The Impact of Cassava Wastewater from Starch Processing Industry on Surrounding Soil: A Case Study of Matna Foods Industry, Ogbese

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Abstract—This study is aimed at determining the impacts of indiscriminate disposal of processed cassava wastewater into the environment by determining the physicochemical characteristics of the wastewater and soil characteristics within the vicinity of starch processing industry. The cassava wastewater quality was tested in accordance with the standard methods for the examination of water and wastewater while soil samples was analyzed using Atomic Absorption Spectrometer. The result of cassava wastewater shows that the effluent is acidic with pH of 3.8 and high conductivity of 6500µΩ. The cyanide content is also very high with 0.17mg/l as compared to 0.05mg/l recommended by WHO. The total solid, total dissolved solid and total suspended solid are also in high range of 20619, 17048 and 3571 mg/l respectively. Its hardness is 812mg/l, chloride 2516mg/l and nitrate 470mg/l. The dissolved oxygen was not detected while COD and BOD were also on the high side with values of 560 and 1410mg/l respectively. The results of soil analysis indicates that the cyanide concentration is high at the surface but reduces with depth. The pH is also in acidic range. However, Magnesium, Sodium, Sulphate, Zinc, Chromium, Vanadium, Europium and Rubidium were not detected in the soil samples. The percentage of calcium, potassium, copper, manganese and titanium were small and varying between 0.07 and 6.37ppm. Three unlined aerobic ponds provided for the treatment of cassava wastewater reduces the pollution strength of the wastewater but the untreated wastewater interfere with the surrounding soil during conveyance to the pond as well as pond environment. It is recommended that the wastewater conveyance and ponds should be well designed to prevent interference with the surrounding soil.

Keywords—Cassava, wastewater, Pollution and Soil

1 INTRODUCTION

Environmental pollution is considered to be one of the most dangerous hazards affecting both developing and developed countries. Most of our water bodies have become polluted due to industrial growth; urbanization and man-made problems resulting from population growth. Poor sanitation and contaminated drinking water arising from human activity and natural phenomena create serious problems in human health. The chief sources of water pollution are sewage and other wastes, industrial effluents, agricultural discharges and industrial wastes from chemical industries, fossils fuel plants and nuclear power plants. They create a larger problem of water pollution rendering water unfit for drinking, agriculture irrigation and, as well as toxic to aquatic plants and animals.

The threat to human and aquatic lives posed by industrial liquid and gaseous effluents cannot be over-emphasized. Industries have long been implicated in the discharge of toxicants in the environment. Industrial pollution has been identified as priority environmental problem, which must be halted without delay before disastrous health and irreversible environmental problem occurs. The production of waste cannot be totally eliminated and the disposal of waste is a necessity. Jordao et al. (2002) assessed river water in the state of Minas Gerais in Brazil that receives both domestic and industrial sewage. Their report showed that the suspended particles in the river was high in zinc and aluminum concentrations while the vegetation samples collected near rivers were heavily contaminated with iron. Also, the three fishes examined were contaminated with chromium.

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In the same vein, Jordao et al. (2007) also reported that TurvoLimpo River basin which receives effluent from domestic activities have its water characteristic far higher than the recommended Brazilian environmental standards limit. Khan et al. (2011) assessed the concentration of heavy metal toxicants in the roadside soil along the N-5 National highway, Pakistan. The results revealed that the non-point source of heavy metal contamination is from vehicular traffic while the unregulated incineration and dumping sites of hazardous waste material along the highway were also responsible for point source contaminations. Further research by Khan and Kathi (2014) on heavy metal and petroleum hydrocarbon contamination of roadside surface soil from a site in close proximity to automobile repair workshop and agricultural field revealed that sampling sites in the proximity to automobile workshops were considerably polluted as compared to soil from agricultural fields along highways. This suggests a direct influence of anthropogenic activities on levels of contamination.

Li et al (2012) reported that the total petroleum hydrocarbons pollution in the agricultural soils near petrochemical complex in Guangzhou, China is largely due to accidental explosions or burning accidents in the area. Suggestion were made that regular monitoring and inspection should be conducted for safety and to avoid or minimize the accidents while necessary measures should be taken to remediate the contaminated areas. In the same vein, Adeniyi and Owoade (2010) also studied the total petroleum hydrocarbons (TPH) and trace metal in roadside soils along the Lagos-Badagry expressway, Nigeria and reported that the sites studied have higher levels of TPH and metals compared to the control soil samples.

