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IMPACT ASSESSMENT OF LIQUID WASTE FROM SOAP MAKING INDUSTRY ON YINGI RIVER JOS NIGERIA

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ABSTRACT

The impact of pollution on the environment requires activities to forestall adverse effects, by the use of various approaches including approaches to predict the effects of pollutants on the environment, determine measures to mitigate the adverse effects and promote the beneficial activities. This research conducted water quality analysis on river Yingi, in Jos, the capital of Plateau State in Nigeria by the assessment of the stream water quality after the effluent from soap industry is disposed into the water body to determine level of pollution in water. Physical, chemical and bacteriological parameters were analyzed, results show that the value of the Biochemical Oxygen Demand of 325mg/l for the polluted water samples at the point of discharge of effluent into the surface water indicates high organic loading into the water body. The average Total Suspended Solids value of 156.44mg/l was reduced to 75.33mg/l at second sampling point, while Total Dissolved Solids value of 679.2mg/l was reduced to 230.25 mg/l by the self purification of the water body; however, there is still need for further treatment to meet standards for various uses. Sodium Absorption ratio of 15.80 shows that the surface water does not meet requirement for use in irrigation purposes. Waste stabilization ponds were designed to reduce the strength of the effluent to a maximum of 25mg/l of Biochemical Oxygen Demand before disposal into the surface water.

Keywords: pollution, effluent, wastes disposal, soap industry, water quality parameters.

INTRODUCTION

Indiscriminate nature of waste disposal and unsustainable waste management methods has been a major challenge in the country due to industrialization and increase in urbanization (Anikwe and Nwobodo, (2002), it is noted that environmental problems are increasing due to industrial pollution from waste generation, disposal of municipal solid waste and biodegradable petrochemical products (Amoo and Fangable, 2013). There has been a wide spread of pollution of rivers, stream, lakes and lagoons with the impact of a high incidence of water related diseases in communities, (FMAWR, 2008), the cholera outbreak in 2009 in communities in Northern Nigeria claimed about 260 lives (Adagbda *et al*, 2012). Air, water and food which are the basic essentials of life are most easily polluted by wastes from various sources (Saxena and Sharma, 2017), although fresh water has a high economic value, the quality fresh water is as an indispensable natural resource as itemized in the Dublin's principles (United Nations, 1992) must be preserved.

The impact of pollution on the environment requires activities to forestall adverse effects, by the use of various approaches (Streatfield and Markless, 2009), including approaches to predict the adverse effects of pollutants on the environment, determine measures to mitigate the adverse effects and promote the beneficial activities. Environmental pollution is defined as "the contamination of the physical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected (Muralikrishna, I. and Manickam, V. 2017) caused by various human activities including commercial and industrial activities and assessed by the impact on the following:

a) Biotic element:- such as all living organisms. This includes the human, the micro and macro fauna and floral that makes up the ecosystem specifically fish life and any form of water plant.
b) Abiotic element such as the air quality, water, soil, oxygen
c) Economic impacts
d) Cultural Impacts
e) Aesthetics factors
f) Political factors
g) Social impacts which includes displacement of people, impacts on privacy, impacts on public and private services.

Impact assessment is thus used to:

a) Predict adverse effects of pollutants on the environment
b) Determine measures to mitigate the adverse effects
c) To promote the beneficial activities (Agunwamba, 2001).

It has been shown by research that in developing countries, waste stream is over 50% organic material (Ogwueleka, 2009) due to the high organic loading water bodies receive, rivers are among the most vulnerable water bodies subjected to pollution due to the availability of rivers in carrying municipal and industrial wastes and runoffs from agricultural lands in drainage basins (Kemetse, 2017), anaerobic digestion of the wastewater before disposal into surface water has been shown to limit negative impacts on surface water bodies. (Edward *et al*, 2013). Waste water that infiltrates to ground water table results in contamination of the groundwater, groundwater resource is a major source of domestic water supply, the high dependence on groundwater places undue pressure on this resource (Omole, 2016), therefore, the need to protect this resource from contamination via the disposal of wastewater.

