An Open Access Journal Available Online

Covenant Journal of Engineering Technology (CJET)

Vol. 1 No. 1, June 2017 (Maiden Edition)

Publication of the College of Engineering,
Covenant University, Canaanland.

Editor-in-Chief: Dr. Charles Ndujiube
editorcjet@covenantuniversity.edu.ng

Managing Editor: Edwin O. Agbaike
me@covenantuniversity.edu.ng

Website: http//Journal.covenantuniversity.edu.ng/cjet/

ISSN: Print xxxx-xxxx
Online xxxx-xxxx

Published by Covenant University Journals,
Covenant University, Canaanland, Km 10, Idiroko Road,
P.M.B. 1023, Ota, Ogun State, Nigeria

Printed by Covenant University Press

Articles

Covenant Journal of Engineering Technology (CJET) Vol. 1, No. 1, June 2017

An Open Access Journal Available Online

Evaluation of the Impact of Dumpsite Leachate on Groundwater Quality in a Residential Institution in Ota, Nigeria

David O. Olukanni, Josiah A. Olujide & Emmanuel O. Kehinde

Department of Civil Engineering, Covenant University, Nigeria
david.olukanni@covenantuniversity.edu.ng; josiah.olujide@stu.cu.edu.ng; oluwaseyi.kehinde@stu.cu.edu.ng

Abstract-The threat of leachate as pollutant on groundwater and soil is of growing concern to human and the environment. The threat is caused by movement of contaminants through leachate from dumpsites and its location to water bodies both at the surface and underground. This research is focused on the impact of leachate from a dumpsite of a residential institution on the groundwater and soil in order to determine the degree of contamination around the institution's environment. The physico- and bio-chemical analysis: BOD, COD, pH, DO, TDS, total hardness, nitrite, chloride, calcium and heavy metals such as Pb, Fe, Zn, and Cu, in line with international standards, were carried out on both soil and water samples obtained from different points on the dumpsite. The results obtained from the tests carried out were compared to the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) standards. Heavy metal concentration showed significant variations from one sample point to another. On comparison, most of the parameters checked in the water samples from boreholes and the streams close to the dumpsites were within the allowable limits except for the Salinity, Iron (Fe) and Calcium (Ca) that exceeded the standards. There is a significant level of acidity which would require proper treatment in order to avoid harm to consumers in the future. The soil samples were also tested after digestion and the results showed that Nitrite (NO2-) and BOD5 exceeded the allowable limits. These results show that the dumpsite has slight effects on the adjacent stream and underlying soil. Therefore, the implementation of a properly designed leachate collection system to prevent future risk of continuous contamination of the underlying soil and groundwater is important.

Keywords: Open dumpsite, Residential Institution, Leachate, Soil, Water quality.

I. Introduction

Open dumps as a method of waste disposal are the oldest and most common way of disposing solid wastes in most cities of developing nations [1]. The awakening to the polluting effects of leachate from these dumpsites on the environment as a whole has motivated a number of studies [2]-[7]. One of the serious problems affiliated with the open dumps is the infiltration of the leachate into the surrounding environment, and consequent contamination of land and water [7, 8]. In recent times, dumpsite pose a major threat due to leachate emerging from solid waste disposal which is strongly influenced by the composition of the wastes, the volume of leachate generated and the location of the dumpsite from water bodies [2, 9, 10]. This has turned into a major issue as it influences the environment, wellbeing of the individual concerned and social prosperity.

Most attention over groundwater pollution has been placed round pollution associated with human activities such as haphazard dumping of wastes followed by the burning of the wastes [11, 12, 13, 14]. The practice of waste burning is actually meant to reduce the volume of waste. According to [15], leachate from such dumpsites comprise major sources of heavy metal pollutants to both aquatic and soil environments. Depending on the climatic conditions of the environment, such pollutants get to the groundwater aquifers through the percolation process. The studies on leachate and groundwater characterization show a serious threat to the local aquifer [16, 17, 18,]. [19] made analysis on samples of solid waste, leachate and groundwater and stated that groundwater pollution is as a result of leachate which is imperative over natural processes in the surroundings of the dumpsite.

Studies have shown that the assessment of impact of pollution sources of groundwater, have brought about major concerns both in the past and present [2, 20, 21]. Sources of major concern to the pollution of groundwater such as domestic wastes, landfills, agricultural chemicals and so on, can generate various types of pollutants which include heavy metals, cyanides, bacteria, nitrogen species, chlorinated hydrocarbons phenols, dissolved organic matter, inorganic macro-components, xenobiotic organic compounds among others [22, 23].

Other research findings have shown that leachate and outflow percolation are the sources of groundwater and surface water pollution close to landfill sites [4, 5, 22, 24, 25, 26]. The quality of groundwater is based on the physical and chemical parameters due to weathering from source rocks and anthropogenic activities i.e. changes in nature made by human beings. The principal impact of the landfill leachate is the contamination of both the groundwater and surface water which has led to a number of studies over the years [17, 27]. The factors which affect leachate generation include;

topography, climate, vegetation, landfill cover, dumpsite characteristics, type of waste and the solid waste management systems in practice [28]. Several controlling factors for the leachate contamination include; rainfall, leachate mode of transportation, redox controls, topography, influence of unlined irrigation canal, age of the MSW dumping site, induced fracturing, surface and sub-surface flow dynamics [29, 30].

The toxic and mobile levels of heavy metals present in soils do not only depend on the total concentrations but also on their specific chemical form, metal properties, binding state, soil properties such as pH , environmental factors and matter content [31]. Soils behave as a natural sink for pollutants released from both natural and anthropogenic sources. The decomposition of organic matter in solid wastes changes the physico-chemical properties of the soil therefore affecting the groundwater sources beneath by the process of leachate percolation. The assessment of soil pollution becomes more complicated as a result of the different sources of the pollutants and their variable distribution [32].

The scope of this research is based on the analysis of the physicochemical parameters of the leachate from the Dumpsite in Covenant University, Ota, Ogun State. The study involves the analysis of the samples obtained from the site: To examine the effects of the leachate from the dumpsite on the groundwater and soil; analyze and determine the physicochemical parameters of the samples in order to assess the pollution effect on soil and groundwater quality; provide general awareness on the effect of leachate from landfill and groundwater and to determine if the quality of water from sources close to the landfill are within the standards of the World Health Organization (WHO)[33].

Description of the Study Area

The study area is the Covenant University dumpsite located right behind Daniel Hall, Ota, Ogun State. The dumpsite is located between latitude 6°40'22.1"N and longitude 3°09'02.4"E. The estimated area of the dumpsite is 18,000m2 or 1.8ha . The total distance of the dumpsite is approximately 636.17m (2087.18ft). All the solid waste generated from the university is usually dumped on this site. The solid waste generated consists primarily of paper waste, human hair waste, packaging waste, glass, plastic bags, leaves from plants, branches from trees, aluminium cans, PVC pipes and condemned water closets. At the site, the dumping and burning of solid waste persist and the dumpsite is not well drained. The site consists of an extensive area that has been in operation since the inception of the institution in 2002. Open dumping is the method of disposal in practice and reduction of waste by incineration is done in order to reduce volume of waste and preserve the life span of the disposal site. There is a stream just downhill from the dumpsite which joins a river at the end of its flow. The Covenant University sewage treatment plant is also located adjacent to the dumpsite and it releases effluents into the stream beside the dumpsite. The water at the site also mixes with that

in the stream and further contaminates it either by surface runoff or percolation.

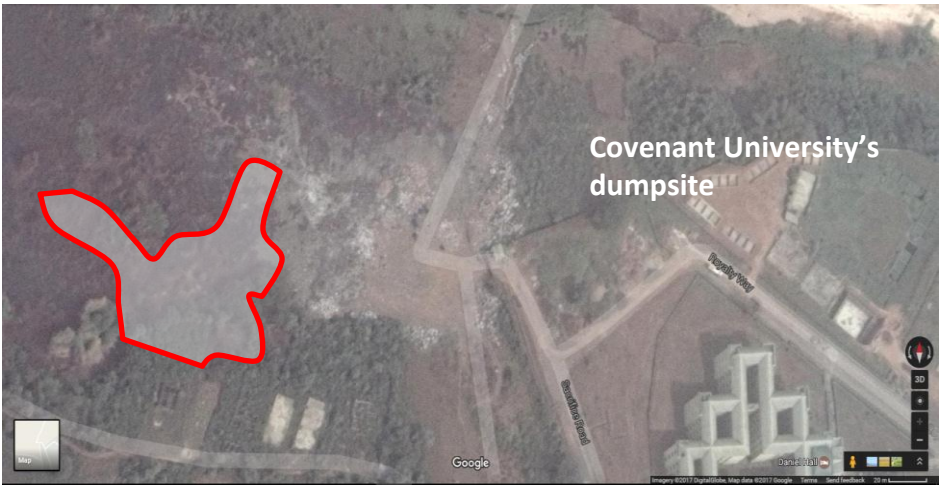

Figure 1 showing the map of Covenant University with dumpsite location.

Figure 2 Solidwaste at the Dumpsite

Climate

Ota has a tropical climate with general humid and hot climatic conditions. It is characterized by high temperatures in the dry season and low temperatures in the wet season. The climatic pattern of the study area includes, the dry season from November to May and the wet season is from June to October. The area experiences maximum rainfall in the wet season. In a year, the average rainfall is 1623 mm. The driest month is December, with 16

mm of rainfall. In June, the precipitation reaches its peak, with an average of 288mm.

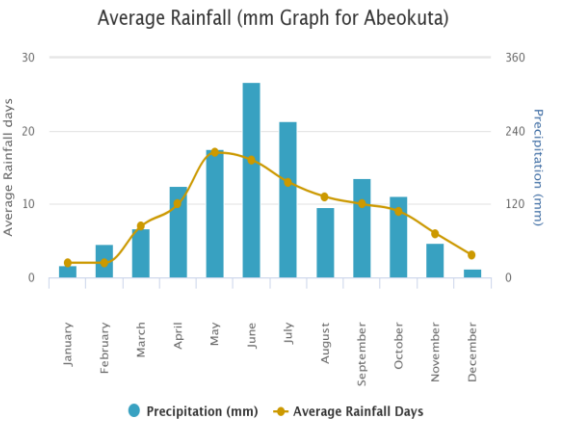

Figure 3: Average monthly rainfall in Ota, Ogun state
Source: [36]

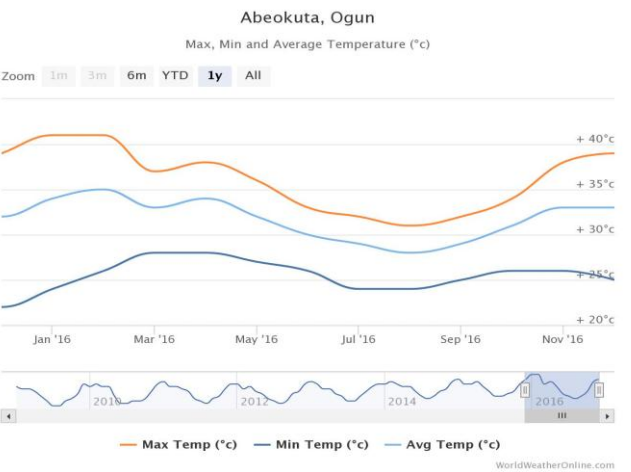

Figure 4: Average monthly temperature in Ota, Ogun State. Source: [36]

II. Materials and Method

Collection of Sampling from the Dumpsite

Systematic random sampling was used for data gathering. Samples were also obtained from a stream located downhill from the dumpsite and also from the borehole water supply at increasing distances from the dumpsite from two nearby houses. Samples were obtained from six (6) different locations; four (4) locations were picked randomly on the dumpsite for sampling. The locations were selected for sampling both on the dumpsite and along the

slope of the dumpsite, the 4 locations on the dumpsite were dug down by 3 metres, and 2 soil samples were obtained for every metre dug into the dumpsite leading to a total of 6 soil samples from each of the 4 locations on the dumpsite, while the other two (2) locations along the slope of the dumpsite were dug down by 2 metres, and 2 soil samples were obtained for every metre dug, leading to a total of 2 soil samples from each of the 2 locations along the slope of the dumpsite. The soil samples were then taken to the laboratory for preservation. A total of 32 soil samples were then taken for digestion in order to obtain the liquid samples from the soil. Physical, chemical and microbiological parameters were analyzed at laboratories of Civil Engineering; Chemistry and Microbiology Departments of the university. Soil samples were also taken from the water sampling points to determine the impact of the leachate on soil and ground water quality within the sampled area.

Sampling from the Stream

Samples were obtained from stream at different intervals and placed in already rinsed 750ml plastic bottles. Duplicate samples were obtained at each of the 3 different points along the stream and taken to the laboratory for preservation and analysis.

Sampling from nearby Houses

Samples were obtained from 2 houses located near the dumpsite and placed in already rinsed 750ml plastic bottles. A total of 2 samples were obtained from the borehole water supply from each of the 2 houses and taken to the laboratory for analysis.

Sampling from a Control site

Two locations away from the dumpsite were selected for sampling. Samples were collected from these locations at 1-3 metre depth for 2 soil samples each, leading to a total of 6 samples from each location. A total of 12 soil samples were then taken for digestion in order to obtain the liquid samples from the soil.

In-Situ Measurements for Physical Parameters

The physical parameters such as; pH, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Salinity were all determined in the field on the freshly collected water samples. These parameters were measured with the use of a PSCTestr 35 multi-parameter. The probe was dipped into the water samples until a stable reading was obtained and recorded.

Analytical Methods

All the samples were analyzed for the following physicochemical parameters and heavy metals which include; pH, temperature, conductivity, Total Dissolved Solids (TDS), Salinity, Iron, Nitrite, Calcium, Chloride, Copper, Zinc, Total Hardness. The physicochemical analysis of the water samples as well as the digested soil samples were carried out according to the standard analytical methods [34, 35].

III. Results and Discussion

Table 1 shows the results from the physicochemical tests carried out on all the samples from the nearby stream that were collected are shown in Table 1. These results are compared to both the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) to ascertain if they are within the permissible standards limits. The pH values of the water samples from the nearby stream and boreholes range from 6.26 to 6.36 and 4.91 to 5.61, respectively. These values are slightly below the WHO and NSDWQ standard values. Water generally becomes more corrosive with

decreasing pH; however, excessively alkaline water also may be corrosive.