Malik et al. (2010) carried out investigation on the level and sources of metal contamination of surface soils in industrial city Sialkot, Pakistan which is known worldwide for tanneries and pharmaceutical industries using a multivariate and GIS approach. The results indicated that the concentration of metals measured in urban soil exceeded the permissible limit of surface soils and advocated an imperative need for detailed baseline investigations of spatial distribution of heavy metals.

Also, Mahanta and Bhattacharyya (2011) reported the results of the assessment of heavy metals carried out in urban soil of Guwahati City, India from 31 sites of five different land use types covering residential, commercial, industrial, public utilities, and roadside. The results showed that there was a significant variation in the heavy metals present in different land use type.

Okonkwo amdMothiba (2005) studied trace metals in surface water from three South Africa rivers as a mean of assessing their level of toxicity to aquatic organisms. The concentration ranges of all the metals measured were found to be below the international guidelines and acceptable concentrations for drinking water except the values for Cadmium (Cd) and lead (Pb).Onyeike et al. (2002) also investigated the inorganic ion concentrations in soils and streams of three locations affected by crude oil spillage in Ogoni land, Nigeria. Their results showed that the inorganic ion concentrations of polluted soils and streams varied significantly in the three locations. Although the concentrations of most of the anions and cations analyzed in the polluted soils and streams were within the World Health Organization's permissible values for the protection of humans and environment, the studied streams are general being polluted with inorganic ions. This make the studies soils and streams unacceptable for domestic and industrial uses if not treated, and soils (farmlands) may also become unsuitable for agricultural purposes.

Cassava (Manihotesculentacrantz) is a staple food crop in many areas of the tropics. The processing of cassava into starch involves several unit operations which include washing, grating, grinding, sieving, de-colourization, pressing and drying. Starch production makes use of large volume of water which results in discharge of large amount of wastewater. Wastewater from starch processing factory contains cellulose carbohydrate, nitrogenous compounds and cyanoglycosides. Cyanogens and glycosides are easily hydrolyzed into hydrogen cyanide which is toxic to aquatic animals and pose serious threat to the environment (Abiona 2005).

Boadi et al. (2008) specifically observed that raw cassava and its peels containsbetween 114.7 to 159.6 and 360.05 to 509.51 mg/kg of cyanide, respectively. Flynn and McGill (1995) also assessed the cooked cassava cyanide to be 6.79 to 24.91 mg/kg.The cyanide contents of the cassava contaminate the soil mainly during processing as reported by Oboh and Akindahunsi (2003).

The aim of this research is therefore to investigate the impact of cassava wastewater on the surrounding soils and the level correlation of cyanide to other heavy metals in the soil as well as determine the efficacy of the unlined channels and ponds to convey and treat cassava wastewater.

2 MATERIALS AND METHODS

2.1 Description of the Study Area

Matna Foods Company Limited is a Nigerian manufacturing outfit, incorporated to process cassava roots into International Standard Food Grade Industrial Starch and allied products. The factory is located at Ogbese in the heart of the cassava producing area of Akure (7o15'North and on longitude 5o15' East) in Ondo State of Nigeria commenced full production in 2002 (Figure 1). The factory commenced operations in 2002 with an installed capacity of 120tons of cassava per day. However, in 2014, production of the company is put at 80tons per day (it makes use of 2 shifts per day with each shift handling 40tons of cassava per day). Water usage in the factory was put at 24000liters/hour (i.e. 384m3/day). This water usage starts from washing of cassava roots through the entire production processes.With this water usage, the amount of wastewater generatedis enormous and the impact on the environment could be highly devastating if not properly handled.

