Asian Research Journal of Agriculture

6(1): 1-7, 2017; Article no.ARJA.34486
ISSN: 2456-561X

Impact of Waste Dump on Heavy Metal Pollution of Riverbank Soil and Physico-chemical Properties of River Arumangye in Doma, Nasarawa State, Nigeria

E. Ndor[1*], S. N. Dauda[1] and O. J. Jayeoba[2]

[1]Department of Crop Production Technology, College of Agriculture, Lafia, Nasarawa State, Nigeria.
[2]Department of Agronomy, Faculty of Agriculture, Nasarawa State University, Shabu-Lafia, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author EN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SND and OJJ managed the analyses of the study. Author EN managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2017/34486
Editor(s):
(1) Tancredo Souza, Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal.
Reviewers:
(1) Ningappa. M. Rolli, BLDEA's Degree College, India.
(2) Osakwe, S. A, Delta State University, Nigeria.
(3) Liliane Catone Soares, Federal University of Ouro Preto, Brazil.
(4) Devraj Chalise, Nepal Agricultural Research Council, Nepal.
Complete Peer review History: http://www.sciencedomain.org/review-history/20686

Original Research Article

Received 29th May 2017
Accepted 7th August 2017
Published 28th August 2017

ABSTRACT

In Nigeria, rivers and streams are natural water bodies that flow through cities and town. These rivers and streams are badly kept with their banks serving as disposal site. A study was conducted in 2015 in river Arumangye, with the aim of evaluating the effect of waste dump on heavy metal pollution index of the riverbank soil and assessed the quality of water. The result revealed that the riverbank soil was contaminated with heavy metals. The largest concentration of heavy metal present was Nickel (54 mg/kg) followed by Iron (5.04 mg/kg), Manganese (1.66 mg/kg), Cadmium (1.15 mg/kg), Cupper (0.65 mg/kg), Zinc (0.64 mg/kg) and the least was Lead (0.16 mg/kg). These metal content increases in ascending order in the soil as follows: Pb < Zn< Cu < Cd< Mn < Fe < Ni. However, the riverbank soil pollution index showed a reverse trend as follows: Mn < Ni< Zn < Cd< Pb < Cu < Fe. The pH Value of water from downstream was 6.45 which is slightly acidic than the

**Corresponding author: E-mail: ndors12@yahoo.com;*

upstream pH value of 8.12, while the midstream was 7.02. The WHO standard for a good drinking water has a pH value of 7.0-8.5. Also, ammonia nitrogen concentration on the downstream is high with a value of 0.64 mg/l, which is higher than the upstream (0.40 mg/l) and the midstream value of 0.49 mg/l; which is lower than the WHO standard value of 0.5 mg/l ammonia. Concentration of chloride at upstream was 23.00 mg/l, midstream sampling point had 24.00 mg/l of chloride compound and the downstream recorded the highest concentration of 28.80 mg/l of chloride. Dissolved oxygen in upstream was 3.80 mg/l of oxygen, midstream had 2.10 mg/l of oxygen and the downstream had a concentration of 1.90 mg/l of dissolved oxygen. The carbon dioxide concentration was more on the midstream (27.62 mg/l) sampling point compare to the upstream (18.67 mg/l) and downstream (18.69 mg/l). The water hardness was more at the upstream (22.00 mg/l), while at the midstream it became 20.00 mg/l and decreases again at the downstream to 18.78 mg/l. Therefore, dumping waste in river Arumangye contributed in polluting the river bank soil with heavy metals. However water quality of the is river still good for consumption; since most of the parameters assessed are within WHO minimum standard requirement of a good drinking water.

Keywords: Waste dump; heavy metals; pollution index; riverbank soil; water quality.