Table 1: Mean Results of Water Samples from the nearby stream and boreholes

Parameter/ Samples	Sample 1a	Sample 1b	Sample 2a	Sample 2b	Sample 3a	Sample 3b	Borehole Sample 1	Borehole Sample2	WHO	NSDWQ
Temp (^{0}C)	**30.5**	**28**	**29.8**	**27.4**	**29.9**	**28.2**	**28**	**36.9**	-	-
pH	6.28	6.26	6.36	6.36	6.36	6.32	4.91	5.61	6.5-8.5	6.5-8.5
Conductivity	204	201	499	499	501	500	42.9	71.2	-	-
TDS	147	145	353	351	353	350	30	47.7	500	500
Salinity	112	113	268	267	267	267	345	442	-	-
Iron(mg/l)	0.3	0.4	1.15	1.25	1.05	1.05	0.2	0.05	0.3	0.3
Nitrate (mg/l)	0.135	0.185	0.125	0.195	0.195	0.08	0.195	0.165	1	1
Chloride (mg/l)	3.3	1.7	2.6	5.1	3	3.5	4.1	1.7	2.5	2.5
Calcium (mg/l)	67	67	76	74	25	86	420	163	75	75
Copper (mg/l)	0	0	0.05	0.1	0.06	0.3	0.82	0.24	2	1
Zinc (mg/l)	0.04	0.18	0.16	0.33	0.3	0.3	0.25	0.15	-	3
-	-	-	-	-	-	-	-	-	-	-

The values for the total dissolve solids in the water samples ranged from 145 mg/l – 353 mg/l, was within the standard (500 mg/l), while the TDS values for the Borehole samples ranged from 30 mg/l – 47.7 mg/l. The salinity values of the water samples ranged from 112 mg/l – 268 mg/l and the values for the borehole samples ranged from 34.5 mg/l – 44.4 mg/l. The values of iron (Fe) detected in the water samples ranged from 0.3 mg/l – 1.25 mg/l was above the standard limits for iron in water (0.3), while for the samples obtained from the boreholes, the iron levels ranged from 0.05 mg/l - 0.2 mg/l which is within the limits. According to the Nigerian Standard for Drinking Water Quality (2007), when Nitrite levels exceed 0.2 mg/l, it causes cyanosis and asphyxia (blue-baby syndrome) in infants less than 3 months. The concentration of nitrite present in the water samples ranged from 0.08 mg/l – 0.195 mg/l which are all within the standard limits, while for the samples obtained from the boreholes, the nitrite concentrations ranged from 0.165 mg/l – 0.195 mg/l was within the limit (0.2 mg/l). Concentrations greater than 1.0 mg/L, as nitrogen, may be injurious to pregnant women, children, and the elder. The values of Chloride detected in the water samples ranged from 1.7 mg/l – 5.1 mg/l is above the limits for Chloride in water (250 mg/l), while for the samples obtained from the boreholes, the Chloride levels ranged from 1.7mg/l–4.1mg/l was within limits. Large concentrations increase the corrosiveness of water and, in

combination with sodium, give water a salty taste. The values of copper detected in the water samples ranged from 0 mg/l – 0.3 mg/l is within the limits for copper in water (2), while for the samples obtained from the boreholes, the copper levels ranged from 0.24 mg/l - 0.82 mg/l is also within the WHO and NSDWQ limits. Total hardness detected in the water samples, which ranged from 25 mg/l – 60 mg/l, was also within the WHO and NSDWQ limits.

Table 2: Chemical properties of the digested soil samples from point 1 at various depth from the dumpsite

Point 1	Sample 1a	Sample 1b	Sample 2a	Sample 2b	Sample 3a	Sample 3b	WHO	NSDWQ
Calcium (mg/l)	nd	nd	nd	nd	nd	Nd	75	75
Copper (mg/l)	1.06	0.89	0.85	0.72	0.75	0.8	2	1
Zinc (mg/l)	0.38	0.33	0.13	0.15	0.41	0.38	3	3
Nitrite (mg/l)	0.334	0.326	0.389	0.391	0.875	0.861	0.2	0.2
Iron (mg/l)	0.12	0.1	0.04	0.07	0.43	0.52	0.3	0.3
Chloride (mg/l)	5.1	5.14	6.9	7	38	39.2	250	250
BOD (mg/l)	25.9	25.4	19	19.2	19.4	18.5	25	-
COD (mgO_2/l)	14880	14550	22000	20580	25880	26005	-	-

nd: not detected

Chemical Parameters of sample at different points

At point 1, Calcium was not detected in the leachate sample. Copper showed a variation from 0.72 to 1.06mg/l which is below the WHO standard of 2.0mg/l but the values from Sample 1a at 1 meter (1.06mg/l) is greater than the NSDWQ standard of 1mg/l. The remaining parameters fell below the standard limits. The result for zinc varied from 0.13 to 0.41mg/l and fell below the standard of 3.0 mg/l. Nitrite concentration varied from 0.326 to 0.875 mg/l which is far higher than the standard limit of 0.2 mg/l. Iron concentration varied from 0.07 to 0.52mg/l. The values from 1 meter and 2 meter depth for iron fell below the recommended standard of WHO and NSDWQ (0.3mg/l), but for the samples taken at 3.0 meter depth, the concentrations of iron were 0.43mg/l and 0.52mg/l which are greater than the recommended standard (0.3 mg/l). Chloride concentration shows variation from 5.1 to 39.2mg/l which implies that it falls below the standard of 250mg/l. The BOD values in the leachate vary from 19.0 to 25.9mg/l. At 1.0 meter depth, the values for BOD were 25.9mg/l and 25.4mg/l which is greater than the WHO standard of 25.0mg/l and at 2.0meters, the values were 19mg/l and 19.2mg/l. At 3meters the values were 19.4 and 18.5mg/l which are all below the recommended value of 25.0mg/l prescribed by WHO. The result for COD in the leachate varied from 14550 to 26005mg/l.

Table 3: Mean Results of Water Samples from Three Boreholes

Point 2	Sample 1a	Sample 1b	Sample 2a	Sample 2b	Sample 3a	Sample 3b	WHO	NSDWQ
Calcium (mg/l)	nd	nd	nd	nd	nd	Nd	75	75
Copper (mg/l)	1	0.9	0.74	0.69	0.5	0.35	2	1
Zinc (mg/l)	0.14	0.09	0.42	0.44	0.09	0.11	3	3
Nitrite (mg/l)	0.125	0.127	0.115	0.11	0.1	0.109	0.2	0.2
Iron (mg/l)	0.06	0.05	0.23	0.25	0.1	0.11	0.3	0.3
Chloride (mg/l)	4.2	3.92	15.5	15.61	14	16.2	250	250
BOD (mg/l)	18.6	18.9	28.2	27.6	22.1	22.2	25	-
COD (mgO_2/l)	21280		22000	14880	14500	19680	18600	-

nd: not detected

At point 2, Copper (Cu) concentration in the samples varied from 0.35 to 1.0mg/l is below the WHO standard of 2.0 mg/l but the values from Sample 1a at 1 meter is 1.0mg/l is the same as NSDWQ standard of 1mg/l. The remaining samples fell below the standard. Zinc concentration show that it varies from 0.09 to 0.44mg/l which fell below the WHO and the NSDWQ standard (3mg/l). Nitrite concentration varied from 0.1 to 0.127mg/l and is below the standard limit (0.2 mg/l). Iron (Fe) concentration varied from 0.06 to 0.25mg/l is below the standard limit (0.3 mg/l). Chloride concentration in the sample varied from 4.2 to 16.2mg/l which implied that it fell below the WHO and the NSDWQ standard of 250mg/l. The BOD results in the leachate vary from 18.6 to 28.2mg/l. At 1meter depth, the value for BOD was 18.6mg/l and 18.9mg/l, which is less than the WHO standard of 25mg/l and at 2meters the values was 28.2mg/l and 27.6mg/l is greater than the WHO standard of 25mg/l. At 3 meters, the values are 22.1 and 22.2mg/l which is below the recommended value of the WHO (25mg/l). The result for COD in the leachate varies from 14500 to 21280mg0_2/l.

Table 4: Chemical properties of the digested soil samples from point 2 at various depth from the dumpsite

POINT 3	Sample 1a	Sample 1b	Sample 2a	Sample 2b	Sample 3a	Sample 3b	WHO	NSDWQ
Calcium (mg/l)	nd	nd	nd	nd	nd	nd	75	75
Copper (mg/l)	0.66	0.72	0.89	0.92	0.36	0.41	2	1
Zinc (mg/l)	0.36	0.34	0.18	0.22	0.23	0.19	3	3
Nitrite (mg/l)	0.086	0.076	0.145	0.15	`0.135	0.126	0.2	0.2
Iron (mg/l)	0.08	0.1	0.24	0.2	0.14	0.17	0.3	0.3
Chloride (mg/l)	6.3	5.9	8.2	7.6	7.2	6.81	250	250
BOD (mg/l)	19.7	20.7	25.1	24.8	46.4	47.1	25	-

COD (mgO_2/l)	21400	19900	15080	15450	22488	22550	-	-

At point 3, Copper concentration varied from 0.36 to 0.92mg/l and is below the WHO standard of 2.0 mg/l and NSDWQ standard of 1.0mg/l. Zinc concentration in the samples varied from 0.19 to 0.36mg/l, which falls below the WHO and the NSDWQ standard (3mg/l). Nitrite concentration varies from 0.076 to 0.145mg/l and falls below the WHO and the NSDWQ standard which was 0.2 mg/l. Iron concentration varies from 0.08 to 0.24mg/l is below the recommended WHO and NSDWQ standards of 0.3 mg/l. The result for chloride varied from 5.9 to 8.2mg/l. The BOD value in the leachate varied from 19.7 to 47.1mg/l. at 1meter depth. The value for BOD was 19.7mg/l and 20.7mg/l is less than the WHO standard of 25mg/l and at 2meters the values was 25.1 mg/l and 24.8 mg/l. At 3meters, the BOD value was 46.4 and 47.1 mg/l are greater than the recommended value of the WHO (25mg/l). The result for COD in the leachate varied from 14080 to 22550mgO_2/l.

Table 5: Chemical properties of the digested soil samples from point 4 at various depth from the dumpsite

POINT 4	Sample 1a	Sample 1b	Sample 2a	Sample 2b	WHO	NSDWQ
Calcium (mg/l)	nd	nd	nd	nd	75	75
Copper (mg/l)	0.52	0.47	0.7	0.68	2	1
Zinc (mg/l)	0.25	0.2	0.38	0.41	3	3
Nitrite (mg/l)	0.195	0.187	0.21	0.199	0.2	0.2
Iron (mg/l)	0.08	0.05	0.06	0.08	0.3	0.3
Chloride (mg/l)	6.6	7	4.5	3.98	250	250
BOD (mg/l)	19.4	19.1	23.6	23.1	25	-
COD (mgO_2/l)	22550	22600	17880	16800	-	-

Nd: not detected

At point 4, Copper concentration varied from 0.47 to 0.7mg/l and was below the WHO standard of 2.0mg/l and the NSDWQ standard of 1mg/l while zinc concentration varied from 0.2 to 0.41mg/l was lower than standard limits of 3.0mg/l. Nitrate concentration varied from 0.187 to 0.199mg/l and was less than the WHO and the NSDWQ standard (0.2 mg/l). Iron (Fe) concentration varies from 0.05 to 0.08mg/l. The samples from 1 m and 2 m depths for Fe fall below the recommended standards of WHO and NSDWQ (0.3mg/l). The result for chloride varied from 4.5 to 7.0mg/l which was below the WHO and the NSDWQ standards (250mg/l). The result for BOD in the leachate varied from 19.1 to 23.6mg/l at 1.0m depth. While at 2 m depth, the BOD values were 19.4 mg/l and 19.1 mg/l which is less than the WHO standard of 25.0 mg/l. At 3 m depth, the values were 23.1 mg/l and 23.6 mg/l which are all below the recommended value of the WHO (25.0 mg/l). The result for COD in

the leachate varies from 16880 to 22600 mgO_2/l.

Table 6: chemical properties of the digested soil samples from point 5 at various depth from the dumpsite

POINT 5	Sample 1a	Sample 1b	Sample 2a	Sample 2b	WHO	NSDWQ
Calcium (mg/l)	nd	nd	nd	nd	75	75
Copper (mg/l)	0.42	0.45	0.9	1	2	1
Zinc (mg/l)	0.19	0.16	0.25	0.28	3	3
Nitrite (mg/l)	0.195	0.2	0.205	0.21	0.2	0.2
Iron (mg/l)	0.09	0.11	0.07	0.08	0.3	0.3
Chloride (mg/l)	5	4.96	10.5	11	250	250
BOD (mg/l)	22	21.6	29.1	28.5	25	-
COD (mgO_2/l)	21280	22060	15440	15550	-	-

nd: not detected

At point 5, Copper concentration varied from 0.42 to 1.0mg/l and while zinc concentration varied from 0.16 to 0.28mg/l. Both assessment values were lower than the standard limits. Nitrate showed a variation from 0.195 to 0.205mg/l, and at 1.0m depth, the value for nitrate was 0.195mg/l and 2.0mg/l which were greater than the WHO and the NSDWQ standard (0.2 mg/l). At 2.0m, the value for nitrate is 0.205mg/l and 0.21mg/l which is greater than the WHO and the NSDWQ standard. Fe concentration varied from 0.07 to 0.11mg/l. The samples from 1 m and 2 m for Fe fell below he recommended standard of WHO and NSDWQ (0.3mg/l). Chloride concentration varied from 5 to 11.0mg/l which was below the WHO and the NSDWQ standard of 250mg/l. The result for BOD in the leachate varies from 21.6 to 29.1mg/l. At 1.0m depth, the value for BOD was 22mg/l and 21.6mg/l which is less than the WHO standard of 25.0mg/l. At 2.0 m depth, the values were 29.1mg/l and 28.5mg/l which are all above the recommended standard (25.0mg/l). The result for COD in the leachate varied from 15440 to 21280 mgO2/l.

Table 7: Chemical properties of the digested soil samples from point 6 at various depth from the dumpsite

Point 6	Sample 1a	Sample 1b	Sample 2a	Sample 2b	WHO	NSDWQ
Calcium (mg/l)	nd	Nd	Nd	nd	75	75
Copper (mg/l)	0.68	0.74	0.66	0.62	2	1
Zinc (mg/l)	0.32	0.36	0.38	0.41	3	3
Nitrite (mg/l)	0.215	0.211	0.17	0.173	0.2	0.2
Iron (mg/l)	0.16	0.12	0.25	0.2	0.3	0.3
Chloride (mg/l)	5.6	5.8	6.9	6.34	250	250
BOD (mg/l)	52.2	51.6	26.1	26.4	25	-

COD (mgO_2/l)	3480	3660	14880	15065	-	-

nd: not detected

At point 6, copper (Cu) concentration varied from 0.62 to 0.74mg/l and was below the WHO standard of 2.0 mg/l and the NSDWQ standard of 1 mg/l. The result for zinc at various points varied from 0.32 to 0.41mg/l which falls below standard limits (3.0mg/l). Nitrate concentration varies from 0.17 to 0.215 mg/l. At 1.0 m depth, the nitrate concentration varies from 0.17 to 0.215 mg/l which is greater than the WHO and the NSDWQ standard (0.2 mg/l). At 2 m, the values for nitrate were 0.17 mg/l and 0.173 mg/l which was less than WHO and NSDWQ standards. The result for Fe varies from 0.12 to 0.25 mg/l. The samples from 1 m and 2 m depths for Fe fell below the recommended standard of 0.3mg/l. Chloride concentration varied from 5.6 to 6.9mg/l which was below the WHO and NSDWQ standard of 250mg/l. The result for BOD in the leachate shows that it varied from 26.1 to 52.2mg/l. At 1.0m depth, the value for BOD was 52.2mg/l and 51.6mg/l which were above WHO standard of 25.0mg/l and at 2.0m, the values were 26.1 mg/l and 26.4 mg/l which are all above the recommended value of the WHO (25.0 mg/l). The result for COD in the leachate varies from 3480 to 15065 mgO2/l.

Table 8: Chemical properties of the digested soil samples from the control site at various depth from the dumpsite.

Parameters/Sample	Sample 1a	Sample 1b	Sample 1c	Sample 2a	Sample 2b	Sample 2c
Calcium (mg/l)	nd	nd	nd	nd	nd	nd
Copper (mg/l)	1.5	1.3	0.98	1	0.68	0.4
Zinc (mg/l)	0.4	0.25	0.32	0.23	0.18	0.2
Nitrite (mg/l)	0.3	0.13	0.08	0.2	0.2	0.2
Iron (mg/l)	0.1	0.09	0.08	0.12	0.07	0.13
Chloride (mg/l)	5.1	4.6	6.2	6.8	5.3	6.5

Conclusion

One of the major impacts on the environment is the release of leachate from disposed waste on dumpsites. Wastes from various sources find their way into the environment and end up in dumpsites which pose a severe threat to the soil as a result of the homogeneity of these wastes. The wastes undergo series of decomposition, thereby generating leachate by excess of stormwater infiltrating it. The content of heavy metals in the leachate is generally very low because of attenuating processes (sorption and precipitation) that take place within the disposed waste. The pH values of the water samples from the nearby stream and boreholes range from 6.26 to 6.36 and 4.91 to 5.61, respectively. These values are slightly below the WHO and NSDWQ standard values. The values indicate that the water from both sources are slightly acidic in nature

and if consumed without proper treatment, may be harmful to the consumers. These results show that the dumpsite has slight effects on the adjacent stream and underlying soil. The research therefore recommends the implementation of a properly designed leachate collection system to prevent future risk of continuous contamination of the underlying soil and groundwater.