The cassava wastewater is channeled through an unlined open channel drain into anunlined three ponds arranged in series and located at approximately 250m from the

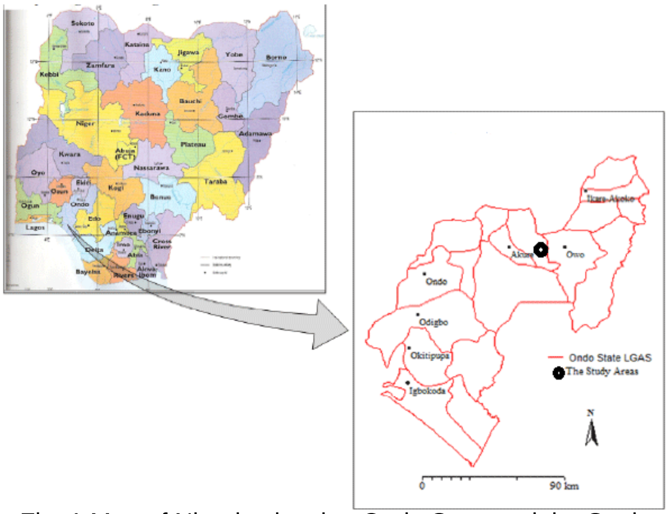

Fig. 1.Map of Nigeria showing Ondo State and the Study Area

factory site. The pond is to biologically stabilize the wastewater before final disposal into a flowing river Ogbese nearby. This work is aimed at investigating the efficacy of this type of system in combating environmental pollution of soil.

2.2 Samples Collections

2.2.1 Cassava Wastewater Samples

Three random samples by volume of cassava wastewater were collected at quick succession in a day operationand pooled together to give a composite sample. Composite samples were collected periodically (one sample per week for three weeks) in accordance with the prescribed standard methods for the examination of water and wastewater (APHA, 1989).All samples were preserved using a cooler filled with granular ice block. This was to make the activities of microorganisms present in the sample inactive before getting to the laboratory. Samples were analyzed within 12 - 24hrs of collection. The physicochemical parameters (temperature,total solid, total dissolved solid, total suspended solid, pH, conductivity, hardness, BOD5, COD, alkalinity, dissolved oxygen, cyanide, nitrate, chloride, odor and color) of the samplewere determined in accordance with Standard Methods for the Examination of Water and Wastewater (APHA1989). Nitrate, conductivity and pH were measured using Hana instrument while the temperature was determined in-situ using mercury in bulb thermometer inserted into the wastewater sample and allowed to stay for 7 minutes before reading was taken.Analyses of odor and color were done by visual inspection.

2.2.2 Soil Samples

Soil samples were taken along horizontal direction at an interval of 50m from the beginning of the unlined open channel that convey the cassava wastewater from the processing unitsto the first unlinedaerobic pond. Soil sampleswere also taken from the second and third unlined aerobic ponds at an offset of 5m from the drain and ponds as depict in Figure 2.

Vertically, soil samples were taken at top soil, 50cm and 100cm depth with the aid of hand auger (Figure 3). Clear amber coloured glass bottles previously rinsed thrice in distilled water solution and dried, were used to store the

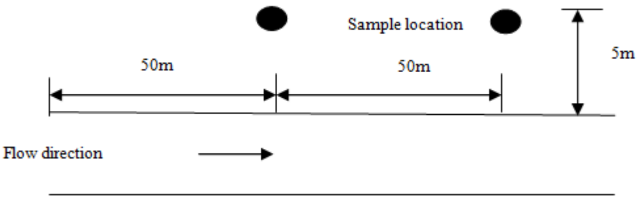

Fig. 2.Soil sample locations (Not to scale)

soil samples for laboratory analysis.Control sample was obtained from a distance of 200m on the opposite direction to the flow of cassava wastewater. Samples were air dried for seven days before they were analyzed.

The elements analyzed for were: Ca2+-calcium, Mg2+-magnesium, Na+-sodium, SO2-4-sulphate, K+-potassium, Zn-zinc, Cu-copper, Mn-manganese, Cr-chromium, Pb-lead, V-vanadium, Co-cobalt, Fe-iron, Al-aluminum, Ti-thallium, Rb-rubidium, Sr-strontium, Zr-zirconium, Eu-europium and Hf-hafnium. These analyses were carried out using the AtomicAbsorption Spectrometer (AAS) method as described in APHA (1989).