Nutrients and trace elements in animal manure can accumulate in the soil at over bearing quantities and become toxic to plants, the area of influence not limited as water movement in soil occurs, increasing the radius of impact (Ruslan, 2015), treatment to reduce the concentration of pollutants to the level where discharge will not adversely affect the environment is therefore required (Nduka *et al*, 2007). Particulate matter in the air also affects human, the effect of particulate matter depends on their chemical composition and particle size, fine particles linger in the atmosphere for a longer time and penetrate the human respiratory tract more easily (Agu, 2014). Other indirect impacts include ecosystem destruction and biodiversity erosion, limiting the ability of the earth's atmosphere to absorb greenhouse gas emissions (Dunlap and Jorgerson, 2012), these various impacts on the environment requires the proffering of solution to some of the existing problems in our environment.

This research was carried out by conducting water quality analysis on river Yingi, in Jos, the capital of Plateau State in Nigeria, the contaminant loading on the stream water quality after the effluent from the soap industry is disposed into the water body was assessed, mitigating measure were proffered by the design of stabilization ponds with the capacity to treat effluent from soap industries to acceptable limits.

METHODOLOGY

Plateau State is located in the North-Central part of the Nigeria; Plateau State capital, Jos, is located on latitude 9.93 degrees North and longitude 8.89 degrees West, the State's total land area covers about 26,899 square kilometers (FMAWR, 2008).

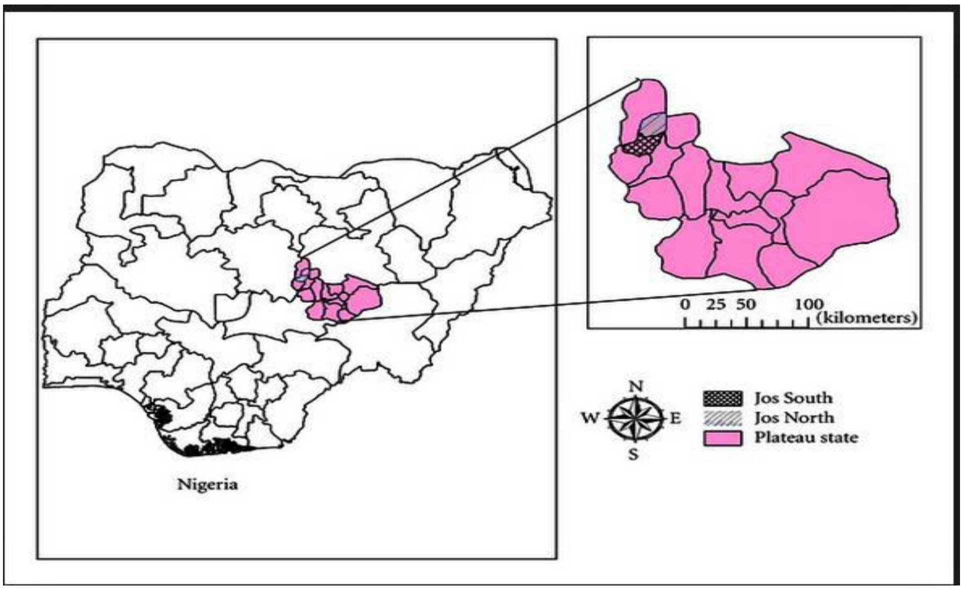

Figure-1. Map of Nigeria showing location of plateau state.

The mean annual rainfall varies from 131.75 cm (52 in) in the southern part to 146 cm (57 in) on the Plateau. The highest rainfall is recorded during the wet season months of July and August. The State has a population of about 3.5 Million people (NBS, 2015) and the name Plateau State was derived from the Jos Plateau, the Plateau is a tourist attraction and the environmental impact of activities in the State is of international concern, which forms the basis of this research.

Surface water samples were collected from river Yingi where the industrial effluent is disposed. Five samples from the two sampling locations were collected for water quality analysis; Location 1: point of discharge of industrial effluent into surface water body designated as Sampling Point 1(SP1), Location 2: 500m away from point of discharge where no other critical activity affects the water body, designated as Sampling Point 2 (SP2) The sampling equipment, procedure and techniques used in the water quality analysis were based on the American Public Health Association (APHA) Standard Methods for the Examination of Water and Wastewater (APHA, 1999). The following samples were collected:

a) Polluted Surface Water (PSW) Samples from the SP1.
b) Polluted Surface Water (PSW) Samples from the SP2.
c) Soil solution samples (SS sample), from land surface bordering the SP1.