Acknowledgments

The management of Covenant University is appreciated for proving enabling environment and a platform for this study.

References

[1] E. Al Sabahi, S.A Rahim, W.W & Zuhairi, "The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen," American Journal of Environmental Sciences, vol. 5(3), 256-266, 2009.

[2] A. Ikem, O. Osibanjo, M.K.C Sridhar, & A.Sobande, "Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria" WaterAir-Soil Pollut., vol. 140, pp 307-333, 2002.

[3] J. M Ball, & L.B Denhann, "A South African Project to Remediate Dumpsites,"In: Proceeding of Ninth International Waste Management and Landfill Symposium, Cagliari, Italy. 2003.

[4] A. A Adepelumi, B.D Ako, T.R Ajayi, O. Afolabi, & E.J Ometoso, "Delineation of saltwater intrusion into the freshwater aquifer of Lekki. Penninsula, Lagos, Nigeria," Environ Geol. Vol. 56, pp 927-933, 2008.

[5] S. A Ugwu, & J.I Nwosu, "Effect of Waste Dumps on Groundwater in Choba using Geophysical Method," J. Appl. Sci. Environ. Manage., vol. 13(1) 85 – 89, 2009.

[6] A.O Aderemi, A.V Oriaku, G.A Adewumi, & A. Otitoloju, "Assessment of groundwater contamination by leachate near a municipal solid waste landfill," African Journal of Environmental Science and Technology, vol. 5(11), pp 933-940, 2011.

[7] A. Oyelami, J. Aladejana, & O. Agbede, "Assessment of the impact of open waste dumpsites on groundwater quality: a case study of the Onibu-Eja dumpsite, southwestern Nigeria," Procedia Earth and Planetary Science, vol. 7, pp 648 – 651, 2013.

[8] D. Kumar, M. Khare, & B. J Alappat, "Threat to groundwater from the municipal landfills in Delhi, India." Proceedings of the 28th WEDC Conference on sustainable environmental sanitation and water services. Kolkata (Calcutta), pp 377–380, 2002.

[9] B. Slomczynska, & T. Slomczynski

"Physicochemical and toxicological characteristics of leachates from MSW landfills,"Polish Journal of Environmental Studies, vol.13(6), pp 627-637, 2004.

[10] O. Ohwoghere–Asuma,& K. E Aweto, (2013). Leachate Characterization and Assessment of Groundwater and Surface Water Qualities near Municipal Solid Waste Dump Site in Effurun, Delta State, Nigeria.Journal of Environment and Earth Science, vol. 3(9), 2013.

[11] M. Sharholy, K. Ahmad, R. Vaishya, & R.Gupta, "Municipal solid waste characteristics and management in Allahabad, India," Waste Management, vol.27 (4), pp 490-496, 2007

[12] B. Bhalla, M.S Saini, & M. Jha,"Characterization of Leachate from Municipal Solid Waste (MSW) Landfilling Sites of Ludhiana, India: A Comparative Study,"International Journal of Engineering Research and Applications (IJERA), vol. 2(6), pp.732-745, 2012.

[13] D. O Olukanni, A. A Busari, & J.O Ogundeji, "Water Withdrawal Trends, Cost and Uses in Ota, Ogun State, Nigeria," Journal of Engineering, Science and Technology, vol. 2(1): 3-7, 2015.

[14] D. O Olukanni, J. O Adeleke, & D. D Aremu, "A Review of Local Factors affecting Solid Waste Collection in Nigeria" Pollution, vol. 2 (3), pp 339-356, 2016.

[15] O. O Odukoya, O. Bamgbose & T.A Arowolo, "Heavy metals in topsoil of Abeokuta dumpsites," Global J. Pure Applied Sci., vol. 7: pp 467-472, 2000.

[16] S. Mor, K. Ravindra, R. Dahiya, & A. Chandra, "Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site". Environ. Monit. Assess., 118, 435-456, 2006.

[17] B. Jaskelevicius, & V. Lynikien, "Investigation of Influence of Lapes Landfill Leachate on Ground and Surface Water Pollution with Heavy Metals," Journal of Environmental Engineering and Landscape Management. vol.17(3), pp 131–139, 2009.

[18] C. Patil, S. Narayanakar, & A. Virupakshi, Assessment of Groundwater Quality Around Solid Waste Landfill Area - A Case Study. International Journal of Innovative Research in Science, Engineering and Technology, vol. 2(7), 2013.

[19] R.P Singh, P. Singh, A.S.F Arouja, M.H Ibrahim, O. Sulaiman, "Management of urban solid waste: vermicomposting a sustainable option," Resourc. Conserv. Recycl., vol. 55, pp. 719-729, 2011.

[20] G.A Ebong, M.M Akpan, & V.N. Mkpenie,"Heavy metal contents of municipal and rural dumpsite soils and rate

of accumulation by Carica Papaya and Talinum triangulare in Uyo, Nigeria". E-J. Chem., vol. 5, pp 281-290, 2008.

[21] G. L Siasu, "Assessing the Effect of a Dumpsite to Ground Water Quality in Payatas", Philippines. Am, J. Environ. Sci. vol.4(4). pp 276-280, 2008.

[22] P. Kjeldsen, M. A Barlaz, A. P Rooker, A. Baun, A. Ledin & H. T Christensen," Present and Long-Term Composition of MSW Landfill Leachate: A Review," Critical Reviews in Environmental Science and Technology, vol.32(4), pp 297–336, 2002.

[23] N. Yusof, M. A. Haraguchi, M. Hassan, R Othman, M. Wakisaka, & Y.Shirai, "Measuring organic carbon, nutrients and heavy metals in rivers receiving leachate from controlled and uncontrolled municipal solid waste (MSW) landfills,".Waste Manage., vol. 29,pp 2666-2680, 2009.

[24] G. J Udom, & E. O Esu, "A Preliminary Assessment of the Impact of Solid Wastes on Soil and Groundwater system in part of Port Harcourt City and its Environs. Rivers State Nigeria," Global Journal of Environmental Sciences, vol. 4 (1), 2004.

[25] D. O Olukanni, M.O Ajetomobi, S.O Tebowei, O. O Ologun, & O.M Kayode, "Water Supply and Sanitation Challenges in an Urban Setting: A Case Study," International Journal of Engineering and Applied Sciences (IJEAS), vol. 1(33), pp 34-38, 2014.

[26] D. O Olukanni, M.A Ebuetse, & W.U. Anake, "Drinking Water Quality and Sanitation Issues: A Survey of a Semi-Urban Setting in Nigeria," International Journal of Research in Engineering and Science, vol. 2 (11), Pp 58-65, 2014.

[27] J. Saarela, "Pilot investigations of surface parts of three closed landfills and factors. environmental monitoring assess," vol. 84, 183-192, 2003.

[28] K. Parameswari, B.V Mudgal, & P. Nelliyat,"Evaluation of groundwater contamination and its impact: an interdisciplinary approach". Environ. Dev. Sustain., vol. 14, 725-744, 2012.

[29] S. Esakku, K. Palanivelu, & J. Kurian, J. "Assessment of Heavy Metals in aMunicipal Solid Waste Dumpsite," Workshop on Sustainable Landfill Management, Chennai, India, 3–5 December,p139-145, 2003.

[30] S. S Kale, A. K Kadam,.& S. Kumar, "Evaluating pollution potential of leachate from landfill site, from the Pune metropolitan city and its impact on shallow basaltic aquifers. Environ. Monit. Assess, .vol. 162, pp 327-346, 2010.

[31] C. Osu, & J. Okoro, "Comparative evaluation of physical and chemical parameter of sewage water

from selected areas in Port Harcourt Metropolis, Rivers state, Nigeria," Continental Journal of Water, Air and Soil pollution; vol. 2, pp 1-14, 2011.

[32] N. N. Vandana Partha, N.N. Murthya, & P. R Saxenab, "Assessment of heavy metal contamination in soil around hazardous waste disposal sites in Hyderabad city (India): natural and anthropogenic implications,". Journal of Environmental Research and Management, vol.2 (2). pp 027-034, 2011.

[33] World Health Organization (WHO) Guidelines for Drinking-water Quality, 4th ed., Geneva, 2011.

[34] APHA "Standard Methods for Examination of Water and Wastewater". 18th Edn. American Public Health Association. 1992.

[35] America Public Health Association (APHA) "American water works Association and water environmental federation. Standard methods for the Examination of water and waste water,". 20thed. New York, USA, 1999.

[36] World Weather: Available online at: https://www.worldweatheronline. com/abeokuta-weather-averages/ogun/ng.aspx.Accessed 13/07/2017

Covenant Journal of Engineering Technology (CJET) Vol. 1, No. 1, June 2017

An Open Access Journal Available Online

Effects of Different Curing Methods on the Strength Development of Concrete Containing Waste Glass as Substitute for Natural Aggregate

Oluwarotimi M. Olofinnade[*, 1, a], Anthony N. Ede,[b], Julius M. Ndambuki [2, c] & David O. Olukanni[d]

[1]Department of Civil Engineering, Covenant University, Ota, Nigeria,
[2]Department of Civil Engineering, Tshwane University of Technology, Pretoria, South Africa
*,arotimi.olofinnade@covenantuniversity.edu.ng,
[b]anthony.ede@covenantuniversity.edu.ng,
[c]ndambukiJM@tut.ac.za,
[d]david.olukanni@covenantuniversity.edu.ng

Abstract – Concrete curing is fundamental to achieve quality and durable concrete. This study examines the influence of curing methods on the mechanical strength development of concrete comprises of waste soda lime glass pulverized into fine and coarse aggregate sizes as partial and complete replacement for natural aggregates in concrete. The primary variables considered are the curing methods. The glass content was varied in steps of 25% by weight from 0 – 100% to replace both natural fine and coarse aggregate in the concrete mixes. Concrete mixes were batched using a mix ratio of 1:2:4 (cement: sand: granite) at water-binder ratio of 0.5 targeting a moderate strength of 20 MPa. Forty-five (45) number concrete cubes and cylinders were cast and tested after 7, 14 and 28 days of curing using two curing methods; namely plastic membrane sheet covering and total immersion in water. The results obtained clearly indicate that waste glass concrete cured by complete immersion in water showed better performance in strength development than those cured by plastic membrane covering. Generally, the results indicate that concrete mix produced with 25% glass content exhibit significant strength that compared well with the control at 28 days of curing.

Keywords: Curing, Compressive strength, Natural aggregate, Waste glass, Split tensile strength

I. Introduction

Concrete is the most commonly used construction material and will continue to be in demand [1, 2]. Concrete is a combination of majorly two components (aggregates and binder) which through the process of hydration, the mixture hardens and gains strength. It is a material widely used for construction of buildings, drainage systems, bridges and road pavement networks, water dams, airfield runways, tunnel systems. However, in order to achieve good and quality concrete, the characteristic strength (compressive strength of the concrete mix and other mechanical properties) must be ascertained. According to [3], compressive strength of a concrete mix is a major index of its quality and it is important that concrete mix be developed beyond its minimum attainable design strength. Moreover, [4], stated that production of quality concrete required that the placement of a suitable concrete mix be followed by curing in an appropriate environment, especially at the premature stages of hardening. Furthermore, curing is one process used for facilitating the hydration of the cementitious binder in concrete, and this involves controlling the concrete environmental conditions; that is, the temperature and movement of moisture [5]. Curing is also referred to as a process of protecting the concrete for some specific duration of time after placement in order to ensure that concrete is not exposed to mechanical disturbance at the early age. This process helps to ensure that concrete retains enough moisture and temperature necessary for hydration which leads to continued strength development [6]. The influence of curing temperature on the strength properties of concrete has been studied in recent times [2] – [11]. Neville and Brooks [4], explained one of the needs for curing arises from the fact that complete hydration of cement can only take place in water-filled capillaries. In addition, provided the concrete is properly cured, the strength of concrete increases with time due to improved degree of hydration. However, Li [2] stated that the concrete strength will continue to go up even after 28 days of curing but the progress of cement hydration under real life conditions may vary greatly from site to site. Furthermore, curing process ensures concrete durability, improves porosity, resistance to abrasion, resistance to freezing and thawing, resistance to chemical attacks, volumetric stability; reduce creep and shrinkage, reduces powdery deposition on concrete surfaces and prevents crazing [5,10,12]. Various methods of curing includes immersion in water, sprinkling, the use of wet coverings, the use of membrane forming compounds, plastic sheet covering and open air curing. Mamlouk et al. [12] stated that factors such as environmental condition, cost implication, size and shape of the concrete structure, availability of curing materials, supervision and aesthetics are considered before adopting any curing method. Many investigators have studied the effect of curing conditions on the strength development of plain and blended cement concrete [13], ordinary concrete [7], [14-17], concrete containing supplementary cementitious materials (SCM) [8-9], [18-21], high-performance concrete [22], self-compacting concrete [23-

25] and concrete under hot weather conditions [11]. However, of recent, the sustainability of concrete as a building material has become a critical issue [26-27]. The production process of concrete consumes much of the natural resources and energy. For instance cement is a major constituent of concrete and its production is regarded as one of the major sources of greenhouse gas (GHG) emission into the atmosphere [27]. Meyer [28] estimated that the demand for concrete is expected to increase to about 18 billion tonnes by the year 2050. However, Terro [29] and Olofinnade et al. [30] opined that reusing and recycling of solid wastes such as waste glass in concrete by the construction industry can help sustain and protect the environment through elimination of waste materials that could have been a concern to the environment. Furthermore, the use of waste glass as concrete aggregate can minimize environmental degradation through depletion of the raw resources. Many studies have investigated the effect of replacing aggregates in concrete with waste glass on the mechanical properties of the concrete [31] – [36]. The methods of curing adopted in most of these cases is total immersion in water. In addition, Rashad [35] reported that of recent, there is an increase in the quantity of glass production and usage. This has resulted in the huge amount of glass waste generated and dumped into dump sites [35] – [37]. However, incorporating these glass waste as aggregate in concrete has the potential to reduce the amount of glass waste in dump sites and also reduce the depletion of natural resource [28-36]. Therefore this research examines the strength development of moderate strength concrete produced with and without crushed waste soda lime glass as sand and granite replacement. The concrete samples were cured by complete immersion in water and covering with polythene sheets for 7, 14 and 28 days.

II. Materials and Methods

Materials

Ordinary Portland Cement (OPC) (ASTM Type I) and natural aggregate used for production of concrete in this study were obtained commercially. The chemical compositions of the Portland cement is presented in Table 1. The soda lime glass wastes were collected from open dump sites and glass waste gathering points in Ota, Ogun State, Nigeria. Dumping of solid wastes such as glass wastes within Ota metropolis is mostly practiced through dumping on open sites [37]. The major portion of such waste glass comprises mostly beer, perfume and wine bottles, glass wares, flat glasses, and glass containers. The waste glasses were carefully washed with water to remove dirt and contaminants such as paper labels, rubber corks and metals, and air dried before the glasses were then pulverized to required particle sizes similar to the natural fine and coarse aggregate sizes using a mill crushing machine. The chemical composition of the waste glass were obtained by using the X-ray fluorescence (XRF) techniques in order to determine the oxide composition of the glass as presented in Table 1. Potable water was used for mixing and curing of concrete specimens.