In addition to the heavy metal analysis, pH and cyanide levels of the soil samples were also determined. The cyanide was analysed by measuring 10g of the sample mixed with 50ml of distilled water and continuously shaken for about 30minutes using the electronic shaker. The solution is then filtered and the filtrate is analysed for cyanide as described by Ademoroti (1996). The pH was analysed by moistening a little of the soil sample with the distilled water and the pH was read using the pH meter.

3 RESULTS AND DISCUSSION

3.1 Cassava Wastewater

Fig. 3.Soil sample collection using hand auger.

The results of the physicochemical properties of the raw cassava wastewater are shown in Table I. The clear trend ofall measured parameters is that they are higher than the WHO recommended standards and there was no trace of dissolved oxygen.

The results of the heavy metals and cyanide for soil samplesare shown in Table 2. There weretwo clear trends of either decreasing orincreasing in amount of metals with

Table 1: Physical and Chemical Characteristics of Cassava Effluent from the Factory

Parameter	Average value of three test samples	WHO standards
Color	Colored	Colorless
Odor	Objectionable	Unobjectionable
Conductivity, μmhos	6500	3000
pH	3.8	6.5 – 8.5
Total Solid, mg/l	20619	2030
Total Dissolved Solid, mg/l	17048	2000
Total Suspended solid, mg/l	3571	30
Alkalinity, mg/l	910	100
Hardness, mg/l	812	500
Chloride, mg/l	2516.9	600
Nitrate, mg/l	470	50
Temperature, °C	27	25
Dissolved Oxygen, DO, mg/l	0	4
Chemical Oxygen Demand, COD, mg/l	560	10
Biological Oxygen Demand, BOD, mg/l	1410	10
Cyanide, mg/l	0.17	0.05

distance along the drain and soil dept.All the measured pH is in acidic region while that of control is neutral. Some elements like Magnesium, Sodium, Sulphate, Zinc, chromium and Vanadium were not detected in both polluted soil and control.

From the result of the analysis (Table 1), it can be seen that all the characteristics of the cassava wastewater analyzed exceed the allowable limits stated by WHO. The electrical conductivity of the effluent is high indicating the presence of conducting ions while the pH value showed that this effluent is acidic. World Health Organization (WHO 2004) admissible limit for pH value in effluent water is 6.5 – 8.5. The high values of pH may be attributable to the presence of prussic acid (Wikipedia 2011).