1. INTRODUCTION

Rivers are natural bodies of water that flow through towns and cities across the world and most of these rivers are the major source of fresh water for man and industrial usage [1]. Despite the importance of these natural water bodies; in developing countries rivers and streams that flow through town and cities are badly kept with their banks serving as disposal site for municipal solid waste and public sewage system draining into these rivers thereby polluting them. The problem of waste management in Nigeria has become a complex issue as a result of high population growth, accelerated urbanization and industrialization [2]. It is estimated that each Nigerian generate about 0.85 kg of waste per day totaling about 119 million tones of municipal solid waste per year [3]. The choice of dumpsite in close proximity to a river or stream is particularly becoming a major concern that merits special attention. This is because most of these surface water bodies still serve as sources of water supply to many urban and rural communities downstream [4]. As such their water is expected to maintain a certain level of quality for their sustainable use by the teeming populations [5]. Information of water quality and pollution sources is important for implementation of sustainable water use management strategies [6]. The closeness of waste dump to a water source can significantly affect its water quality [7].

Riverbanks are made up of rich alluvial soils that are very fertile for growing vegetable crops like: Amaranths, pepper, carrot [8]. However, some of these riverbank soils are converted into dumpsite where both solid and liquid municipal and industrial wastes are deposited on daily basis. Some of these river bank soils are heavily contaminated with heavy metals and other poisonous metal that may be injurious to crops and also human when such crops are consumed [9]. The use of contaminated water from these streams and rivers for irrigation, also poses the greatest threat to human life. Previous studies by [10] have revealed the presence of some heavy metal in some urban riverbank soil, water and fish in river Uke of Nasarawa state. It has also been established that some of the farmers use sludge along these riverbanks and stream banks as manure for crop production which has negative effect on soil physical and chemical properties [11]. The objective of this study is to evaluate the heavy metal pollution index of riverbank soil of river Arumangye which house one of the largest solid waste dumpsite in Doma town and also assess its water quality for human consumption.

2. MATERIALS AND METHODS

2.1 Experimental Area

The experiment was conducted in River Arumangye in Doma Local Government of Nasarawa State; which is located on latitude 8° 23' 35.05" N and longitude 8° 21' 19.58" E. River Arumangye is the major stream that transverse the eastern part of Doma town. This river started from a small highland in Doma and flow from east to west to connect with a bigger river called river Uke, which subsequently emptied its content into river Benue. River Arumangye is used by the inhabitants of Doma as a source of water for both domestic and industrial purposes; since the urban water supply system is not

available. Large irrigation farms are also practice along the riverbank; since the river retained water even in dry season. Due to urban expansion of Doma town, there is high generation of municipal solid and liquid waste and no appropriate waste disposal or management facilities put in place. The inhabitants now empty their dustbins or dump their waste into Arumangye stream banks which is threatening the survival of the stream. The width of the stream is reducing yearly because of dumping of solid waste on the stream bank. Whereas, stream banks are known for their rich alluvial soil that supports the growth of diverse kinds of crops especially vegetable.

2.2 Data Collection

2.2.1 Soil sampling

A total of ten soil samples were collected by random sampling methods using soil auger from the riverbank close to the dumpsite. After thorough mixing, 200 g of representative samples was taken and homogenized using pestle and mortar, sieved using 2 mm mesh. Also, another reference soil sample was collected 30 mtetres away from the dumpsite and labeled as the control using the same method as above; for calculation of soil pollution index. All the soil samples collected were air-dried before subjecting them for analysis using standard laboratory procedures described by [12].

2.2.2 Water sampling

The duration of study was twelve weeks between the months of March and April during which human activities are more pronounced along the stream, because of the scarcity of water from other sources like hand dug wells, rainfall etc. Sampling was done fortnightly during the morning hours between 7:30-10:00 am from the up, mid (dumpsite) and downstream of river Arumangye for both the physical parameters which were done at the site; while the chemical compositions were determined in the laboratory. The following parameters were analyzed from the water samples: pH, Temperature, Ammonia Nitrogen, Nitrite Nitrogen, Alkalinity, carbon dioxide, chloride, Hardness and dissolved oxygen.