Laboratory tests conducted include the physical, chemical and biological/ bacteriological quality parameters as follows:

Physical parameters - Suspended Solids, Total Dissolved Solids, Electrical Conductivity and pH;

Chemical parameters - Copper, Calcium, Magnesium, Sodium, Chromium, Lead, Arsenic, Boron, Potassium, Cadmium and Phosphorous.

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Biological/ Bacteriological parameters: Bio-chemical Oxygen Demand (BOD) and Feacal Coliform Count.

Reaction rate constant (K) for the water samples were determined by collecting 24 hourly values of oxygen consumption from samples during to the BOD experiment, values obtained were used to plot $(t/BOD)^{1/3}$ against time (days) from equation (1) required for design purposes.

$(t/BOD)^{1/3} = (KLo)^{-1/3} + t(K^{2/3}/6Lo^{1/3})$ ………(1)

Where $(KLo)^{-1/3}$ is the intercept on the y-axis and $K^{2/3}/6Lo^{1/3}$ is the slope, t = time, K is the reaction rate constant and Lo is the ultimate BOD of water sample

RESULTS

Results obtained from samples are presented in tables 1 to 12:

Table-1 presents results of Chemical Analysis from collected samples, average values were determined from the five samples collected per point.

Table-1. Results of chemical analysis-average values for samples from SP1, SP2 and SS.

Elements	Symbols and units	Average values for samples from SP1	Average values for samples from SP2	Soil solution sample (SS)	WHO standards for drinking water quality
Copper	Cu - mg/l	0.01	0.00	1.50	2.00
Calcium	Ca - mg/l	14.8	0.00	2.63	No health based guideline values
Magnesium	Mg - mg/l	26.8	0.00	0.79	No health based guideline values
Sodium	Na - mg/l	52.1	47.3	43.0	200
Chromium	Cr - mg/l	0.01	0.01	7.26	0.05
Lead	Pb - mg/l	0.05	0.00	12.02	0.01
Arsenic	As - mg/l	0.03	0.00	0.45	0.01
Boron	B - mg/l	3.25	0.45	3.60	0.5
Potassium	K - mg/l	-	-	28.6	No health based guideline values
Cadmium	Cd - mg/l	0.01	0.00	0.73	0.003
Phosphorus	P - mg/l	-	-	4.5	

Table-2 presents the average values obtained for BOD analysis on collected water samples:

Table-2. Average values of BOD from SP1 and SP2.

Sample number	1	2	3	4	5	Average value(mg/l)
BOD of Samples from SP1 (mg/l)	294	305	299	341	385	325
BOD of Samples from SP2 (mg/l)	171	191	205	165	197	186

Table-3 presents the results obtained from the 24 hourly analysis of dissolved oxygen content in collected water samples:

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Table-3. Results of oxygen consumed and average daily BOD values for calculations of reaction rate constant (K).

Time(days)	**1**	**2**	**3**	**4**	**5**
Total (Average) Oxygen Consumed (mg/l)	0.6	1.96	2.04	3.36	3.6
Average Daily BOD Values for Samples from SP2 (mg/l)	30	98.2	132	168.0	186.0
$(t/BOD)^{1/3}$	0.279	0.256	0.272	0.279	0.303

Tables 4 and 5 present the total suspended solids results for collected water samples at points 1and 2:

Table-4. Average concentration of total suspended solid (TSS) for samples from SP1.

Sample No.	**Weight of paper** (mg)	**Weight of paper + Solid** (mg)	**Volume of sample** (ml)	**TSS** (mg/l)	**Mean TSS** (mg/l)
1	0.7	47.5	300	156.0	156.44
2	0.8	47.87	300	156.90	
3	0.9	47.36	300	154.87	
4	0.8	48.20	300	158.00	

Table-5. Average concentration of total suspended solid (TSS) for samples from SP2.

Sample No.	**Weight of filter paper** (mg)	**Weight of paper + Solid** (mg)	**Volume of sample** (ml)	**TSS** (mg/l)	**Mean TSS** (mg/l)
1	0.7	23.40	300	75.67	75.33
2	0.9	23.34	300	74.80	
3	0.6	23.30	300	75.67	
4	0.8	23.35	300	75.17	

Results obtained for the total dissolved solids content of collected water samples are presented in Tables 6 and 7:

Table-6. Average concentration of total dissolved solid (TDS) for samples from SP1.