Table 2: Soil Characteristics*

Sample	pH	cyanide	Ca^{2+}	Mg^{2+}	Na^{+}	SO_4^{2-}	K^{+}	Zn	Cu	Mn	Cr	Pd	V	Zr	Fe	Al	Ti	Rb	Ge	Si	Eu	Hf
At the Point of Discharge																						
Top Soil	4.2	0.21	3.1	ND	ND	ND	0.6	ND	2.8	1.2	ND	20	ND	14	29.3	ND	1.8	ND	ND	19	ND	8.5
50 cm depth	4.9	0.19	2.1	ND	ND	ND	0.6	ND	ND	ND	ND	11	ND	5.8	53.1	ND	0.81	ND	0.6	15	ND	11
At Distance 50m from the Point of Discharge																						
Top Soil	4.3	0.21	3.2	ND	ND	ND	ND	ND	ND	0.86	ND	ND	ND	9.6	11.3	23	1.1	ND	ND	41	ND	9.4
50cm Depth	5.0	0.19	2.8	ND	ND	ND	0.2	ND	2.4	ND	ND	13	ND	7.2	20.4	18	1.4	ND	ND	28	ND	6.9
100cm Depth	5.5	0.11	1.9	ND	ND	ND	ND	ND	ND	1.3	ND	17	ND	0.5	53.6	ND	1.2	ND	ND	4	ND	1.8
At Distance 100m from the Point of Discharge																						
Top Soil	5.0	0.19	3.2	ND	ND	ND	0.9	ND	3.6	ND	ND	16	ND	16.4	33.1	ND	1.5	ND	ND	24	ND	ND
50cm Depth	5.2	0.15	ND	ND	ND	ND	ND	ND	ND	1.4	ND	ND	ND	15	30.8	ND	2.0	ND	ND	32	ND	14
100cm Depth	5.4	0.11	15.9	ND	ND	ND	4.13	ND	0.37	0.27	ND	ND	0.22	2.03	41.0	7.9	5.7	0.25	0.15	19	0.72	ND
At Distance 150m from the Point of Discharge																						
Top Soil	5.4	0.18	4.2	ND	ND	ND	1.6	ND	ND	ND	ND	15	ND	7.3	13.1	17	1.5	ND	ND	32	ND	8.4
50cm Depth	6.3	0.14	2.8	ND	ND	ND	1	ND	2.6	ND	ND	ND	ND	8.7	18.9	26	1.7	ND	ND	31	ND	7.3
100cm Depth	6.0	0.13	1.7	ND	ND	ND	1.9	ND	1.2	ND	ND	ND	ND	2.3	21.3	28	0.94	ND	ND	38	ND	4.1
At Distance 200m from the Point of Discharge																						
Top Soil	5.7	0.15	2.5	ND	ND	ND	ND	ND	1.9	ND	ND	10	ND	4.5	10.4	ND	1.5	ND	ND	65	ND	4.0
50cm Depth	6.4	0.11	2.4	ND	ND	ND	1	ND	2.3	0.96	ND	15	ND	13	32.2	ND	1.7	ND	ND	23	ND	7.6
100cm Depth	6.4	0.10	15.9	ND	ND	ND	4.13	ND	0.37	0.27	ND	ND	0.22	2.03	41.0	7.9	5.7	0.25	0.15	19	0.72	ND
At Pond 1 site																						
Top Soil	3.9	0.29	2.5	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	7.2	17	29	1.2	ND	ND	35	ND	5.4
50cm Depth	4.4	0.28	ND	ND	ND	ND	ND	ND	ND	1.8	ND	ND	ND	0.3	56.7	ND	1.7	ND	ND	4	ND	23
100cm Depth	4.9	0.20	2.2	ND	ND	ND	0.6	ND	2	ND	ND	ND	ND	7.0	23.1	26	1.3	ND	ND	31	ND	6.2
At Pond 2 site																						
Top Soil	5.0	0.18	2.1	ND	ND	ND	0.6	ND	ND	0.5	ND	ND	ND	11.3	17.8	26	ND	ND	1.4	28	3	7.2
50cm Depth	5.6	0.14	2.5	ND	ND	ND	1.4	ND	1.7	0.76	ND	12	ND	14.4	22.5	13	2.0	0.67	1.5	22	ND	4.5
100cm Depth	6.1	0.10	3.3	ND	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND	48.3	ND	2.0	ND	ND	14	ND	30
AtPond 3 site																						
Top Soil	6.2	0.10	3.5	ND	ND	ND	2	ND	ND	ND	ND	22	ND	11	10.4	ND	2	ND	ND	37	ND	10
50cm Depth	6.7	0.07	3.6	ND	ND	ND	1	ND	2.8	ND	ND	23	ND	16	11.4	ND	2.1	ND	1.5	28	ND	7.7
100cm Depth	7.2	0.05	5.2	ND	ND	ND	1	ND	3.9	0	ND	ND	ND	10	9.0	ND	2	ND	ND	51	5.0	12
Control																						
Top Soil	6.6	0.06	2.6	ND	ND	ND	0.6	ND	2.4	1.6	ND	16	ND	12	37.0	ND	1.3	ND	ND	18	ND	7.9
50cm	6.9	0.05	1.8	ND	ND	ND	0.3	ND	2.1	0.91	ND	11	ND	9.0	55.5	ND	1.2	ND	ND	15	ND	7.4
100cm	7.0	0.04	2.1	ND	ND	ND	0.6	ND	1.6	0.57	ND	7.1	ND	4.3	47.6	14	0.7	ND	ND	15	ND	5.5

*All parameters are measured in part per million (ppm); ND – Not Detected

According to Ademoroti (1996), water quality is low when its dissolved oxygen is lower than 9.2mg/l and the suspended solid is higher than 9.2 ppm. Therefore, the effluent if untreated before discharge into the environment is a potential source of water pollution within the vicinity. Also the level of cyanide content was observed to be very high (about 340%) as against WHO (2004) admissible limit of 0.05 ppm.