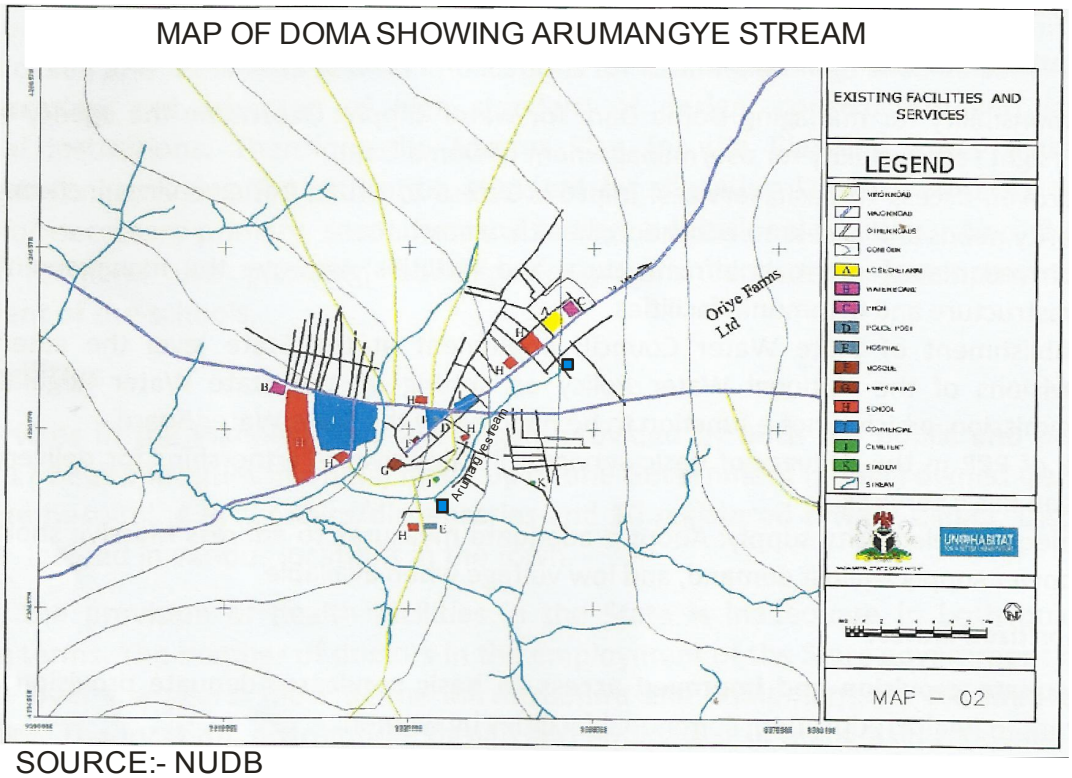

Fig. 1. Map of Doma showing River Arumangye

2.2.3 Quantification of soil heavy metal contamination/pollution index (MPI)

The quantification of pollution index was derived by adopting the pollution index of heavy metals in soil as defined by [13]

$$MPI = \frac{CMS}{CMRS}$$

Where MPI is metal pollution index, CMS is concentration of metal in the soil and CMRS is the concentration of metals in reference soil.

2.2.4 Soil analysis

2.2.4.1 Digestion method

In order to estimate the total heavy metal content, soil samples were digested in (3:1, hydrochloric acid + nitric acid) at 150°C for 2 hours. The digested samples were cooled and filtered through Whatman No. 1 filter paper and then the volumes were made up to 50 ml using volumetric flasks. Metal analyses of all the digested soil samples were carried out by atomic absorption spectrometry (Perkin Elmer, Model No. 2380). In accordance with principles and methods previously conducted by [8].

2.2.5 Water analysis

The standard laboratory analysis of the water sample carried out for the following parameters: pH, Ammonia Nitrogen, Nitrite Nitrogen, carbon dioxide, chloride, Hardness, and Dissolved oxygen.

3. RESULTS

3.1 Riverbank Soil Pollution Index

The study revealed that the riverbank soil was contaminated with heavy metals (Table 1). The largest quantity of heavy metal present was Nickel (5.46 mg/kg) followed by Iron (5.04 mg/kg), Manganese (1.66 mg/kg), Cadmium (1.15 mg/kg), Cupper (0.65 mg/kg), Zinc (0.64 mg/kg) and least was Lead (0.16 mg/kg). These metal increases in ascending order in the soil as follows: Pb < Zn< Cu < Cd< Mn < Fe < Ni. However, the riverbank soil pollution index showed a reverse trend as follows: Mn < Ni< Zn < Cd< Pb < Cu < Fe. The metal pollution index (MPI) of all the heavy metal in riverbank soil fall within the range of 1.1-2.0 on (Table 2). This means that the soil is slightly polluted with heavy metal and may constitute a positive risk on the plant and the environment.