Sample No.	**Weight** (mg) **of paper** (B) (gm)	**Weight of paper + Solid A** (gm)	**Volume of sample** (ml) **C**	**TDS** (mg/l)	**Mean TDS** (mg/l)
1	0.8	204.8	300	680.0	679.2
2	0.7	204.64	300	679.8	
3	0.8	204.2	300	678.0	
4	0.9	204.6	300	679.0	

Table-7. Average concentration of total dissolved solids (TDS) for samples from SP2.

Sample No.	**Weight** (mg) **of paper** (B) (gm)	**Weight of paper + Solid A** (gm)	**Volume of sample** (ml) **C**	**TSS** (mg/l)	**Mean TSS** (mg/l)
1	0.7	71.35	300	235.5	230.25
2	0.6	68.4	300	226.0	
3	0.6	69.3	300	229.0	
4	0.8	69.95	300	230.5	

Results for the micro-biological analysis of water samples are presented in Tables 8 and 9:

Table-8. Average values obtained for Faecal Coliform (FC) for water samples from SP1.

Sample No.	Dilution	FC/100ml	Average value FC/100ml
1	$1/10^5$	1×10^6	2.7×10^5
2	$1/10^6$	3×10^5	
3	$1/10^7$	5×10^4	
4	$1/10^8$	2×10^3	
5	$1/10^9$	1×10^3	

Table-9. Average values obtained for Faecal Coliform (FC) for Water Samples from SP2.

Sample No.	Dilution	FC/100ml	Average value FC/100ml
1	$1/10^5$	1×10^5	2.1×10^4
2	$1/10^6$	3×10^3	
3	$1/10^7$	2×10^4	
4	$1/10^8$	4×10^3	
5	$1/10^9$	1×10^3	

The electrical conductivity of the water samples was determined and the results are presented in Table-10:

Table-10. Mean value of electrical conductivity test ($\mu\Omega^{-1}$ cm^{-1}).

Samples	1	2	3	4	5	Mean
Samples from SP1	25.2	24.9	24.81	25,0	25.1	25.0
Samples from SP2	20.9	21.6	22.5	22.1	22.9	22.0

Table-11 presents the pH and ambient temperature of samples from points 1 and 2:

Table-11. pH and ambient temperature of SP1 and SP2.

Samples	pH valsue	Temperature °C
Samples from SP1	7.45	27.1
Samples from SP2	9.73	26.3
SSsample	9.90	

Results obtained from the analysis of the organic carbon, nitrogen content from soil sample is presented in Table-12, this table also presents the calculate Sodium Absorption Ration (SAR) from water samples from points 1 and 2:

Table-12. Results of organic carbon, nitrogen content and sodium absorption ratio.

Percentage organic carbon in soil sample	7%
Percentage Nitrogen Content in Soil sample	0.16%
SAR – Samples from SP1	15.80
SAR – Samples from SP2	11.42
SAR SS	32.90

DISCUSSION OF RESULTS

Chemical analysis of the water samples and soil sample presented in Table-1 shows that the chemical values of Lead, Arsenic, Boron and Cadmium for water samples from SP1 were above the required limits required by standards for drinking water quality, impact of waste generation in the vicinity can lead tochemical pollutants in water (Ibitola *et al,* 2011, Oyelami *et al*, 2013), the need of protection of water sources from pollution is therefore paramount (Cairncross and Feachem, 2005). Values of the Biochemical Oxygen Demand (BOD) from Table-2 show that the value of the Biochemical Oxygen Demand (BOD) of 325mg/l for water samples from SP1 indicates high organic loading into the water body, removal of organic content from water source is critical before domestic use. Table-3 presents daily values obtained for oxygen consumed to determine the reaction rate constant K for the samples. Tables 4 to 7 present results obtained of the Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) for samples from SP1 and SP2, average TSS value of 156.44mg/l for SP1 was reduced to 75.33mg/l at SP2, while TDS value of 679.2mg/l at SP1 was reduced to 230.25 mg/l at SP2 by the self purification of the water body, however, there is still need for further treatment to meet standards for various uses. The removal of these pollutants from the water body is critical for domestic and industrial use; the design of a water treatment plant in this report provides required technical output for the community that depends on the water source. Tables 8 and 9 shows values of 2.7 x 10^5 and 2.1 x 10^4 Fecal Coliform /100ml for samples from SP1 and SP2 respectively as human activities alter the natural composition of water through disposal of microbial matter (Harter, 2003), these values also show the critical need to treat the water body for domestic use. Tables 10 show mean values of 25 $\mu\Omega^{-1}$ cm^{-1} and 22 $\mu\Omega^{-1}$ cm^{-1} for the electrical conductivity of samples from SP1 and SP2 respectively while Table-11 show average pH values of 7.45, 9.73 and 9.90 for samples from SP1, SP2 and soil water samples respectively, average laboratory temperature are given as 27.1 °C and 26.3 °C for samples from SP1 and SP2. Table 12 shows a value of 7% of organic carbon in the soil water sample and 0.16% of Nitrogen content in the soil water sample, Sodium Absorption ratio of 15.80, 11.42 and 32.90 were recorded for the samples obtained by calculations.