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BOD5 is the amount of oxygen required to break down to simpler substances, the decomposable organic matter in water or effluent water; therefore, the reason for the great BOD5 value (Metcalf and Eddy, 2003). The result of the study has shown high level of micro-organisms and high value of BOD which is 1410mg/L. Also the COD is equally very high (560mg/l) showing that this effluent water contain high amount of organic matter.

Metcalf and Eddy (2003) made it known that nitrate is the most oxidized form of nitrogen found in wastewaters. Its concentration is very important in wastewater and should be very small because of its serious and occasionally fatal effects on infants.

Table 2 shows the results of the soil analysis done it can be observed that, the values of heavy metals obtained decreased as the depth of excavation increased and incase of iron (Fe), the values obtained increased with increase in excavation. Where the values decreased with depth of excavation, no much trouble is anticipated but where otherwise, heavy pollution of underground water is anticipated. From the analysis of the soil, it was observed that the cyanide concentration reduced as the depth analyzed increased, although the concentration is high showing most concentration at the point of discharge and least at pond 3.

The results of the pH analysis showed the soil to be acidic. The value of the pH increased as the depth of soil analyzed increased with variation varied from one sample point to the other. Also, there is corresponding increase in the level of the pH along the discharge path towards the ponds showing the effects of prolonged interaction with the soil. Also the soil is found to be most acidic at the point of discharged, followed by pond 1 while the least acidic place is pond 3. This is a clear indication that the pond is sufficient enough to treat the cassava effluent waste but it needs to be designed and well lined to prevent interference with the surrounding soil during transportation to the ponds.

Low pH and aluminium toxicity can cause massive kills of aquatic life, including large numbers of fish, despite the ability of mobile organisms to often avoid poor quality water. Red spot disease of fish (Epizootic Ulcerative Syndrome) has also been linked to acid water. Potassium is very important in plant growth; its deficiency affects the growth of the plant severely because it stimulates early plant growth, increases protein production, improves the efficiency of water use and improves resistance to diseases and insects. Zirconium on the other hand has health hazard only when taken into the body because only about 0.2% can be used by the body. It has the likelihood of inducing cancer.

4 CONCLUSION

The cassava wastewater characteristics shows that the values of all physicochemical parametersobtained exceed the World Health Organization Standard for industrial wastewaters and therefore should not be discharged directly into the water bodies in their surroundings.

The percentage of calcium, potassium, copper, manganese and titanium were small, varying between 0.07ppm and 6.37ppm. Vanadium, rubidium, germanium and europium were found to be infinitesimal with the most concentration found to be 1.67ppm at pond 1 and showing 0 at most of the other locations. Zirconium and hafnium have a little higher concentrations varying between 6.10ppm and 13.9ppm. Iron aluminum and silicon were with the highest concentrations having values as high as 46.6ppm, with the least of them as 10.27ppm.

All the elements analyzed for; increased in concentration with increase in depth of soil and also along the discharge path except those that were not detected. In all of the samples analysed, Magnesium ion – Mg^{2+}, Sodium ion - Na^+, Sulphate ion - SO_4^{2-}, Zinc – Zn, chromium Cr, Vanadium – V, Europium – Eu and Rubidium – Rb were not detected. The level of cyanide contamination in both cassava wastewater and soil samples is very high. This portends a grievous consequence on the underground water resources in the nearest future if urgent steps are not taken to properly convey the cassava wastewater to the aerobic treatment ponds.

5 RECOMMENDATIONS

A renewed program of action is needed to stimulate the efforts of the National and State Environmental Agencies to take steps that will result in the strict adherence of manufacturing company to the environmental laws and standards. Also penalties could be placed on defaulters or violators. Reduction of wastewater could be achieved by recycling. For instance, the wastewater discharged could be used for the cassava washing process of the operation before grating. It is also necessary that the drain that conveys the wastewater to pond must be lined to prevent interference with the surrounding soil. The ponds should also be properly designed to prevent future groundwater pollution and the pollution of the surrounding soils.

REFERENCES

Abiona, O. O., Sanni, L. and Bamgbose, O. (2005). An evaluation of microbial load, heavy metals and cyanide contents of water sources, effluent and peels from three cassava processing locations. International Journal of Food and Agricultural Environment Vol.3, 207-208

Ademoroti, C.M.A. (1996). Standard Methods for Water and Effluents Analysis. Foludex Press Limited, Ibadan.

