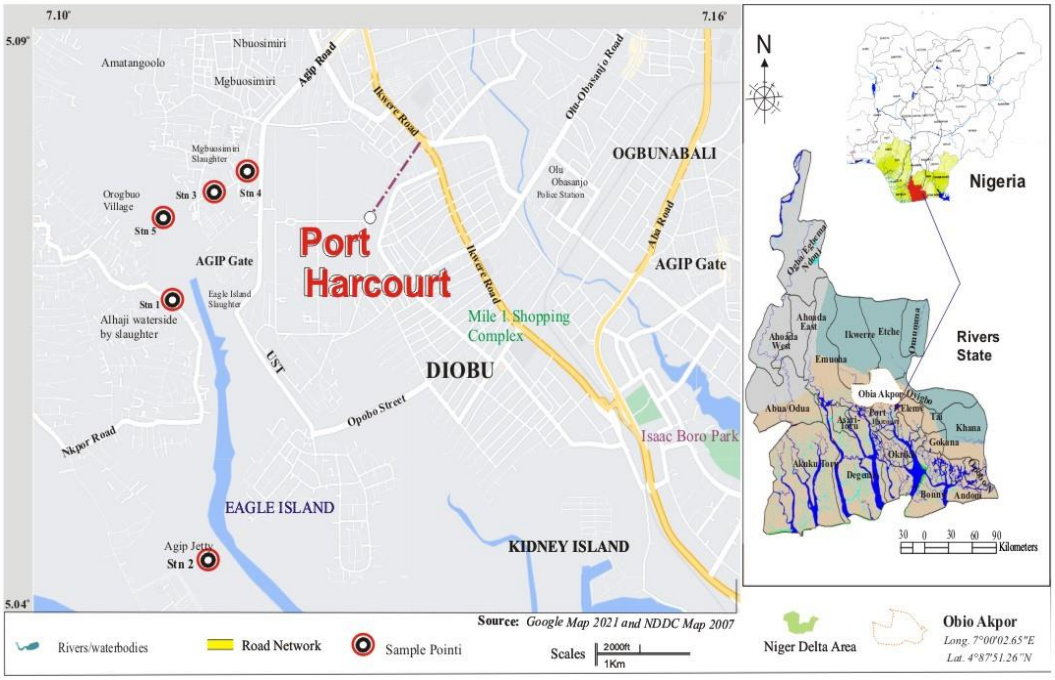

Figure 1: Map of the Study Area showing Sampling Locations

Determination of Polycyclic Aromatic Hydrocarbons (PAHs)

Determination of PAHs in Water Sample

The respective samples were raised into micro vials (100 microliters) and preserved in the refrigerator until they were injected into the Gas Chromatography – Mass Spectrometer (GC-MS) instrument. The PAHs extracts were analyzed by using a 3800 Varian Gas Chromatography Coupled to a Varian Saturn 2200 Mass Spectrometer, equipped with a 30m x 0.25 mm i.d (inner diameter) WCOTCP-Sil 8 CB column. The GC – MS was operated under the following conditions: the initial column temperature was 70 °C. After an initial holding time of 1 min, the temperature was programmed to rise to 300 °C at a rate of 10 °C /min for 30mins.

The injector and detector temperatures were 25 °C and 300 °C respectively. Helium was used as the carrier gas at a flow rate of 2 ml/min. The method was according to the established procedure by the EPA method 8270D. PAHs concentrations were identified based on their retention time and confirmed by comparing their mass spectra with the reference standard.

Determination of PAHs in sediment sample

The respective samples were raised into micro vials (100 microliters) and preserved in the refrigerator until they were injected into the Gas Chromatography – Mass Spectrometer (GC-MS) instrument. The PAHs extracts were analyzed by using a 3800 Varian Gas Chromatography Coupled to a Varian Saturn 2200 Mass Spectrometer, equipped with a 30m x 0.25 mm i.d (inner diameter) WCOTCP-Sil 8 CB column. The GC – MS was operated under the following conditions: the initial column temperature was 70 °C. After an initial holding time of 1 min, the temperature was programmed to rise to 300 °C at a rate of 10 °C /min for 30mins.