Table 1: Chemical compositions of Portland cement and waste glass

Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	Cr_2O_3
Glass (% wt)	64.31	2.98	6.25	10.61	0.63	0.74	12.52	0.61	0.23
Cement (% wt)	21.08	5.40	6.28	60.25	3.96	0.85	0.33	0.62	-

Table 2: Physical properties of the natural and waste glass aggregates

Material Properties	Natural aggregate		Waste glass aggregate		Water	ement
	Sand	Granite	Coarse	Fine		
Specific gravity	2.63	2.70	1.93	2.50		
Fineness Modulus	2.69	2.85	2.72	2.99		3.15
Water absorption (%)	2.28	0.25	0.36	0.4		
Unit weight (kN/m^3)	16.04	24.12	23.57	22.37	9.81	14.12
Initial setting time (min)						68
Final setting time (min)						185

Material Preparation

For preparation of the concrete mix, river sand of sieve size 0.075 mm – 4.75 mm and crushed granite of maximum aggregate size of 20 mm mixed with the cement (binder) were used to produce the reference concrete specimens and other concrete mixes containing waste glass used for this research work. Figure 1 depicts the sieve analysis showing the particle size distribution of the river sand, granite and crushed waste glass while Table 2 reveals the physical properties of the natural aggregate and crushed waste glass aggregate used in this study. All mixtures were batched by weight, using a mix ratio of 1:2:4 (cement: sand: granite) and a water-binder ratio of 0.5. The design strength targeted in this study is 20 MPa at 28 days curing period. Four (4) resulting mixtures were produced by blending the pulverized waste glass aggregate as substitute for both the natural fine and coarse aggregates in the same mixture in proportions of 25%, 50%, 75% and 100%. Table 3 shows a summary of batching for the mix ratio by weight.

Preparation of Test Specimens

A total of 45 cube specimens of dimension 150 x 150 x 150 mm and cylinder specimens of 100 mm diameter by 200 mm in height were cast in mold, kept in a cool place and removed after 24±2 hours. Each specimen was filled in three layers and tampered 25 times to remove entrapped air and was appropriately labelled for identification.

Table 3: Batching of Concrete

Material Batching (kg)	Percentage Glass Content				
	0	25	50	75	100
Water	138	138	138	138	138
Cement	275	275	275	275	275
Natural fine aggregate	550	413	275	138	0
Natural coarse aggregate	1100	825	550	275	0
Waste glass coarse aggregate	0	275	550	825	1100
Waste glass fine aggregate	0	138	275	413	550

Curing Methods

The concrete specimens were cured in the laboratory under two types of curing conditions before testing. The first method was curing by total immersion in potable water (WC) at mean daily temperature that ranged from 28 – 32°C all through the period of curing with mean relative humidity that ranged from 60 – 85%. Secondly, curing by wrapping the concrete specimens with polythene nylon sheets (PC). The edges of the sheets were fastened together with tapes to prevent loss of moisture from the concrete surface.

Testing of the hardened concrete

The hardened concrete were tested for compressive- and split tensile-strength at ages of 7, 14 and 28 days for each percentage replacement of both natural fine and coarse aggregate with crushed waste glass aggregate content in the same concrete mix. The average strength of three specimens were determined for the various tests. The compressive and the split tensile strengths of the concrete cubes and cylinders were determined in compliance with the provision of BS 12390 [38] using a digital display compression machine.

All materials and concrete specimens preparation and testing were carried out at the Structures and Material testing Laboratory of Civil Engineering, Covenant University, Ota.

III. Results and Discussion

Environmental Curing Conditions

Environmental factors such as moisture and temperature are vital environmental conditions considered in concrete curing. These factors affect the hydration process of the concrete and are usually not constant except in controlled environment [3]. Throughout the curing period in this study, the mean daily temperature and daily relative humidity in the laboratory, ranged from 28 to 32°C and 60 to 90%, respectively.

Particle Size Distribution of Materials

Figure 1 shows the result of the sieve analysis carried out on the sand, granite and crushed glass aggregate materials in order to determine the particle size distribution. The sieve plot for the sand used depicts a uniform gradation size (i.e. poorly graded). A larger portion of the sand particles are within medium to coarse range. The value of the uniformity coefficient and coefficient of curvature (Cc) calculated gives 3.25 and 0.94, respectively. Furthermore, based on the classification system used by the Unified Soil

Classification System, uniformity coefficient (CU) less than 6 for sand indicates that grain sizes were of uniform size that is; poorly or uniformly-graded. The particle size distribution for the granite particles also indicate that the particles were also uniformly graded. The gradation plots for the crushed waste glass aggregates shows uneven particle size distribution similar to the natural sand and granite aggregate. The particle size distribution of the glass and natural materials are closely equal.

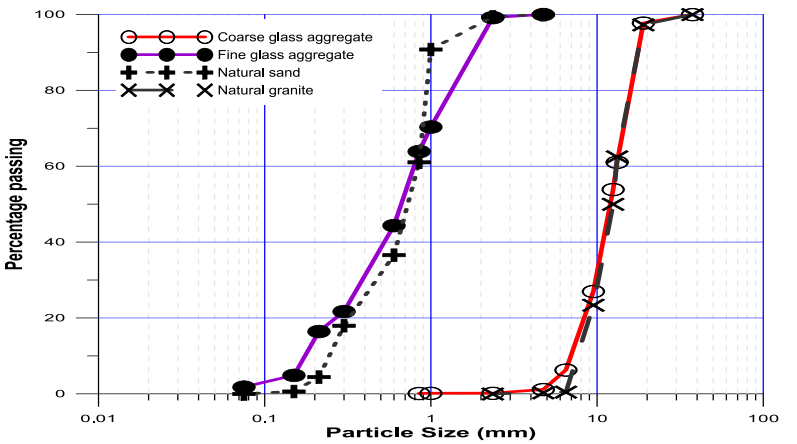

Figure 1: Sieve analysis for the waste glass, sand and granite material

Properties of Fresh Concrete - Slump

The obtained test result for the slump gives a value of 60 mm for the control mix, while the mixtures containing glass aggregate exhibit a reduction tendency in slump ranging from 20% to 22% reduction in concrete workability as the proportion of glass content increases. The results clearly indicate that workability of the concrete mixes decreases as the glass content increase from 25% to 100% as also reported by Olofinnade et al. [34]. The decrease in the slump may be attributed to the angular shape and geometry of the glass particles which reduces the fluidity of the mixes [39]. The concrete mixes were workable with no immoderate segregation.

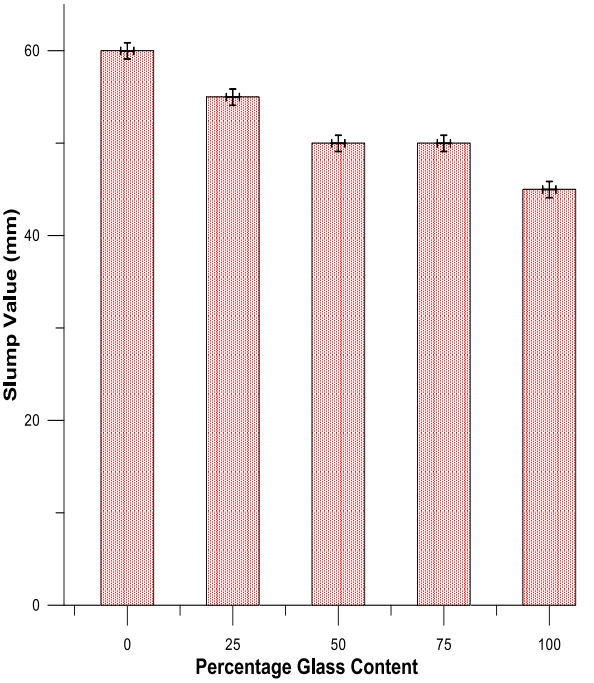

Figure 2: Changes in slump value with glass content

Compressive Strength

The results of the average compressive strength are shown in Figures 3 – 4, which depicts the average compressive strength against the curing age of the concrete cubes at ages 7, 14 and 28 days; for water curing and polythene sheet covering curing methods, respectively. As shown in Figures 2 and 3, the curves show clearly that the compressive strength development of all cube specimens increased with age; that is, the reference concrete and concrete cubes containing crushed glass content cured by immersion in water and polythene sheet covering increased in strength as the period of curing increased for both curing conditions. However, it was observed in Figures 5, 6, and 7 that as the percentage substitution of both sand and granite with the glass content increases beyond 25% replacement, the compressive strength follows a steady decline in strength for all the curing medium at 7, 14 and 28-day testing, irrespective of the curing methods. The development of higher compressive strength was achieved through curing by total immersion in Water (WC). All the concrete cube specimens cured by total immersion in water performed better compared to those cured using the polythene sheet covering. This could be attributed to the sufficient moisture that is available for continued hydration of cement in the concrete as reported by Neville and Brooks [4] and Raheem et al. [40]. The control concrete and concrete containing crushed waste glass at 25% content were able to achieve the targeted minimum strength of 20 MPa at 28-day compared to the same concrete specimens cured by polythene sheet covering with a

lower 28-day compressive strength of 17.78 and 18.67 MPa respectively. This result could be attributed to the inability of the concrete to have adequate access to external water to replace the used up internal water in the concrete pores in order to ensure 100% relative humidity as reported by [5]. Early drying of water in the concrete halts or slows down hydration process.

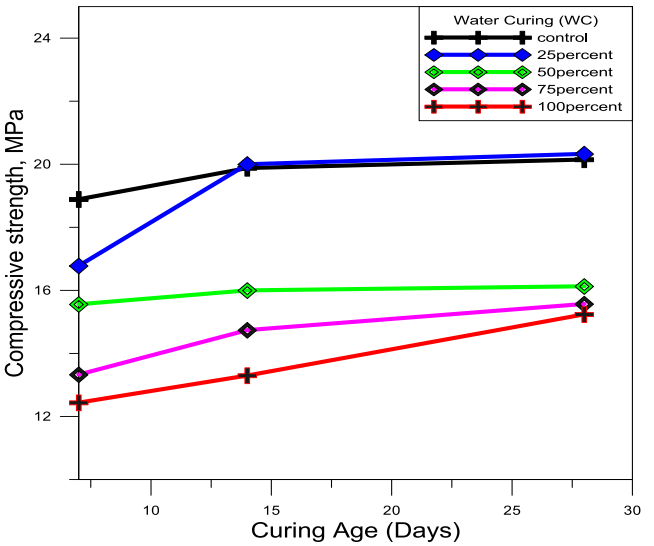

Figure 3: Compressive strength variation with curing age by immersion in water

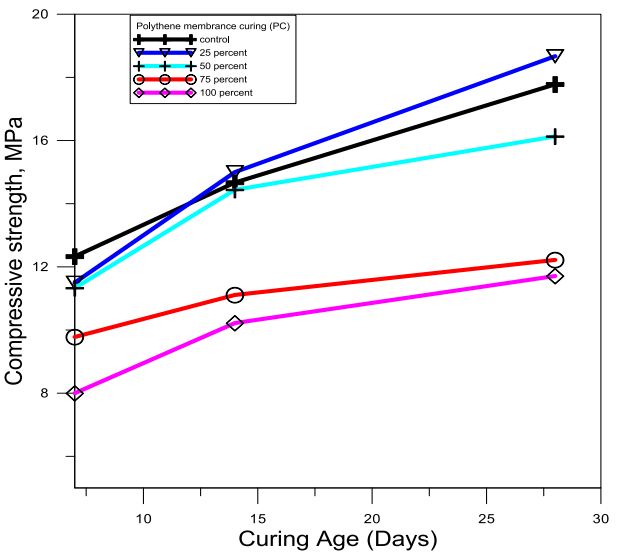

Figure 4: Compressive strength variation with curing age by polythene sheet covering

The concrete cube specimens recorded 80% of its 28-day strength just after 7 days of curing by immersion in water while curing with polythene sheet covering achieved 60% of its 28-day strength after 14-day of curing.

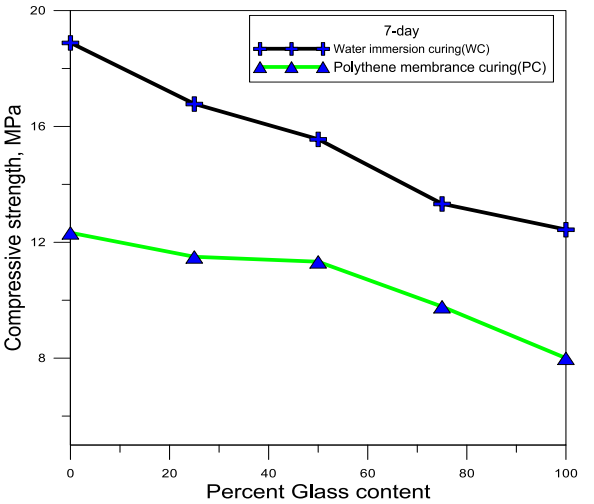

Figure 5: Comparison of compressive strength against glass content for 7-day and 14-day water and polythene curing

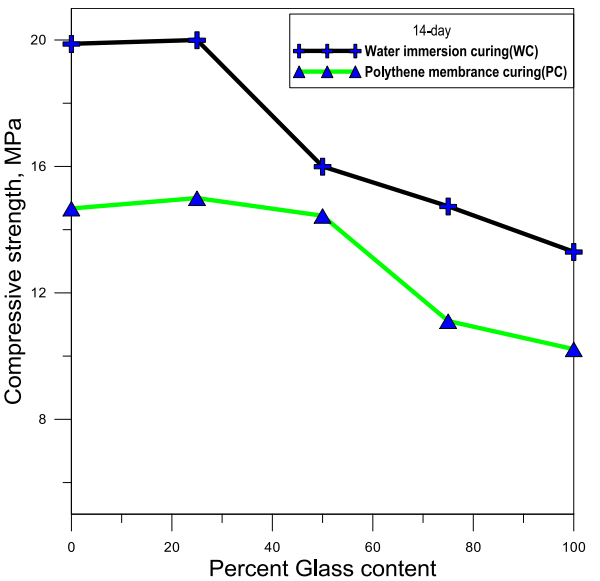

Figure 6: Comparison of compressive strength against glass content for 7-day and 14-day for water and polythene curing

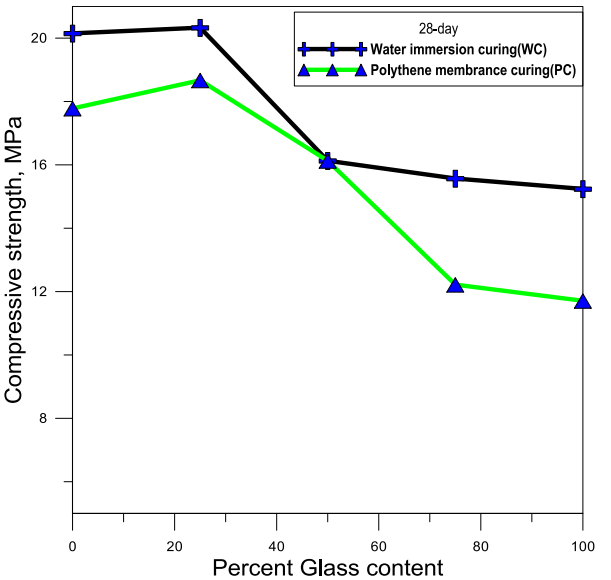

Figure 7: Comparison of compressive strength against glass content for 28-day water and polythene curing

Split Tensile Strength

The observed results for the average split tensile strength tests are presented in Figures 8 and 9 for 7, 14 and 28-day of curing by water immersion and polythene sheet covering respectively. The tensile strength test is used to evaluate the tensile stress resistance of the concrete. The tensile strength of concrete containing crushed waste glass at 25% glass replacement performed better compare to the control; exhibiting split tensile strength values of 3.09 and 3.50 MPa at 28-day for water curing and polythene sheet covering curing respectively, compared to tensile strength values of 3.80 and 3.25 MPa for the control. It was observed that the split tensile strength follows the same strength development trend exhibited by the compressive strength. Figure 10, 11 and 12 clearly depicts a reduction in the tensile strength development as the proportion of glass content increases for both the water curing method and curing by polythene covering sheet. However, all concrete specimens cured by water immersion performed better than those cured with polythene sheet covering. Generally, as expected there is a progressive increase in the tensile strength development over the curing period for both the water curing and polythene sheet covering curing methods.