Adeniyi A. A. and Owoade, O. J. (2010). Total petroleum hydrocarbons and trace heavy metals in roadside soils along the Lagos–Badagry expressway, Nigeria Environmental Monitoring and Assessment,Vol.167 No. (1-4), 625-630

American Public Health Association (1989).Standard Method for the Examination of Water and Wastewater. American Water Work Association and Water Environment Federation, 22nd Edition, Washington D. C.

Boadi, N. O., Twumasi, S. K. and Ephraim, J. H. (2008).Impact of Cyanide Utilization in Mining on the Environment. International Journal Environmental Research,Vol.3 No.1, 101-108.

Flynn, C. M. and McGill, S. L. (1995). Cyanide Chemistry-Precious Metals Processing and Waste Treatment. U.S. Bureau of Mines, NTIS Pub., pp. 96-117841

Jordao, C. P., Pereira, M. G., Belalato, C. R., Pereira, J. L. and Matos, A. T. (2002). Assessment of water systems for contaminants from domestic and industrial sewages, Environmental Monitoring and Assessment,Vol.79 No.1, 75 – 100

Jordao, C. P., Ribeiro, P. R. S., Matos, A. T., Bastos, R. K. X., Fernandes, R. B. A. and Fontes, R. L. F. (2007). Environmental Assessment of water courses of the TurvoLimpo River basin at the Minas Gerais state, Brazil,Environmental Monitoring and Assessment,Vol.127 No.1-2, 315 – 326

Khan, A. B. and Kathi, S. (2014). Evaluation of heavy metal and total petroleum hydrocarbon contamination of roadside surface soil,International Journal of Environmental Science and Technology,Vol.11 No.8, 2259-2270.

Khan, M. N., Wasim, A.A., Sarwar, A and Rasheed, M. F. (2011). Assessment of heavy metal toxicants in the roadside soil along the N-5, National Highway, Pakistan, Environmental Monitoring Assessment,Vol.182 No.1-4, 587-595

Li, J., Zhang, J., Lu, Y., Chen Y., Dong, S. and Shim, H. (2012). Determination of total petroleum hydrocarbons (TPH) in agricultural soils near a petrochemical complex in Guangzhou, China, Environmental Monitoring and Assessment,Vol.184 No.1, 281-287

Mahanta, M. J. and Bhattacharyya, K. G. (2011). Total concentrations, fractionation and mobility of heavy metals in soils of urban area of Guwahati, India, Environmental Monitoring and Assessment,Vol.173 No.1-4, 221-240

Malik, R. N., Jadoon, W. A. and Husain, S. Z. (2010). Metal contamination of surface soils of industrial city Sialkot, Pakistan: a multivariate and GIS approach,Environmental Geochemistry and HealthVol.32 No.3, 179-191

Metcalf and Eddy Inc., Tchobanoglous, G., Burton, F.L. and Stensel, H.D. (ed.) (2003).Wastewater engineering; treatment and reuse, McGraw-Hill, New York.

Oboh G and Akindahunsi, A. A. (2003). Chemical changes in cassava peels fermented with mixed culture of Aspergillusniger and two species of Lactobacillus in integrated bio-system,Applied Tropical Agriculture, Vol.8 No.2, 63-68.

Okonkwo, J. O. and Mothiba, M. (2005).Physico-chemical characteristics and pollution levels of heavy metals in the rivers in Thohoyandou, South Africa,Journal of Hydrology,Vol.308 No.1-4, 122- 127

Onyeike, E. N., Ogbuja, S. I. and Nwinuka, N. M. (2002). Inorganic Ion Levels of Soils and Streams in some Areas of Ogoni land, Nigeria as Affected by Crude Oil Spillage, Environmental Monitoring and Assessment,Vol.73 No.2, 191 – 204.

World Health Organization (WHO), (2004). Maximum Allowable Concentration of Selected Water Quality Variables.

Wikipedia, free online Encyclopaedia (2014).Wastewater. From http://en.wikipedia.org/wiki/Hydrogen_cyanide.Accessed15th August, 2014.