Table 1. Content of heavy metals and metal pollution index for riverbank soil of River Arumangye

Heavy metal	Metal content (mg/kg)		MPI
	Riverbank soil	Control soil	
Cd	1.15	0.68	1.69
Cu	0.65	0.38	1.71
Fe	5.04	2.58	1.95
Mn	1.66	1.23	1.35
Ni	5.46	3.98	1.78
Pb	0.16	0.09	1.37
Zn	0.64	0.41	1.56

MPI= metal pollution index

Table 2. Interval of pollution index of heavy metals in soil and its significance

MPI	Significance	Remark
< 0.1	Very slight contamination	No positive effect on soil, plant and environment
0.10 – 0.25	Slight contamination	’
0.26 – 0.5	Moderate contamination	’
0.5 – 0.75	Severe contamination	’
0.76 – 1.00	Very severe contamination	’
1.1 – 2.0	Slight pollution	Will pose a positive effect on soil, plant and environment
2.1 – 4.0	Moderate pollution	’
4.1 – 8.0	Severe pollution	’
8.1 – 16.0	Very severe pollution	’
> 16.0	Excessive pollution	’

Adapted from [13]

3.2 Physico-chemical Properties of the Water

The result of water analysis of river Arumangye is presented on Table 3. The pH Value of water from river Arumangye from the three sampling points presented a different pH values. The downstream had a pH value of 6.45 which is slightly acidic than the upstream of pH value of 8.12 (more alkaline), while the midstream (dumpsite) pH value was 7.02. The WHO standard for a good drinking water is pH value of 7.0-8.5. Also, ammonia nitrogen concentration on the downstream is high with a value of 0.64 mg/l, which is higher than the upstream (0.40 mg/l)and the midstream (dumpsite) value of ammonia nitrogen is also 0.49 mg/l; which is lower than the WHO standard value of 0.5 mg/l ammonia. The same trend was also observed in the concentration of chloride in the water of river Arumangye. The upstream had a small quantity of 23.00 mg/l chloride, dumpsite sampling point had 24.00 mg/l of chloride compound and the downstream recorded the highest concentration of 28.80 mg/l of chloride. A reverse trend was observed in the distribution of dissolved oxygen in river Arumangye, where the upstream had a larger quantity of 3.80 mg/l of oxygen, midstream (dumpsite) had 2.10 mg/l of oxygen and the downstream had a concentration of 1.90 mg/l of dissolved oxygen. The carbon dioxide concentration was more on the (midstream) dumpsite (27.62 mg/l) sampling point compare to the upstream (18.67mg/l) and downstream (18.69 mg/l) sampling point. The water hardness of river arumangye was less at the upstream (20.00 mg/l), while at the midstream (dumpsite) sampling point it became 23.00 mg/l and increases again at the downstream to 25.00 mg/l.

4. DISCUSSION

The relative increased in the heavy metal concentration in the riverbank soil compared with the control soil may be as a result of