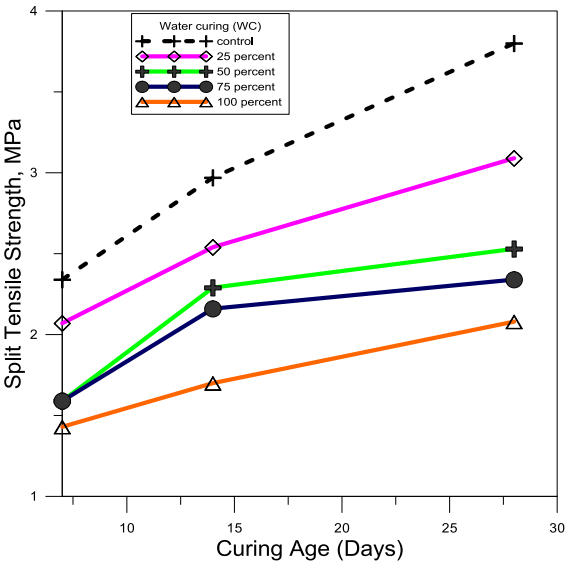

Figure 8: Split tensile strength variation with curing age by immersion in water

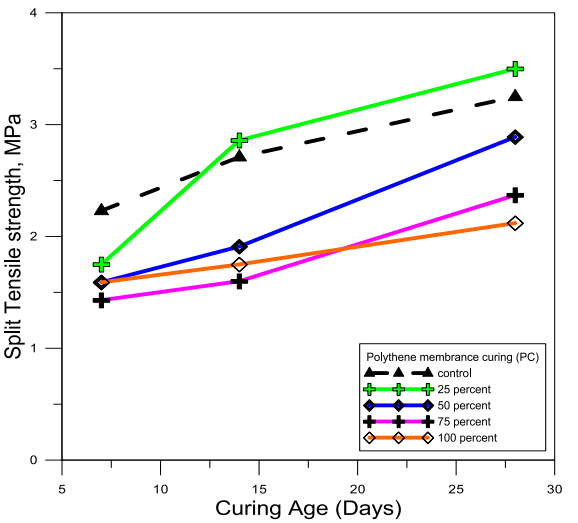

Figure 9: Split tensile strength variation with curing age with polythene covering

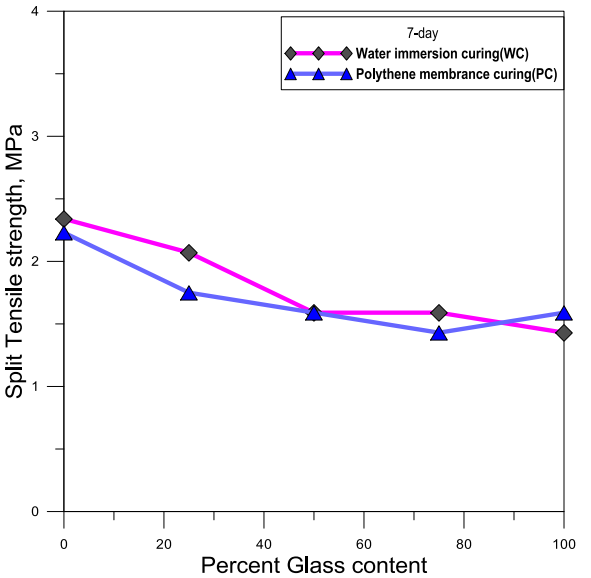

Figure 10: Comparison of split tensile strength against glass content for 7-day and 14-day water and polythene curing

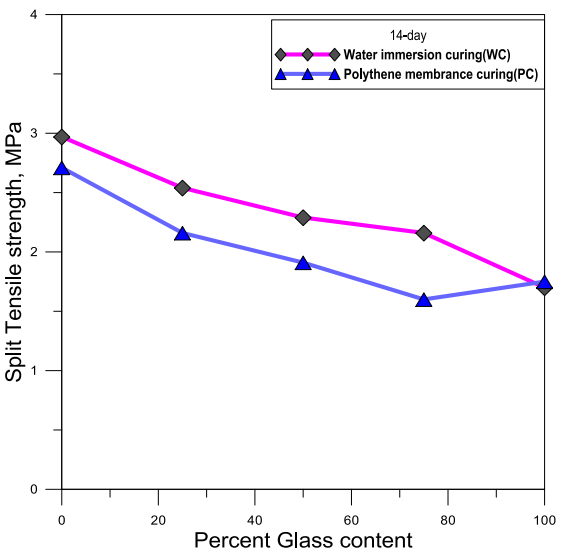

Figure 11: Comparison of split tensile strength against glass content for 7-day and 14-day water and polythene curing

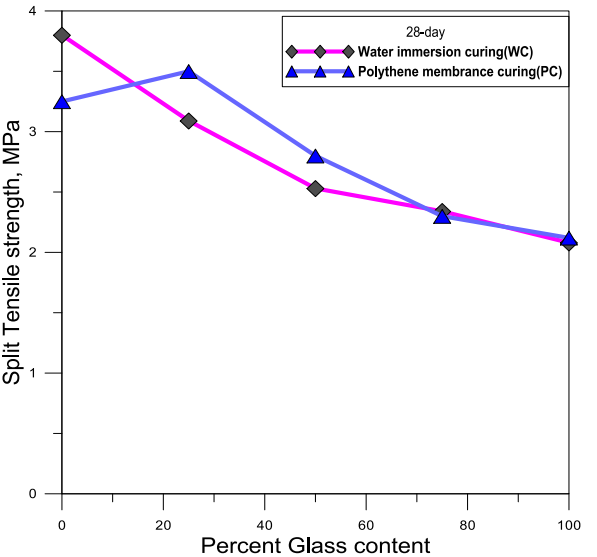

Figure 12: Comparison of split tensile strength against glass content for 28-day water and polythene curing

IV. Conclusions

Based on the experimental test results obtained in this research, the following conclusions can be drawn:

i. The control concrete specimens and concrete specimens containing crushed waste glass cured in water and those cured by polythene sheet covering showed similarity in their compressive and split tensile strength development.

ii. The use of curing by complete immersion in water is more effective. The concrete cured by immersion in water met the minimum required strength of 20 MPa at 28-day curing period. This is attributed to the sufficient moisture available for good cement hydration reaction resulting in improvement of the concrete pore structure.

iii. The use of polythene sheet covering as curing method gives a lower compressive and split tensile strength. This may be as a result of early moisture movement from the concrete resulting in drying out of the concrete.

iv. The drying out of the concrete resulted in the slowing down or stopping of the hydration process which will significantly affect the strength development of the concrete.

v. However, the highest compressive and split tensile strength was obtained for concrete containing crushed waste glass at 25% replacement cured by water immersion, at 28-day curing period.

vi. Generally, the study show that curing by complete immersion in water is the more effective method of curing for concrete. This is necessary to achieve a better performance hardened concrete.

Acknowledgement

The authors are pleased to deeply appreciate the funding support from the management of Covenant University, Ota, Nigeria.

References

[1] K.P Mehta & P.J.M Monteiro, Concrete: microstructure, properties, and materials, New York: McGraw-Hill, .2006

[2] Z. Li, Advanced concrete technology, New Jersey: John Wiley & Sons, 2011

[3] I.I Akinwumi & Z.O. Gbadamosi, "Effects of curing condition and curing period on the compressive strength development of plain concrete," International Journal of Civil and Environmental Research, Vol. 1, Issue 2, pp 83-99, 2014

[4] A.M Neville & J.J Brooks, Concrete Technology, England: Longman, 2010.

[5] A.M Neville, Properties of Concrete, New York: John Wiley and Sons, 1996.

[6] W.H Price, "Factors influencing concrete strength," J. Am. Concrete Institute, Vol. 47, Issue 2, pp 417-432, 1951.

[7] J.K Kim, Y.H. Moon, & S.H. Eo, "Compressive strength development of concrete with different curing time and temperature," Cement and Concrete Research, vol. 28, issue 12, pp 1761-1773, 1998

[8] B. Liu, Y. Xie, & J. Li, "Influence of steam curing on the compressive strength of concrete containing supplementary cementing materials," Cement and Concrete Research, vol 35, pp 994-998, 2005.

[9] T.Y. Lo, A. Nadeem, W.C.P. Tang, & P.C. Yu, "The effect of high temperature curing on the strength and carbonation of pozzolanic structural lightweight concretes," Construction and Building Materials, vol 23, pp 1306-1310, 2009.

[10] M.S. Siddiqui, W. Nyberg, W. Smith, B. Blackwell, & K.A. Riding, "Effect of curing water availability and composition on cement hydration," ACI Materials Journal, vol. 110, issue 3, pp 315-322, 2013.

[11] M. Ibrahim, M. Shameem, M. Al-Mehthel, M. Maslehuddin, "Effect of curing methods on strength and durability of concrete under hot weather conditions," Cement and Concrete Composites, vol. 41, pp 60-69, 2013.

[12] M.S. Mamlouk, & J.P Zaniewski, Materials for civil and construction engineers, New Jersey: Pearson Education, Inc., 2006.

[13] A.S. Al-Gahtani, "Effect of curing methods on the properties of plain and blended cement concretes. Construction and Building Materials," Vol. 24, pp 308-314, 2010

[14] S. Popovics, "Effect of curing method and final moisture condition on compressive strength of concrete," ACI Journal, vol. 83, issue 4, pp 650-657, 1986.

[15] A. Arafah, R. Al-Zaid, & M. Al-Haddad, "Influence of non-standard curing on the strength of concrete in arid areas," Cement and Concrete Research, vol. 26, pp1341-1350, 1996

[16] H. Marzouk, & A. Hussein, "Effect of curing age in high-strength concrete at low temperatures. Journal of Materials in Civil Engineering, vol. 7, issue 3, pp 161-167, 1995

[17] B. Ozer, & M. Hulusi, "The influence of initial water curing on the strength development of ordinary Portland and pozzolanic cement concretes," Cement and Concrete Research, vol. 34, issue 1, pp 13-18, 2004

[18] C. D. Atis, F. Ozcan, A. Kilic, O. Karahan, C. Bilim, & M.H. Severcan, "Influence of dry and wet curing conditions on compressive strength of silica fume concrete," Building and Environment, vol. 40, pp 1678-1683, 2005.

[19] H. Yazici, "The effect of curing conditions on compressive strength of ultra-high strength concrete with high volume mineral admixtures," Bui & Env., vol. 42, pp 2083-2089, 2007.

[20] M. Ba, C. Qian, X. Guo, & X. Han, "Effects of steam curing on strength and porous structure of concrete with low water/binder ratio," Construction and Building Material, vol 25, pp 123-128, 2011.

[21] A.F. Bingol & I. Tohumcu, "Effects of different curing regimes on the compressive strength properties of self-compacting concrete incorporating fly ash and silica fume," Materials and Design, vol. 51, pp 12-18, 2013.

[22] S. Kakooei, H. Md Akil, A. Dolati, & R. Rouhi, "The corrosion investigation of rebar embedded in the fibers reinforced concrete," Construction & Building Material, vol. 35, pp 564–570, 2012.

[23] S. Yazicioglu, S. Caliskan, & K. Turk, "Effect of curing conditions on the engineering properties of self-compacting concrete," Indian Journal of Engineering & Materials Sciences, vol. 13, issue 1,pp 25-29, 2006.

[24] H. Zhao, W. Sun, X. Wu, & B. Gao, "Effect of initial water-curing period and curing condition on the properties of self-compacting concrete," Materials and Design, vol. 35, pp 194-200, 2012.

[25] J.R. Al-Feel & M. Abdul-Aziz, "Fresh and hardened properties of self-compacted concrete at different curing regimes," Al-Rafidain Engineering

Journal, vol. 21, pp 46-58, 2013.

[26] A. Bilodeau & V.M Malhotra, "High –volume fly ash system: concrete solution for sustainable development," ACI Mater J., vol. 97, issue 1, pp 41-47, 2000.

[27] J. Kline and L. Barcelo, "Cement and CO2, a victim of success," Cement Industry Technical Conference, IEEE Press, pp. 1-14, May 2012

[28] C. Meyer, "The greening of the concrete industry," Cement and Concrete composites, vol. 31, pp 601-5, 2009.

[29] M. J. Terro, "Properties of concrete made with recycled crushed glass at elevated temperatures," Building and Environment, vol. 41, no. 5, pp. 633-639, 2006.

[30] O.M Olofinnade, J.M Ndambuki, A.N Ede & C. Booth. "Application of Waste Glass Powder as a Partial Cement Substitute towards more Sustainable Concrete Production," International Journal of Engineering Research in Africa, Vol. 31, pp 77-93, 2017

[31] C. Polley, S.M Cramer, & R.V Cruz, "Potential for using waste glass in Portland cement concrete," Journal of materials in Civil Engineering, vol. 10, issue 4, pp 210 – 219, 1998.

[32] A. Shayan, & A. Xu, "Value-added utilization of waste glass in concrete. Cement and concrete research, vol. 34, issue 1, pp 81 – 89, 2004.

[33] B. Taha, & G. Nounu, "Utilizing waste recycled glass as sand/cement replacement in concrete," Journal of material civil engineering, vol. 21, issue 2, pp 709 – 721, 2009.

[34] O.M Olofinnade, J.M Ndambuki, A.N Ede, & D.O Olukanni, "Effect of Substitution of Crushed Waste Glass as Partial Replacement for Natural Fine and Coarse Aggregate in Concrete," Mat. Sci. Forum, vol. 866, pp 58-62, 2016.

[35] A.M Rashad, "Recycled waste glass as fine aggregate replacement in cementitious materials based on Portland cement," Construction and Building Materials, vol. 72, 340–357, 2014.

[36] O.M. Olofinnade, A.N. Ede, & J.M. Ndambuki, "Sustainable green environment through utilization of waste soda-lime glass for production of concrete," Jour. of Mat. Env. Sci., vol. 8, pp 1139-1152, 2017.

[37] D.O Olukanni, O.M Akinyinka, A.N Ede, I.I Akinwumi, & K.O Ajanaku, "Appraisal of Municipal Solid Waste Management, its Effect and Resources Potential in Semi Urban City: A Case Study," Journal of South African

Bus. Research, pp 1-13, 2014

[38] BS EN 12390-3, "Testing hardened concrete," European Committee for Standardization, 2002

[39] M. Adaway & Y. Wang, "Recycled glass as a partial replacement for fine aggregate in structural concrete – Effects on compressive strength. Elec. J. of Structural Engineering," vol. 14, pp116-122, 2015.

[40] A.A. Raheem, A.A Soyingbe, & A.J. Emenike, "Effect of curing methods on density and compressive strength of concrete," International Journal of Applied Science and Technology, vol. 3, issue 4, pp 55-64, 2013.