The injector and detector temperatures were 25 °C and 300 °C respectively. Helium was used as the carrier gas at a flow rate of 2 ml/min. The method was according to the established procedure by the EPA method 8270D. PAHs concentrations were identified based on their retention time and confirmed by comparing their mass spectra with the reference standard.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

RESULTS AND DISCUSSION

Polycyclic Aromatic Hydrocarbon (PAH) Analysis in Surface Water Samples

The results of PAH analysis of the surface water samples is shown in Table 1. The levels of the various PAH within detection limit are Naphthalene levels ranged between 0.015 – 0.366 ppm; Acenaphthene levels ranged between 0.032 – 0.200 ppm; Acenaphthylene levels ranged between 0.002 – 0.012 ppm; Fluorene levels ranged between 0.011 – 0.020 ppm; Phenanthrene levels ranged between 0.014 – 0.052 ppm; Anthracene levels fell between 0.014 – 0.081 ppm; Fluoranthene levels fell between 0.014 – 0.064 ppm; Pyrene levels fell between 0.023 – 0.252 ppm; Benz(a)anthracene levels fell between 0.007 – 0.025 ppm; Chrysene levels fell between 0.032 – 0.124 ppm; Benzo(b)fluoranthene levels fell between 0.013 – 0.073 ppm; Benzo(k)fluoranthene levels fell between 0.029 – 0.046 ppm; Benzo(a)pyrene levels fell between 0.032 – 0.050 ppm; Indeno(1,2,3-c,d))pyrene levels fell between 0.035 – 0.074 ppm; Dibenz(a,h)anthracene levels fell between 0.025 – 0.047 ppm while Benzo{g,h,i)perylene levels fell between 0.012 – 0.069 ppm.

In the surface water, the Total Polycyclic Aromatic Hydrocarbons (PAHs) levels were above the WHO (2011) limit of 0.0002 mg/L. The PAH levels obtained in this study may pose serious environmental and health risks due to bioaccumulation of these PAH compounds. The health effects of PAH compounds are not stereotyped as individual PAH compounds have different health effects (Rengarajan *et al.,* 2015).

Table 1: Mean Levels of Polycyclic Aromatic Hydrocarbons (PAHs) in Surface Water Samples

PAHs (ppm)	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	USEPA Limits
Naphthalene	0.015±0.0	0.053±0.1	0.366±0.3	0.264±0.1	0.202±0.2	4.0×10^{-2} c
Acenaphthylene	0.150±0.2	0.187±0.2	0.200±0.2	0.032±0.0	0.175±0.0	2.0×10^{-1} b
Acenaphthene	0.002±0.0	0.004±0.1	0.012±0.1	0.009±0.2	0.007±0.0	2.0×10^{-1} b
Florene	0.011±0.0	0.014±0.2	0.016±0.0	0.016±0.1	0.020±0.0	2.0×10^{-1} b
Phenanthrene	0.014±0.0	0.033±0.0	0.035±0.0	0.032±0.2	0.052±0.0	2.0×10^{-1} b
Anthracene	0.021±0.0	0.033±0.0	0.035±0.0	0.014±0.1	0.081±0.1	2.0×10^{-1} b
Fluoranthene	0.014±0.0	0.020±0.0	0.024±0.1	0.017±0.0	0.064±0.1	2.0×10^{-1} b
Pyrene	0.214±0.2	0.023±0.0	0.252±0.2	0.036±0.0	0.054±0.1	2.0×10^{-1} b
Benz (a) Anthracene	0.016±0.0	0.023±0.0	0.025±0.1	0.007±0.3	0.015±0.2	1.0×10^{-4} a
Chrysene	0.124±0.1	0.044±0.0	0.036±0.2	0.032±0.0	0.063±0.1	2.0×10^{-4} a
Benzo (b) Fluoranthene	0.061±0.1	0.073±0.1	0.065±0.1	0.013±0.1	0.056±0.1	2.0×10^{-4} a
Benzo (k) Fluoranthene	0.037±0.2	0.044±0.2	0.034±0.2	0.029±0.0	0.046±0.0	2.0×10^{-4} a
Benzo (a) Pyrene	0.032±0.0	0.042±0.0	0.032±0.1	0.050±0.0	0.048±0.2	2.0×10^{-4} a
Indeno (1, 2, 3,-c,d) Pyrene	0.051±0.0	0.059±0.0	0.035±0.0	0.050±0.0	0.074±0.1	4.0×10^{-4} a
Dibenz (a, h) anthracene	0.038±0.2	0.047±0.2	0.036±0.1	0.025±0.0	0.037±0.0	3.0×10^{-4} a
Benzo (g, h, i) pyrylene	0.025±0.1	0.042±0.1	0.012±0.0	0.050±0.1	0.069±0.1	4.0×10^{-2} c