Table-13 presents the comparison of the experimental values against guidelines for interpretation of surface water quality for irrigation purposes.

Table-13. Comparison of experimental values with guidelines for irrigation purposes.

Parameters	Guidelines for irrigation water use	Average values for samples from POA1	Average values for samples from POA2	SS sample
Sodium[mg/l]	3-9	52.1	47.3	43.0
Boron[mg/l]	0.7-3.0	3.25	0.45	3.60
pH	6.5-8.4	7.45	9.73	9.60
SAR	<15	11.42	15.80	32.90
Electrical conductivity ($\mu\Omega^{-1}$ cm^{-1})	0.7-3.0	25.0	22.0	

Table-13 shows the sodium value of the water body after receiving effluent is higher than required for irrigation purposes, treatment is required in order to meet the standards to reduce the concentration of pollutants to the level where discharge will not adversely affect the environment (Nduka *et al*, 2007), values are monitored based on regular review of policies significant in achieving expected results (Akintayo and Godwin, 2017). Also, the high concentration of sodium in the samples can be attributed to the high percentage of sodium compounds used in the manufacture of detergents, the area of influence not limited as water movement in soil occurs increasing the radius of impact (Ruslan, 2015). The Sodium absorption ratio of 15.80 for samples from SP2 and 32.90mg/l for SS samples shows that the sodium and salinity hazard are higher than required. The high values of the electrical conductivity result in salinity of the water body, above limits for irrigation.

Design of waste stabilization ponds

The Waste Stabilization pond is recommended for the treatment of the effluent from the soap industry so as to ensure conformity with standards as research has shown that industrial effluent can be treated by the use of biological waste water treatment (Nur *et al*, 2016). The strength of 385mg/l of BOD obtained from the polluted water sample must be reduced to <25mg/l to sustain biological life in the surface water body. The method is chosen due to its outstanding advantages of availability of land for the construction of the ponds in the environment, easy to operate and maintain compared to other methods of sewage treatment, it is capable of ensuring an 80 - 85% reduction on the initial strength of the BOD (Mara, 1998). The process includes the preliminary treatment, primary sedimentation, biological treatment and secondary sedimentation.

The preliminary treatment comprises of screening or communitor and grease removal. Screening is the removal of coarse solids such as rags, woods and so on by closing spaced mild steel bars.

The primary sedimentation is aimed at removing readily settleable solids contents. The sedimentation tank is designed to remove from 50 - 70%, suspended solids and 25 - 40% BOD_5.

Biological treatment is achieved by the waste stabilization ponds whereby micro- organisms such as Bacteria, algae, fungi are basically used in the decomposition and oxidation of the organic wastes.

Secondary sedimentation tanks allow for the setting of the larger flocs and sludge sedimentation with coagulation removes about 90% of the suspended solids.

Design Parameters:

The design of the waste stabilization ponds is based on an effluent Discharge, Q in the range of 150-300m^3 /day, BOD_5 for the sample = 325mg/l, total suspended solids (TSS) = 75.33mg/l, Total dissolved

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solids (TDS) = 680mg/l, Faecal coliform density = 2.7 x 10^5 Fc/100ml, First order rate constant, K = 0.29 for the sample and design temperature of 20 °C.

Anaerobic pond geometry:

Optimum retention time, t=5days, (Mara, 1998) Maximum discharge, Q = 300m^3 /day, Depth = 3m, calculated Area A = 500m^2, the length to breadth ratio of 2:1, Length = 32m, Width = 16m. Embankment of slope 1 in 3 gives a top length = 41m, bottom length = 23m, top width = 25m, bottom width = 7m.