Covenant Journal of Engineering Technology (CJET) Vol. 1, No. 1, June 2017

An Open Access Journal Available Online

Formulation and Evaluation of Synthetic Drilling Mud for Low Temperature Regions

Fadairo Adesina, Olutola Patrick, Ogunkunle Temitope & Oladepo Adebowale

Department of Petroleum Engineering, Covenant University, Ota, Nigeria,

Abstract: The temperate world such American and Canada are extensively increasing environmental legislations against oil-based muds and increasing exploratory activities in the offshore, it imperative to develop an oil based drilling muds that have resistance to the weather and relatively stable rheological properties at low temperature of -5oC to 20oC. This study investigates the use of non-edible algae oil to formulate ethyl biodiesel as based fluid for drilling mud that can perform the same function as convectional oil based drilling fluid and as well comply with the HSE (Health, safety and environment) standard in the temperate region and offshore environment. Experimental tests were performed at temperature condition of -5oC to 20oC on the synthetic ethyl biodiesel oil based mud samples so as to evaluate the rheological properties of the drilling mud formulations. The synthetic oil based was obtained from offshore drilling company and was used as control experiment. The following tests were run on these muds including; viscosity pH, gel strength, density and filtration tests at varied temperature and constant pressure and toxicity test to determine their usability in the defined conditions.

The results obtained showed that ethyl biodiesel mud had a lower viscosity than the industrial biodiesel mud, which implied lesser resistance to the flow of the mud. It also had a more stable density than the industrial variant, smaller mud cake thickness, higher gel strength and pH than the industrial variant. Likewise, the toxicity test proved that the ethyl biodiesel mud was more biodegradable than the industrial variant.

This study helps in surface facilities storage of synthetic based muds and their use during drilling operation in relatively low temperature region of -5oC to 20oC. Also enable the drilling engineer to refine their procedure and better manage the risk associated with the use of oil based mud in such region.

Introduction

With new developments in the drilling engineering sector of the global oil industry, mud should necessarily fulfil three requirements according to Khodja et al. (2010), and should be: easy to use, not too expensive and environmentally safe. It will also not be erroneous to include correct rheology as a requirement. Therefore, there is a constant conflict in the mud selection program concerning the particular mud to choose in order to fulfil adequately all the requirements at once.

It is notably without argument that oil-based muds fare better than water-based muds in nearly all aspects of concern except in terms of environmental issues and costs, which includes financial costs. Such issues and costs arise from non-biodegradability of the mud, the disposal and treatment of oil-based muds. This is the reason that their widespread application in the industry is checked by Environmental Agencies leading to development of synthetic variants that will comply with the standards set in relation to disposal.

The temperate world has some of the strongest environmental policies attached to the disposal of wastes from oil-based muds. The temperate regions, beginning with the US in the 1970s and 1980s called for stringent policies against the disposal of mud wastes to save their environment from toxicity.

For temperate countries, muds must be able to have viscosity that can be maintained over long periods of time, which implies a small change in viscosity per temperature increase or decrease. This must also correspond to surface conditions in which muds are kept. To expand, muds need to be resistant to temperature change as they should not gel up but have constant viscosity or have slight viscosity decrease. This proves useful for the storage of oil that can be re-used.

The temperate world is home to an undeniable amount of the oil that is in the world, it also accounts for a significant percentage of the world oil drilled and also the in terms of reserves today. However, weather patterns in that region affect the productivity of oil ventures leading to less than optimal results. Likewise, environmental sanctions also limit the use of oil-based muds in temperate nations since their disposal is considered harmful to their biosphere. The problem at hand is how temperate regions can create weather-resistant muds that will be active downhole yet conform to environmental standards. This research will seek to bridge two extremes into a single formulation.

Literature Review

In our industry, it is observed that the developments that occur do so because of certain restrictions on the use of some particular technology and respective governments pushed these changes (Khodja et al., 2010; Fadairo et al., 2012c). This has increased the need for flexibility in the formulations and consideration of performance in specific situations (Khodja et al., 2010). Relating the concept of specific performance of drilling fluids have been an age-long consideration and has been expressed (Anderson et al., 2009) severally in the views of several researchers but

none have had zero impact (Apaleke et al., 2012; Behnamanhar et al, 2014).

A study undertaken by Bleier et al. (1993) in conjunction with the United States Environmental Protection Agency (EPA) focused on the state of the environment then and stressed that budding technologies be adopted to meet with the future projections as their studies, which encompassed biodegradability, toxicity and the effects of ions and salts, were conducted and even proffered techniques for waste minimization.

However, Lee's work on synthetic muds was overwhelmingly theoretical and was only focused on his work in the Gulf of Mexico at the time. An error in his analysis is in his belief that toxicity of a substance reduced with the increase in carbon number as against a decrease in the carbon number. Toxicity and bioaccumulation on the surface actually signify a more viscous substance. Lighter compounds will actually have less bioaccumulation on the surface because of their volatility over heavier component. The reason for less bioaccumulation is the fact that the lighter components or products have less aromatic components in their structure with the reduction of the carbon number (Khodja et al., 2010; Fadairo et al., 2012a).

Talalay and Gundestrup (2002) looked at drilling mud design from a different standpoint and studied the mud in relation to the geographical location of the drilling site. This work was an extension of their research work of 1999. In this they considered a number of factors that could lead to optimal mud design for the polar region and by extension in the temperate region. They established that the parameters for drilling for the region must focus on the following namely frost-resistance, stability, sufficient viscosity and environmental friendliness. Talalay and Gundestrup introduced that the viscosity and density of the mud was the central to the realization of the conceptual design for the drilling mud for most of these parameters with the exception of frost-resistance. The viscosity they believed could affect the total drill time and they opined that low viscosity was necessary to achieve optimal drill rate and hence they disqualified the use of silicone oil, as it was highly viscous at sub-zero temperatures. Likewise, for a mud to be stable they pointed that the mobile phase should be unable to disintegrate easily, that implies that the properties must not change considerably during storage, transportation and use in the borehole. However, practical research implies that a biodegradable mud will naturally maintain stability through addition of a weighting agent (Ramirez et al., 2005).

For a mud to be frost-resistant and in extension weather-resistant, they believed that compounds with low-temperature will achieve such desire. They pointed out that the freezing point of the mud must be greater than the minimal temperature in the borehole and at the surface and that the pour point must be low to avoid gelling of the mud. A mud's resistance to external conditions will also reflect storability of the mud. Talalay and Gundestrup (2002) adjudged that paraffin- (kerosene-) based muds are the best for the

region due to the presence of naphthenes and due to slight density change of kerosene with temperature. However, they believed that kerosene would have long residence time in the environment if the mud were discharged. Khodja et al (2010) and Fadairo et al. (2012a) disputed this view of kerosene having a long residence time as stated earlier in this review section. Fadairo et al. (2012a) further expressed their view that the degradability of the mud could affect the health of the environment. This is because degradation of mud in the sediments is affected by the temperature, oxygen content and energy.

Another aspect many reviewers had defined mud usability in the area of temperature and pressure of which they concluded rheology to be the center of such mud design such as Santoyo et al. in 1999 and Amani in 2012. Santoyo et al. (1999) sought to derive a mathematical correlation between viscosity and temperature and this was achieved by an experimental evaluation of 11 muds with different compositions that were chemically characterized. They posited that current models had underestimated the true viscosity value and acknowledged that temperature needed to be considered when measuring the viscosity of drilling muds. The exclusion of temperature variation, they believed constituted an error to viscosity graphing and measurement. Their work was modeled for geothermal wells, which can be likewise correlated for the oil well too. The study was done only on high-temperature wells that are water-based and likewise, the study did not account for surface conditions in which the muds would be kept and the work neither considered the environmental impact of the formulated muds.

Fadairo et al. (2012b) incorporated an environmental view into his work, which can be seen as an extension to an earlier work. In this, they sought to determine by the use of Artificial Neural Network on the Matlab platform and MS Excel with the application of extrapolation, the relationship between density and temperature through the use of three muds namely Jatropha, canola and diesel. For the canola based mud had the slightest density change over a wide temperature margin of 290°C but Jatropha according to the previous study had a better toxicity level while Jatropha had the highest pH (Fadairo et al., 2012a,b) and this would ensure stability and cause bentonite to be lightly affected (Fadairo et al., 2012c). However, viscosity change in diesel mud is smaller than the Jatropha mud (Anawe et al., 2012). This implied that the combination of environmental factors with density variation could not be expressly achieved without shortfalls at their objectives. Culling from the previous work, the Jatropha and canola muds were still more biodegradable than diesel muds and this still placed synthetic muds over oil-based muds (Fadairo et al., 2012a). Fadairo et al. (2012b) had a correlation that yielded a quadratic function of density against temperature much similar to the work of Santoyo et al. (1999) that derived a quadratic equation relating viscosity and temperature (Santoyo et al, 1999; Fadairo et al., 2012b).

Amani (Amani, 2012; Amani and al-Jubouri, 2012) in two works looked at the effect of temperature and pressure on water-based muds and the rheological properties of oil-based muds under high pressure and temperature. He believed that rheological properties could be altered to achieve formulations that consider the temperature and pressure and must not fail. This is considerably an extension of the work conducted by Ibeh et al. (2008) and in line with Talalay and Gundestrup (2002). He (they) had stressed that the viscosity and yield point were evident in low temperature (250°F and below) but they increase with pressure increment. However, an area of alternate perspective is in the fact that Santoyo et al. (1999) and Fadairo et al. (2012) in their works had quadratic relationship with temperature and viscosity and density respectively (Santoyo et. al, 1999; Fadairo et. al, 2012b) while Amani (and al-Jubouri) (2012) believed the relationship of viscosity and temperature was more of an exponential one with both pressure and temperature (Amani, 2012; Amani and al-Jubouri, 2012).

However, a shortcoming in the work done by Fadairo et al. (2012b) was that the work did not account for time change or temperature change and pressure variation. Amani accounted for these parameters in his own work. In retrospect, the two research views were focused on only high-temperature and high-pressure wells and conventional wells and did not account for low temperature regions.

As for the use of biodiesel in synthetic drilling mud, Ismail et al. (2014) visually showed that rice bran oil was the most degradable and most non-toxic amongst other vegetable oils. This was based on a study conducted by the same to show the application of biodiesels in drilling muds. This was done with an environmental leaning in view. They undertook a study of the biodiesel-based muds in relation to the physical properties and toxicity. They stated that the vegetable biodiesel-derived muds fulfilled all the physical quality requirements of their tests. Likewise, Fadairo et al. (2012c) undertook another comparative study, which can be assumed to be an extension of the team's previous works and they undertook a study using inedible plants such as Jatropha, Moringa, algae and canola as the continuous phase in their experiment. Their work exposed that the inedible oils prove to have better filtration properties than diesel but algae had the lowest gel strength, plastic and apparent viscosity of the inedible oil-based muds and had the highest pH which would ensure hole stability and reduce wear rate during drilling. This experiment proved that the unicellular "vegetable" algae had preferable qualities when it came to their viscosity parameters followed by canola then Moringa and then Jatropha. This continues as a line of thought that vegetable oils have better qualities than the conventional diesel (Fadairo et al., 2012c; Ismail et al., 2014). In terms of toxicity research, Ismail et al. (2014) conceived a study on toxicity based on effect of fish namely sea bass and red snapper while Fadairo et al. (2012c) used bean seedlings.

This paper is considerably an extension of the works of Talalay and Gundestrup (2002), Khodja et al. (2010) and Fadairo et al. (2012a, b, c). Elements from Amani (2012) and Amani and al-Jubouri (2012) as well as Ismail et al. (2014) will be incorporated into the methodology framework of this research.

Methodology

Materials and Equipment

The following reagents and materials were utilized; Bentonite, Barite, Water, Algae, Bean Seeds, Cork, Filter Papers, Soxhlet Extractor, Mass Balance, Conical Flasks, Rotary Viscometer, pH Meter, Separating Funnel, Mixer, Hot Plate, Stirrer, API Filter Press, Mud Balance, Resistivity Meter, Beakers, Heating Mantle, Retort and Clamp, Measuring Cylinder, Condensers, Round-Bottom Flasks, Reagent Bottles, Mortar and Pestle, Spatula, Vernier Caliper, Oven, Cleveland Open Cup Flash Tester, Ethanol, Methanol, Sodium Hydroxide and N-Hexane.

Procedure

Algae Collection

The algae were sourced from the gutters within the University complex.

Ethyl biodiesel Preparation

The biodiesel was prepared in the laboratory. First the algal oil was extracted from the algae using a hexane extraction process with the aid of a Soxhlet's extractor. The extracted oil was distilled to remove the hexane so as it could be reused in further extractions.

Fatty acid experiment was conducted on 7ml of distilled algal oil, which is used to determine the viability of the transesterification process.

The remaining portion of the algal oil was trans-esterified using KOH as the catalyst. At this point a mixture of coconut and algae was used, as the portion was small. The mixture of the ester and glycerin was placed in a separating funnel and left for 12 hours to separate.

The separated biodiesel was washed with warm water and then separated to remove any entrained glycerin. The final product was then stored.

This stored biodiesel was mixed in proportions with the ethanol to produce ethyl biodiesel. Subsequently, a flash point test was conducted on the "ethyl biodiesel".

Mud Preparation

The mud was prepared to a set density of 9.5 ppg. This was determined from the mud used for comparison.

The mud was formulated in the ratio of 50% oil, to 30% water to 9% barite to 7% clay to 3% salt to 1% emulsifying agent.

Tests were run on the mud obtained to make comparative analysis with an industrial-obtained drilling mud. The tests included viscosity, gel strength, filtration and density tests as well as a toxicity test.

The viscosity and gel strength tests were done using a rotary viscometer, while the filtration test was done using an API Low-Pressure Filter Press and the Density test was done using a mud balance.

The toxicity test is an environmental test that analyses the effect of the muds on growth of plants (bean) seeds in days of exposure.

Results and Discussion

Lipid Content and Phytochemical Analysis of Algae

According to the conditions the sample species was subjected to in

this study, the Spirulina platensis sample was seen to have a lipid yield of 8.57% by weight of the Spirulina platensis powdered. The experiment obtained 710 grams of dried and powdered algae after a bucket weight equivalent. It can be implied that the conditions in which the Spirulina was obtained affected the overall yield of the species, such conditions being the weather (the algae collected during the dry season which was likewise very humid and cold), lighting conditions of the environment and lack of nutrients for the algae. Likewise, the yield was small and could have been improved through catalyst use (H.I. El-Shimi et al., 2013).

The phytochemical properties of the mud such as the density, the acid value and percentage of free fatty acid were analyzed in the lab and are outlined in Table 1.0. These data were used to distinguish the extracted oil for the production of biodiesel. Due to the yield obtained the biodiesel could not be formed from the algae obtained alone and a mixture with coconut was used to further the experiment.

Temperature Effect on Density

As depicted in the plot of temperature against density in Fig. 1.0, it can be seen that for the industry-obtained synthetic mud the density saw a slight density increase overall through a 22°C rise in the mud temperature from -1°C through to room temperature from 9.4 to 9.5 ppg. This indicates that the arithmetic linear density change per 1°C temperature rise is 0.0045ppg/°C. However, for the ethyl biodiesel formulated mud there was a more marginal rise in the density in the ethyl biodiesel based mud from 9.45ppg to 9.5ppg within the same temperature rise of 22°C. This implies that the density drop in the formulated mud is lower than the biodiesel mud by 50% over the same temperature range. Therefore it means that the fluid will become compact earlier due to a drop in average temperate region temperatures.

In looking at the industrial mud, the density increased by 1% over the temperature range (-1° and 21°C) while the ethyl biodiesel density increased by 0.5% over the same range. The rationale behind this density change is that the formulated mud has a longer time for molecules to be compacted than the biodiesel variant.

The more stable density of ethyl biodiesel based mud implies that the mud can maintain necessary hydrostatic pressure over reduced temperatures and carry cuttings leading to better cleaning of the hole.