USEPA Limits: a = 2013; b = 2014; c = 1996

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

Polycyclic Aromatic Hydrocarbon (PAH) Analysis in Sediment Samples

The results of the PAH analysis of the Sediment samples are shown in Table 2. The levels of the various PAH within detection limit are, Naphthalene levels ranged between 0.010 – 0.10 ppm; Acenaphthene levels ranged between 4.58 – 12.15 ppm; Acenaphthylene levels ranged between 0.000 – 0.35 ppm; Fluorene levels ranged between 0.10 – 1.57 ppm; Phenanthrene levels ranged between 0.44 – 7.37 ppm; Anthracene levels fell between 0.30 – 1.23 ppm; Fluoranthene levels fell between 0.49 – 4.23 ppm; Pyrene levels fell between 0.34 – 10.48 ppm; Benz(a)anthracene levels fell between 0.33 – 1.050 ppm; Chrysene levels fell between 0.70 – 4.23 ppm; Benzo(b)fluoranthene levels fell between 0.98 – 6.21 ppm; Benzo(k)fluoranthene levels fell between 0.38 – 3.42 ppm; Benzo(a)pyrene levels fell between 0.54 – 1.01 ppm; Indeno(1,2,3-c,d))pyrene levels fell between 0.70 – 4.89 ppm; Dibenz(a,h)anthracene levels fell between 0.75 – 2.64 ppm while Benzo{g,h,i)perylene levels fell between 0.43 – 2.13 ppm.

In the sediment, the levels of PAHs were above WHO acceptable limits of 0.007 ppm in all stations. This poses serious environmental concerns to humans and aquatic life over time as there is possibly carcinogenic health risk due to bioaccumulation of these PAH compounds. The high values obtained might be due to atmospheric deposition of dust containing PAHs into the river system or runoff of industrial wastes containing PAHs. These results were higher than those reported by Ambade *et al.* (2021). The levels of PAHs in the sediment samples were above WHO acceptable limits of 0.007 ppm in all stations. This poses serious environmental concerns to humans and aquatic life over time as there is possibly carcinogenic health risk due to bioaccumulation of these PAH compounds.

Table 2: Mean Levels of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediment Samples

PAHs (ppm)	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	USEPA Limits
Naphthalene	0.01±0.02	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	4.0×10^{-2} c
Acenaphthylene	9.76±1.22	4.58±0.95	5.77±1.52	12.15±0.00	6.38±1.21	2.0×10^{-1} b
Acenaphthene	0.35±0.28	0.15±0.09	0.05±0.04	0.00±0.00	0.15±0.01	2.0×10^{-1} b
Flourene	1.57±1.91	0.10±0.02	0.20±0.01	0.72±0.00	0.38±0.18	2.0×10^{-1} b
Phenanthrene	4.46±1.97	1.67±1.85	0.44±0.10	7.37±0.00	1.89±0.89	2.0×10^{-1} b
Anthracene	1.23±1.40	0.30±0.06	0.60±0.14	0.98±0.01	1.10±1.21	2.0×10^{-1} b
Fluoranthene	4.23±5.54	2.70±2.65	0.80±0.78	0.49±0.00	1.19±1.27	2.0×10^{-1} b
Pyrene	10.48±0.49	0.34±0.44	0.60±0.55	0.34±0.00	4.22±3.01	2.0×10^{-1} b
Benz (a) anthracene	1.050±1.08	0.34±0.11	0.39±0.15	0.86±0.00	0.33±0.21	1.0×10^{-4} a
Chrysene	4.23±5.19	0.70±0.25	0.97±0.56	0.84±0.00	2.74±1.20	2.0×10^{-4} a
Benzo (b) Fluoranthene	6.21±5.10	1.62±0.57	0.98±0.69	4.09±0.00	1.71±0.22	2.0×10^{-4} a
Benzo (k) Fluoranthene	3.42±4.28	0.38±0.44	0.49±0.66	0.96±0.00	0.47±0.61	2.0×10^{-4} a
Benzo (a) Pyrene	0.98±0.63	0.80±0.35	0.72±0.37	1.01±0.00	0.54±0.05	2.0×10^{-4} a
Indeno (1, 2, 3,-c,d) Pyrene	4.89±5.74	1.15±0.53	0.83±0.17	0.70±0.00	0.86±0.20	4.0×10^{-4} a
Dibenz (a, h) anthracene	2.64±2.92	1.29±0.27	0.80±0.10	1.23±0.00	0.75±0.15	3.0×10^{-4} a
Benzo (g, h, i) pyrylene	2.13±2.01	1.06±0.01	0.43±0.69	0.89±0.00	0.62±0.12	4.0×10^{-2} c

USEPA Limits: a = 2013; b = 2014; c = 1996

CONCLUSION

The assessment of surface water and sediment from five locations in the study area revealed the PAH levels recorded exceeded their limits and were much higher in the sediment than those obtained in the surface water samples. The levels of PAH in the area could be attributed to effluents and spillages from marine transport systems and artisanal petroleum activities in addition to atmospheric depositions.