Table 3. Physico-chemical properties of the water

Parameters	WHO (standard)	mean	Mini	Maxi	SD	SE	% CV
Up stream							
pH	7.0 – 8.5	8.12	7.01	10.87	1.90	0.63	27.77
Temperature (O^C)		28	26	30	1.07	0.70	2.76
Ammonia nitrogen (mg/l)	0.5	0.40	0.20	0.80	0.19	0.06	38.85
Nitrite nitrogen (mg/l)	0.1 – 3	0.05	0.03	0.05	0.02	0.01	34.64
Dissolved Oxygen (mg/l)	6 – 8	3.80	1.00	5.00	0.97	0.39	41.50
Carbon dioxide (mg/l)	20.00	18.67	16.00	29.00	4.44	1.48	20.51
Chloride (mg/l)	32.00	20.00	19.00	28.00	3.87	1.92	13.87
Water hardness (mg/l)	20.00	22.00	18.00	30.00	1.87	1.29	16.14
Alkalinity (mg/l)		11.62	10.50	12.23	0.67	0.22	5.75
Mid stream (dumpsite)							
pH	7.0 – 8.5	7.02	6.21	9.87	1.00	0.45	29.23
Temperature (O^C)		28	26	30	1.07	0.70	2.76
Ammonia nitrogen (mg/l)	0.5	0.49	0.23	0.89	0.12	0.04	45.95
Nitrite nitrogen (mg/l)	0.1 – 3	0.03	0.01	0.05	0.02	0.04	38.14
Dissolved Oxygen (mg/l)	6 – 8	2.10	1.00	4.00	0.23	0.29	49.20
Carbon dioxide (mg/l)	20.00	27.62	15.00	29.00	2.41	1.27	25.55
Chloride (mg/l)	32.00	24.00	20.00	35.00	3.23	1.21	36.87
Water hardness (mg/l)	20.00	23.00	21.00	34.00	3.84	1.29	16.14
Alkalinity (mg/l)		10.03	9.30	11.21	0.17	0.24	4.85
Downstream							
Ph	7.0 – 8.5	6.42	6.02	8.82	1.20	0.43	26.25
Temperature (O^C)		28	26	30	1.07	0.70	2.76
Ammonia nitrogen (mg/l)	0.5	0.64	0.30	0.90	0.12	0.07	48.64
Nitrite nitrogen (mg/l)	0.1 – 3	0.04	0.01	0.05	0.04	0.05	39.21
Dissolved Oxygen (mg/l)	6 – 8	1.90	1.00	4.00	0.42	0.21	51.10
Carbon dioxide (mg/l)	20.00	18.69	16.00	28.00	3.41	1.34	27.81
Chloride (mg/l)	32.00	28.80	20.00	34.00	3.32	1.19	36.24
Water hardness (mg/l)	20.00	25.78	23.00	36.00	2.17	1.21	16.14
Alkalinity (mg/l)		9.25	8.70	10.29	0.62	0.32	5.45

WHO, 2004 [14]

decomposition and subsequent released of all kinds of elements from these materials that were dumped on this dumpsite [15]. The heavy metals (Nickel) that had the highest concentration (5.46 mg/kg) in the riverbank soil had one of the lowest heavy metal pollution indexes of 1.37. Iron was also one among the largest heavy metal present in the riverbank soil. This may be attributed to the fact that there were large presences of scrap iron bodies of wore out vehicles and other accessories that were gradually decomposing and releasing their leachates to pollute the soil environment [16]. However, some of these heavy metals (Fe, Cu, Zn, Mn) at a micro level in the soil are also beneficial to the growth and yield of crops. Therefore, in crop production; they are not regarded as agents that contaminate the soil; but a micro-nutrient that improves growth and yield of crops [12]. Copper at 1.5mgkg^{-1} when added to the soil in pot experiment was able to produced the best in terms of growth and yield parameters of wheat [17].

The water of river Arumangye showed increased acidicity from the upstream to the downstream; the same was also observed ammonia nitrogen. This may be as a result of decomposition of materials at the dumpsite and subsequent released of hydrogen ions [18]. The hardness of water increased when the water passed through the dumpsite to the downstream. This may be attributed to the fact that elements like magnesium, calcium that were released by the decomposed materials on the dumpsite reacted with the hard water and subsequently increased it hardness [19]. The reduction in dissolved oxygen may be as a result of increased in the activities of microorganism in the midstream where the dumpsite is located through the downstream. This is in tandem with the result obtained by [20], when they were studying the impact of industries on the water quality of River Ona and River Aloro in Oluyoke Industrial Estate, Ibadan, Nigeria.

5. CONCLUSION

The results of this research showed that the waste dump in river Arumengye contributed in polluting the riverbank soil with heavy metals. The water quality of river Arumangye is still good for consumption; since most of parameters assessed are within WHO minimum standard requirement of water.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20686