Facultative pond geometry:

For a 70% reduction of BOD in the anaerobic pond to be achieved, the influent BOD_5 into the facultative pond will be 0.3 x 325 = 97.5mg/l. Depth = 1.5, an effluent value of 60mg/l area, Calculated value for Area A by the use of the equation $\frac{Q\,(Li-60)}{18D\,(1.05)}^{T-20}$ is given as 417m^2

Length to breadth ratio of 2 to 1, length = 30m, breadth = 15m. Embankment slope of 1 in 3 gives a top width of 19.5m, top length =34.5m, bottom width =10.5m, bottom length =25.5m

Geometry and design of maturation pond

In order to produce an effluent with a BOD_5 of 25mg/l, two maturation pond in series each with a retention time of 7 days is required.

Depth D = 1.5m, retention time t = 7d, Area A =1400m^2, length = 55m, width = 26m, an embankment of slope 1 in 3, top length = 60m, top width = 31m, bottom length = 51m, bottom width = 22m

Bacterial Reduction:

The reduction of faecal bacteria in the pond has been found as follow first order kinetics viz,

$$N_e = \frac{Ni}{(1+Kbt*)(1+Kbt*fac)(1+Kbt*mat)^2}$$

Where t^* = retention times in the anaerobic, facultative and maturation ponds, N_e = number of Fc/100ml of effluent, N_i = number of Fc/100ml of influent, K_b = first order rate constant for Fc removal d^{-1}, $K_{b(T)}$ = the value of K_b at T^0C, $K_{b(20)} = 2.6\ (1.9)^{20-20} = 2.6d^{-1}$

N_e is therefore given as 8.44Fc/100ml.

Effluent Re - Use Possibilities

Expected values of the strength of water samples from SP1 by the use of waste stabilization ponds is given in Table-14.

Table-14. Reduction in strength of the effluent (BOD_5 mg/l and the FC/100ml) by use of waste stabilization ponds.

Design parameters	**Influent value** (Before Treatment)	**Effluent value** (After treatment)	**% Reduction**
BOD (mg/l)	325	<25	93%
Faecal coliform Fc/100ml	2.7 x 10^5	8.44	99.99≈ 100%

Liquid effluent re-use possibilities

It is noted that 3.6% in the total daily global burden of diseases and about 1.5 million deaths annually (Gaurav, R *et al*, 2018) are as a result of the lack of access to safe water sources, standards for surface water specifies a faecal coliform density of Fc<100/100ml and BOD_S of <25mg/l (Mara, 1998) and referring to the proposed stream standards for portable domestic water, a faecal coliform density of <10 Fc/100ml is specified

CONCLUSIONS

Based on the analysis and discussion of result, the following conclusions are drawn:

a) The strength of the Biochemical Oxygen Demand (BOD) of the polluted surface water was found to be 325mg/l; this high organic content must be treated to acceptable limits to prevent stagnation in the surface water body.
b) The impact of the industrial activity on river Yingi can be successfully managed the use of waste stabilization ponds as achieved by the design of waste stabilization ponds.
c) Waste stabilization ponds were designed to reduce the strength of the BOD in polluted water body to 25mg/l. Anaerobic digestion as part of the treatment process limits negative impacts on surface water bodies by handling high organic loading from wastewater.
d) Recommended dimensions of designed waste stabilization pond are: Anaerobic pond - 41m x 25m x 3m depth, Facultative pond- 35m x 20m x 1.5m depth and maturation pond of 60m x 30m x 1.5m depth.
e) The value of the Sodium Absorption ratio of 15.80 at the Sampling Point1 (SP1) shows that the surface water does not meet requirement for use in irrigation purposes.
f) Liquid effluent from maturation pond is designed to achieve faecal coliform value of 8.4 Fc/100ml and BOD (mg/l) of <25mg/l.

RECOMMENDATIONS

- Environmental impact assessment should be conducted for all intending/proposed Industries and factories in the environment towards proffering mitigating measures that will protect vulnerable water bodies.
- The installation of sewage treatment plants should be provided as designed in the report to protect the surface water body in Yingi.
- Implementation of water pollution control legislations should be reinforced for the reduction of pollution by

strong implementation of legislative measures (Kumar, S. *et al*, 2017).

- Training and teaching of basic sanitation and hygiene to communities on the need to sanitize the environment, education on the quality of water to be used for drinking, bathing and agricultural activities should be instituted. (UN, 2017)

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