REFERENCES

1. Ali, S., Amir, S., Ali, S., Rehman, M. U., Majid, S., & Yatoo, A. M. (2021). Water pollution: Diseases and health impacts. In Freshwater Pollution and Aquatic Ecosystems (pp. 1-23). Apple Academic Press.
2. Ambade, B., Sethi, S. S., Kurwadkar, S., Kumar, A., & Sankar, T. K. (2021). Toxicity and health risk assessment of polycyclic aromatic hydrocarbons in surface water, sediments and groundwater vulnerability in Damodar River Basin. Groundwater for Sustainable Development, 13, 100553.
3. Aneck-Hahn, N. H., Bornman, M. S., & De Jager, C. (2009). Oestrogenic activity in drinking waters from a rural area in the Waterberg District, Limpopo Province, South Africa. Water SA, 35(3).
4. Bhumbla DK. (2011). Agriculture practices and nitrate pollution of water. Available from http://www.caf.wvu.edu/~forage/nitratepollution/nitrate.htm.
5. Camargo, J. A., Alonso, A., & De La Puente, M. (2004). Multimetric assessment of nutrient enrichment in impounded rivers based on benthic macroinvertebrates. Environmental Monitoring and Assessment, 96, 233-249.
6. Hutton, G., Haller, L., & Bartram, J. (2007). Global cost-benefit analysis of water supply and sanitation interventions. Journal of water and health, 5(4), 481-502.
7. Isaiah, O., Obunwo, C., Boisa, N., & Ihunwo, O. (2019). Quality assessment of surface waters and sediments of Anya-Ogologo River. Journal of Water Resources and Ocean Science, 8(5), 77-85.
8. Kalagbor, I. A., & Andrew, D. O. (2021). The Use of Eel Fish as a Bioindicator for Heavy Metals Pollution of Surface Water: A Case Study of Ibeno Beach, Akwa Ibom State.
9. Koltun, P., Yang, S., & O'Halloran, R. (1997). Identification and tracking of water parcels using linguistic cluster analysis.
10. Maria, S., Burone, L., Muniz, P., Pires-Vanin, A. N. A. & RODRIGUES, M. (2003). Spatial distribution of organic matter in the surface sediments of Ubatuba Bay (Southeastern-Brazil). Anais da Academia Brasileira de Ciências, 75, 77-80.
11. Oster, C. G., Foster, K. A., Mayer, M. M., Avery, M. L., & Audus, K. L. (1998). Characterization of the A549 cell line as a type II pulmonary epithelial cell model for drug metabolism. Experimental cell research, 243(2), 359-366.
12. Pal, M., Ayele, Y., Hadush, M., Panigrahi, S., & Jadhav, V. J. (2018). Public health hazards due to unsafe drinking water. Air Water Borne Dis, 7(1000138), 2.
13. Rengarajan, T., Rajendran, P., Nandakumar, N., Lokeshkumar, B., Rajendran, P. and Nishigaki, I. (2015). Exposure to Polycyclic Aromatic Hydrocarbons with Special Focus on Cancer. Asian Pacific Journal of Tropical Biomedical, 5, 182–189.
14. Sun, Y., Asante, F., & Birner, R. (2010). Opportunities and challenges of community-based rural drinking water supplies. International Food Policy Research Institute IFPRI.
15. UNICEF. (2006). Progress for children: a report card on water and sanitation (No. 5). UNICEF.
16. USEPA (United States Environmental Protection Agency) (1998) Drinking water contaminant list. EPA Document No. 815-F-98-002. GPO, Washington, DC.
17. USEPA (United States Environmental Protection Agency) (2013). Polycyclic Aromatic Hydrocarbons (PAHs) what are the standards and regulations for PAH exposure? United States Environmental Protection Agency (USEPA).
18. World Health Organization (WHO) (2011). Guidelines for Drinking-Water Quality. 4th Edition, World Health Organization, Geneva.