Table 1.0: Phytochemical Properties of *Spirulina Platensis*

Properties	Unit	Value
Dried Powder Weight	g	710
Lipid Weight	g	60
Lipid Content	%	8.45
Lipid Density	$g.m^{-3}$	875
Acid Value	mgKOH/g	49
Free Fatty Acid	%	24.5

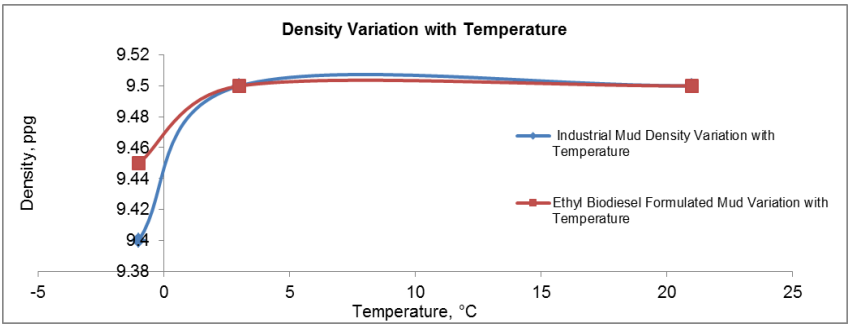

Figure 1.0: A Plot of Density Variation against Temperature

Temperature Effect on the Mud Viscosity

For the industrial synthetic base mud, it can be seen that the dial readings greatly increased with the decrease in temperature but for the formulated mud, the dial readings slightly increased with a decrease in temperature. Culling from Figure 2.0, at 600RPM and 300RPM at -1°C the dial reading was 179 and 110 while at 3°C the dial reading was 85 and 64 and at 21°C it was 138 and 78 respectively for the industrial mud and for the formulated mud, the dial read for 600RPM and 300RPM at -1°C. However, there was only a slight increase in the plastic viscosity of the biodiesel mud over the same range of temperature decrement, that is, from 60 cp at 21°C to 69cp at -1°C as seen in Fig. 3.0. The apparent viscosity of the biodiesel mud rose by 20.5 cp over the same range of temperature decrease also as noticed in Fig. 4.0 while the apparent viscosity for the ethyl biodiesel based mud increased by 9cp over that same temperature range.

It can be seen that the Fig. 5.0 and 6.0 above that between dial speed of 200 and 300 rpm there is a sharp and slight change in the dial readings at all temperatures with greater deviation at lower temperatures. This shows that within that transition it takes more torque to overcome viscous friction at those speeds. At the varied temperatures it implies that both muds are Arrhenius temperature-dependent fluids. The higher the viscosity, the lower the temperature and vice versa. The viscosity, which is a function of the activation energy, is inversely related to the temperature (Amani, 2012). The ethyl biodiesel based mud has less surface tension than the industrial mud as seen by the lower viscosity of the mud as against the temperature.

The abrupt changes in the dial readings at that dial speed is caused by possible change in the activation energy at isothermal conditions caused by increased torque during rotations.

The plastic viscosity of the ethyl biodiesel based mud only saw a 5cp rise in the decrease of temperature against the 20cp rise of the biodiesel variant. This slight plastic viscosity drop in the ethyl biodiesel based mud is seen

as better because there would be an increase in the faster drilling rate as against the slower drilling rate in the industrial mud as a result of increased wear and tear. The drop in plastic viscosity of the ethyl biodiesel based mud from lower -1°C to the room temperature is 44.4% lower than the industrial mud. The stability of the biokerosene mud also causes more enhanced performance in reduced temperatures including reduced trip time. For the plastic viscosity, the industrial mud decreased 13% over the 21°C-rise while the ethyl biodiesel based decreased 15.6% over the same temperature rise.

This implies that although the plastic viscosity of the ethyl biodiesel based is lower than the industrial mud, the viscosity will reduce faster despite the profile above. Likewise, for the apparent viscosity of the industrial mud, the viscosity at 21°C was 22.9% lower than the viscosity at -1°C; however the ethyl biodiesel based mud had an 8% decrease in viscosity at 21°C. However, the relationship of the mud viscosity displayed a more exponential relationship as against a quadratic relationship as stated by previous works. This exponential relationship was still closely related to the Bingham format.

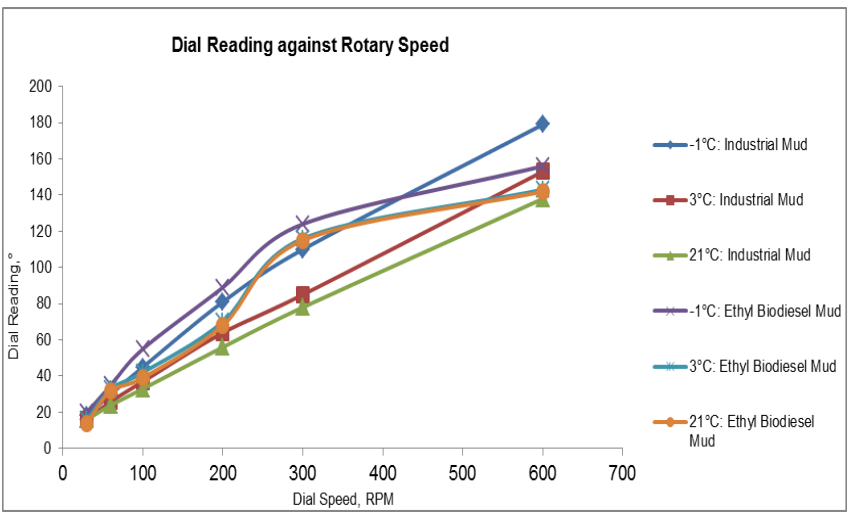

Figure 2.0: A Plot of Dial Reading against Rotary Dial Speed

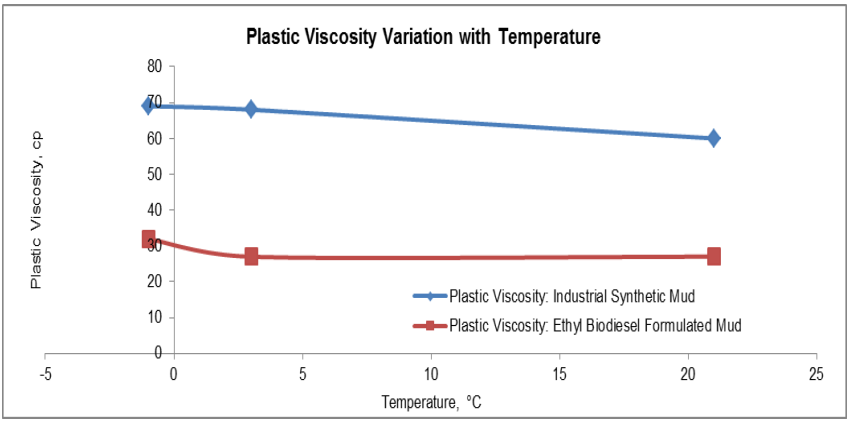

Figure 3.0: A Plot of Plastic Viscosity against Temperature

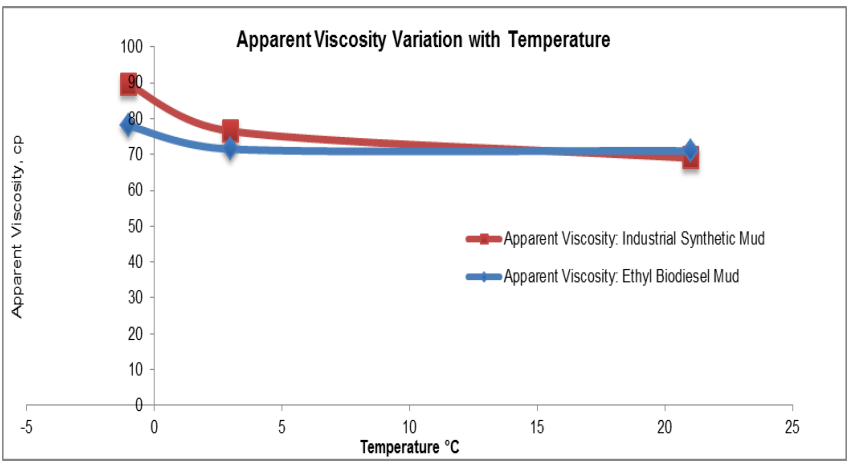

Figure 4.0: A Plot of Apparent Viscosity Variation against Temperature

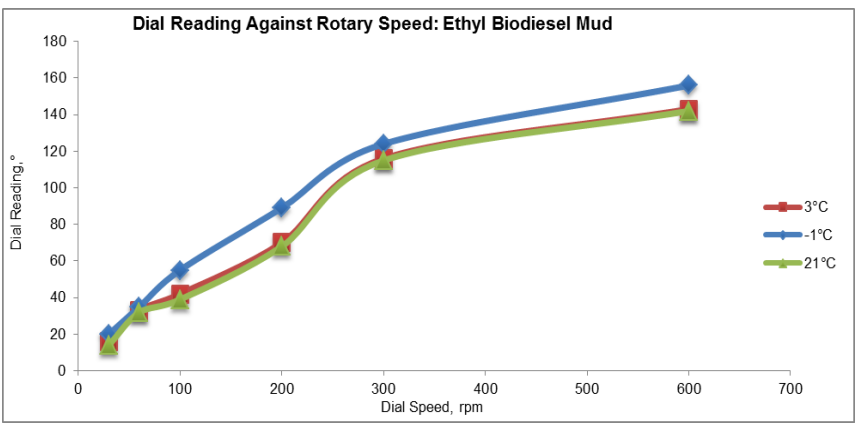

Figure 5.0: A Plot of Dial Reading against Rotary Dial Speed for Ethyl biodiesel Mud

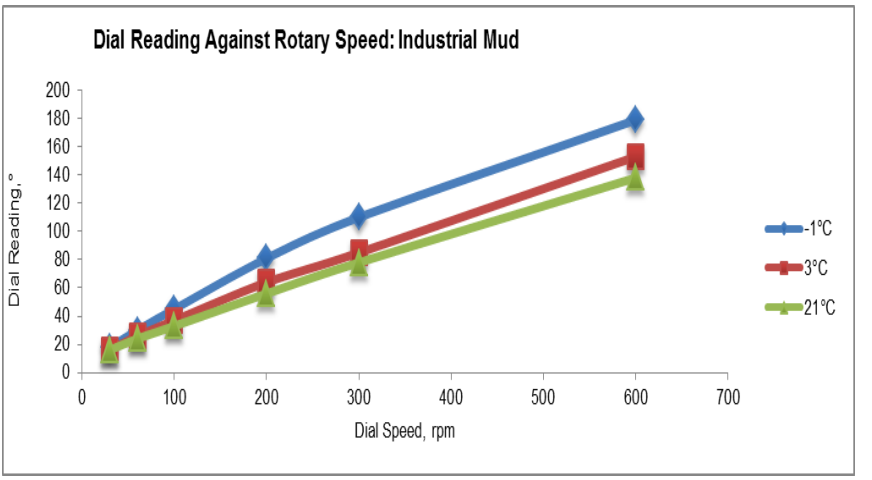

Figure 6.0: A Plot of Dial Reading against Rotary Dial Speed for Industrial Mud

Temperature Effect on Mud Gel Strength

It was seen that temperature of the mud affected the gel strength of the two muds quite differently. The ethyl biodiesel based mud had higher gel strength for the 10-second test than the biodiesel industrial variant. Also observed from Figure 7.0, it can be inferred that the gel strength of ethyl biodiesel after 10 minutes had an overall decrease with the lowest recorded ethyl biodiesel gel strength at 3°C, however the gel strength after 10 minutes was still higher than the ones of the industrial mud. This implies that the biofuel can carry and suspend cuttings more easily than the ethyl biodiesel can, although the change in the biodiesel mud gel strength is less pronounced over the temperature range than the ethyl biodiesel. It was noticed that there was a zero net change between the differential values across the temperature ranges after the 10-minute test but there was a 200% increase in differential value across the temperature range. The gel strength of the industrial mud decreased 22% and 16.7% respectively for the 10-minute and 10-second tests while the ethyl biodiesel based mud gel strength decreased 14% and 16.7% for the 10-minute and the 10-second tests.

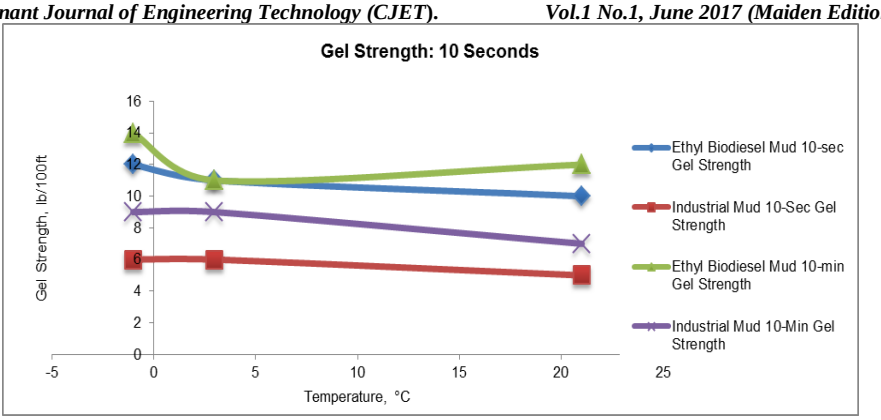

Figure 3.0: A Plot of Gel Strength (10-second and 10-minute) against Temperature

Low Pressure and Ambient Temperature Effect on the Mud Filtration Properties

It was observed that the effect of pressure also was varied for the muds. The ethyl biodiesel brought a lower thickness of mud cake at 0.1mm while the biodiesel brought a mud cake thickness of 0.2mm. This implies that the ethyl biodiesel based mud can contain the fluid in the reservoir enough not to damage the formation. The thicker mud cake can cause for the drillstring to be stuck so as not to let it rotate easily within the borehole. Likewise for the two muds there was negligible fluid loss after filtration for 30 minutes and this can be attributed to the low pressure and inability of the fluid to seep through the mud cake formed at such pressure. This implies, as seen from Figure 8.0, that the muds are not porous but the ethyl biodiesel based mud is selected over the diesel mud based on the thickness of the mud cake. The mud cake thickness of the ethyl biodiesel based mud falls well below the acceptable limit of $\frac{2}{32}$ inches at 0.0394 inches while that of biodiesel is 0.0787 inches that is 50% thicker than the ethyl biodiesel, which is also well above the acceptable thickness.

The volume of filtrates was negligible due to the pressure at which they were exerted.

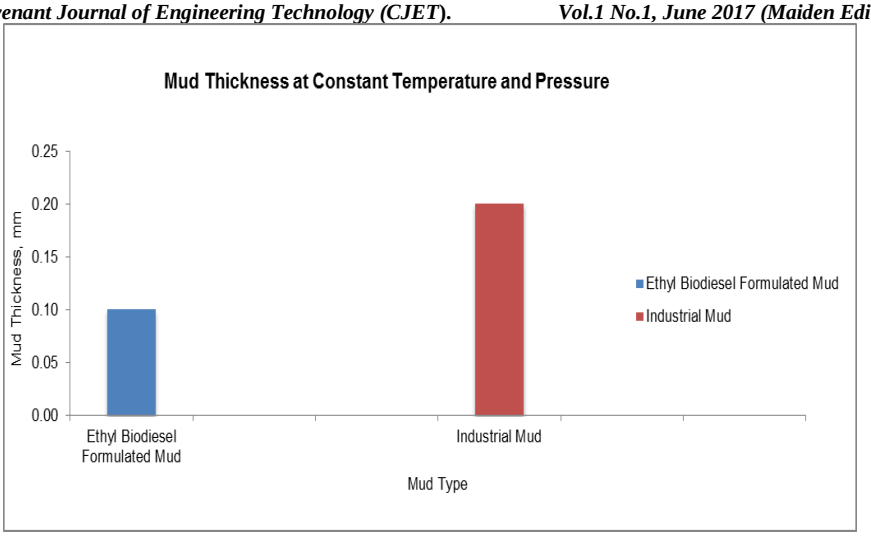

Figure 4: A Plot of Mud Thickness against Type of Mud

Effect of Exposure Time on Seed Growth

When bean seeds were exposed to the muds, the seeds started experiencing growth on the 4th day of the test. It was observed that the bean seed exposed to ethyl biodiesel grew much more than the one exposed to biodiesel (industrial). The height of the beanstalk exceeded 11 cm in 10 days while exposed to ethyl biodiesel and the beanstalk had a total growth of 8.9 cm in the same amount of days. This represents 24.7% more growth in the ethyl biodiesel based mud over the biodiesel industrial mud. Also the seed exposed to the ethyl biodiesel lasted 16.7% times longer than the one exposed to the industrial mud. This implies that the biodiesel is more toxic to the bean seeds than the ethyl biodiesel as shown on Figure 9.0, where the bean plant started to die after the 8th day when exposed to the biodiesel. This can be explained with the chemical structure of ethyl biodiesel, which has less aromatic components than the ethyl biodiesel.

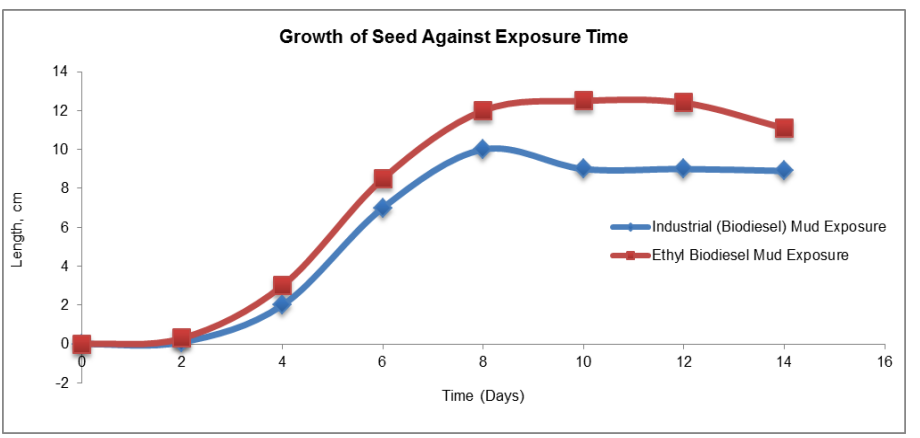

Figure 5: A Plot of Exposure Time against Seed Growth

Conclusion

From the undertaken research, it can be seen that the ethyl biodiesel based mud passed all the tests it was subjected to over the industrial mud. Although, both muds experienced rises in the viscosities over temperature decrease, the ethyl biodiesel had more stable viscosity readings over the temperature range examined. This has implications on the optimal drill rate being achieved faster in the mud than in biodiesel mud and this also has implication on the effects of the environmental temperatures being less due to that near slight change in the ethyl biodiesel based mud viscosity. In area of density, the ethyl biodiesel based mud had much lower density change, which is a requirement for temperate-region muds. This implies that the overburden pressure of the mud can be maintained at cold temperatures over the biodiesel mud. It was also noticed that the ethyl biodiesel based mud would not affect the environment due to higher biodegradation than biodiesel mud variant as the seeds exposed to the ethyl biodiesel based mud continued to grow even after 10 days in the soil.

References

This draws the conclusions that the ethyl biodiesel based mud has better rheological and environmental properties than the industrial (biodiesel mud) at reduced temperatures.

1.Amani, M. (2012). The Rheological Properties of Oil-Based Mud Under High Pressure and High Temperature Conditions. Advances in Petroleum Exploration and Development , 3 (2), 21-30.

2.Amani, M., & Al-Jubouri, M. (2012). The Effect of High Pressure and High Temperatures on the Properties of Water Based Drilling Fluids. Energy Science and Technology , 4 (1), 27-33.

3.Anawe, P., Efeovbokhan, V., Ayoola, A., & Akpanobong, O. (2014). Investigating Alternatives to Diesel in Oil Based Drilling Mud Formulations Used in the Oil Industry. Journal of Environment and Earth Science , 4 (14), 70-77.

4.Apaleke, A., Al-Majed, A., & Hossain, M. (2012). Drilling Fluid: State of the Art and Future Trend. North Africa Technical Conference and Exhibition. Cairo: SPE 149555, pp. 1-13.

5.Behnamanhar, H., Noorbakhsh, S., & Maghsoudloojafari, H. (2014). Environmentally Friendly Water-Based Drilling Fluid for Drilling of Water-Sensitive Formation. Journal of Petroleum and Gas Exploration Research , 4 (4), 60-71.

6.Fadairo, A., Adeyemi, A., Ameloko, A., & Falode, O. (2011/2012). Modeling the Effect of Temperature On Environmentally Safe Oil Based Drilling Mud Using Artificial Neural Network Algorithm. Petroleum & Coal , 54 (1).b

7.Fadairo, A., Ameloko, A., Adeyemi, G., Ogidigbo, E.,

& Airende, O. (2012). Environmental Impact Evaluation of a Safe Drilling Mud. SPE Middle East Health, Safety, Security and Environment Conference and Exhibition., Abu Dhabi: SPE152865, pp. 1-9.a

8.Fadairo, A., Falode, O., Ako, C., Adeyemi, A., & Ameloko, A. (2012). Novel Formulation of Environmentally Friendly Oil Based Drilling Mud. New Technologies in the Oil and Gas Industry , 49-80.c

9.Ismail, A., Ismail, N., Jaafar, M., & Ruhana, H. (2014). The Application of Biodiesel as an Environmental Friendly Fluid to Drill Oil and Gas Wells. The 5th Sriwijaya International Seminar on Energy and Environmental Science & Technology, (pp. 16-20). Palembang.

10.Khodja, M., Khodja-Saber, M., Canselier, J. P., Cohaut, N., & Bergaya, F. (2010, November 02). Drilling Fluid Technology: Performances and Environmental Considerations. (I. Fuerstner, Ed.) Products and Services; from R&D to Final Solutions , 227-256.

11.Ramirez, M., Clapper, D., Sanchez, G., Luna, E., & Preciado, O. S. (2005). Aluminum-Based HPWBM Successfully Replaces Oil-Based Mud To Drill Exploratory Wells in an Environmentally Sensitive Area. 2005 SPE Latin America and Caribbean Petroleum Engineering Conference. SPE 94437.

12.Santoyo, E., Santoyo-Gutierrez, S., Garcia, A., Espinosa, G., & Moya, S. (1999/2000). Rheological Property Measurement of Drilling Fluids Used in Geothermal Wells. Applied Thermal Engineering , 21, 283-3012.

13.Schilithius, R. (1938). Connate Water in Oil and Gas Sands. Trans. , 127, 199-212.

14.Talalay, P., & Gundestrup, N. (2002). Hole Fluids for Deep Ice Core Drilling. National Institute of Polar Research (

Covenant Journal of Engineering Technology (CJET) Vol. 1, No. 1, June 2017

An Open Access Journal Available Online

Insight into Possibility of Producing Biokerosene From Jatropha Curcas Plant in Nigeria

Fadairo Adesina*, Adeyemi Gbadegesin, Anawe Paul & Orodu Oyinkepreye

Department of Petroleum Engineering, Covenant University,
Ota, Ogun State,
*(corresponding author) adesinafadairo@yahoo.com

Abstract: In this research project, a non-edible vegetable oil was produced from jatropha curcas seed through chemical extraction method using the soxlet apparatus as a substitute fuel for kerosene lamps and its usability was investigated as pure oil and as a blend with ethanol. Biodiesel produced from jatropha oil was analyzed, from the analysis, properties such as free fatty acid content, acid value, pour point, viscosity @ 400C, density, specific gravity etc. where determined. The oil had 14% free fatty acid content, density of 920.4 3), specific gravity of 0.92.

Bio-kerosene production in this project attempted two methods which are; distillation of the biodiesel and blending of the biodiesel with ethanol to raise the cetane number to that close to the cetane number of fossil kerosene. Distillation of the biodiesel using the distillation apparatus to remove the light end of the biodiesel to produce a lighter liquid with low flash and boiling point compare to the biodiesel. The distillation temperature used was about 1750C-3250C, this is the boiling temperature range for fossil kerosene.

The second approach focused on blending biodiesel with ethanol, with aim to improve the cetane number. Ethanol was blended with biodiesel at different percentage; E5B95 (5% ethanol, 95% biodiesel), E20B80 (20% methanol, 80% biodiesel), E50B50 (50% methanol,50% biodiesel), E70B30(70% methanol, 30% biodiesel). Each sample was analyzed for its physicochemical properties and compared with that of fossil kerosene.

Introduction

Biodiesel is defined by ASTM International as a fuel composed of mono-alkyl esters of long-chain fatty acids derived from renewable vegetable oils or animal fats meeting

the requirements of ASTM D6751. Biodiesel is receiving increased attention as substitute, non–toxic, biodegradable, and renewable diesel fuel. Its properties vary depending on the oil feedstock and alcohol used but it can always be used as a direct substitute for diesel fuel (Fernando, 2004). A sustainable bio-fuel has two favorable properties which are its availability from renewable raw material and its less negative environmental impact than that of fossil fuels. Various vegetable oil extraction and trans-esterification technologies are currently used in the production of biodiesel fuel. As an alternative fuel, vegetable oil is one of the renewable fuels (Fernando, 2004; Bryan, 2009). Vegetable oil is a potentially inexhaustible source of energy with an energetic content close to that of Diesel fuel. The vegetable oil fuels have not been acceptable because they were more expensive than petroleum fuels. The major problem associated with the use of pure vegetable oils as fuels, for diesel engines, is caused by the high fuel viscosity in compression ignition, practically the high viscosity of vegetable oils ranges from (30-200 Centistokes) as compared to that to diesel (5.8-6.4 Centistokes) (Chakraborty and Sarkar, 2008). There are more than 350 oil bearing crops identified, among which only sunflower, safflower, soybean, jatropha curcas, cotton-seed, rape-seed and peanut oils are considered as potential alternative fuels for diesel engines. There are different ways the viscosity can be reduced; Trans esterification seems to be the best choice, as the physical characteristics of fatty acid esters (biodiesels) are very close to those of Diesel fuel and the process is relatively simple (Fernando, 2004; Chakraborty and Sarkar, 2008; Falasca, Ulberich and weldman, 2006; Aldo, Okullo, Temn, Ogwok, and Ntalikwe, 2011).

Energy Content of Biofuels

1. The energy content of biodiesel is about 90% that of petroleum diesel.
2. The energy content of ethanol is about 50% that of gasoline.
3. The energy content of butanol is about 80% that of gasoline.
4. Most biofuels are at least as energy dense as coal, but produce less carbon dioxide when burned.
5. The lower energy content of biofuels means vehicles travel shorter distances on the same amount of fuel. This has to be taken into account when considering emissions.

Every single part of the plant can be useful for human consumption directly or indirectly. Below are some of its uses (Chakraborty and Sarkar, 2008):

1. The Jatropha oil has its characteristic which is similar to diesel, a distillate from crude oil. So cars can use this oil with little change in their design.
2. It is used as a domestic livestock for skin diseases, sore and rheumatism.
3. The roots are believed to serve as an antidote for snake bites.
4. A dark blue die is extracted from the bark which serves as a coloring matter for clothes, fishing nets and lines.

Materials

The materials and reagents used in carrying out the research are as follows: Jatropha oil, Potassium

hydroxide (KOH), Sodium hydroxide (NaOH), Hydrochloric acid (HCl), Sulphuric acid, Isopropyl alcohol, Sodium methoxide, Phenolphthalein Additives. The instruments and equipment used in carrying out this study are: Soxhlets apparatus, Heating mantle/hot plate, Brookfield viscometer, Refrigerator, Conical flasks, weighing balance, Measuring cylinders, Beakers, Magnetic stirrer, Liebig condensers, Thermometer (capable of measuring both negative and positive temperatures), Pipettes and burette, Distillation apparatus, methanol (99% purity)

Methodology

A. Oil Extraction

1. A standard weight of Jatropha seed is crushed and placed in a three necked flask of reasonable capacity to accommodate the material.
2. Hexane was used as a solvent for the extraction of the oil. The volume of hexane needed was determined by the ratio of 6:1.
3. A reflux condenser was connected to the flask and placed in a heating mantle with a set temperature of 55oC - 60oC
4. The mixture was allowed to stir for about 8 hours. The solvent mixture and resulting oil were filtered to remove suspend solids.
5. The mixture was placed in a rotary evaporator to evaporate the solvent and thus, Jatropha oil was obtained.

B. Free Fatty Acid Test

The acid value is defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids present in one gram of fat. It is a relative measure of rancidity as free fatty acids are normally formed during decomposition of oil glycerides. The value is also expressed as percentage of free fatty acid calculated as oleic acid.

i. Principle

The acid value is determined by titrating directly the oil/fat in an alcohol medium against standard KOH or NaOH solution.

ii. Analytical importance

The value is a measure of the amount of fatty acid which has been liberated by hydrolysis from the glycerides due to the action of moisture, temperature and or lypolytic enzyme lipase.

iii. Procedure

- Prepare a known base solution (weigh one gram of KOH and dissolve in in one liter of distilled water.)
- Take 10ml of isopropyl alcohol using syringe and put into a small beaker.
- Measure out 1ml of sample oil using syringe, pour into the small beaker containing the 10ml isopropyl alcohol, the mix (titration solution)
- Add few drops of phenolphthalein into the titration solution
- Using syringe, take 20ml to 50ml of your know base solution
- Titrating the (oil, propyl alcohol and phenolphthalein) against the base solution by adding drops of the base solution using the syringe into the titration solution until it turns pink.
- Titration value is recorded.

C. Acid Value Determination

Two grams of sample was dissolved in 50 cm3 of mixed neutral solvent (25 cm3 diethyl ether with 25 cm3 ethanol carefully neutralized with 0.1M NaOH using 1 %

phenolphthalein solution), the mixture was titrated with 0.1M NaOH aqueous solution with constant shaken to faint pink color.

i. Calculation

$$Acid\ Value = \frac{Titre\ Value \times 5 \times 61 \times 0.0028}{Weight\ of\ Sample\ (g)} = \left(\frac{mgKOH}{g}\right) \quad (1)$$

$$FFA = \frac{Acid\ Value}{2} = \left(\frac{mgKOH}{g}\right) \quad (2)$$

D. Determination of Saponification Value

The saponification value is the number of mg of potassium hydroxide required to saponify 1 gram of oil/fat.

i. Principle

The oil sample is saponified by refluxing with a known excess of alcoholic potassium hydroxide solution. The alkali required for saponification is determined by titration of the excess potassium hydroxide with standard hydrochloric acid.

ii.Analytical importance

The saponification value is an index of mean molecular weight of the fatty acids of glycerides comprising a fat. Lower the saponification value, larger the molecular weight of fatty acids in the glycerides and vice-versa.

iii.Procedure

0.5 M KOH was prepared in 95 % ethanol, 2g of oil sample was weighed and 25 cm of the KOH was added, 25 cm3 of the blank solution was also measured into a conical flask, the two sample were then connected to a reflux apparatus and allowed to boil for an hour until the reflux is completed, 1 cm3 of phenolphthalein was added to the mixture and the resulting mixture was titrated while hot against 0.5 M HCl acid solution, the volume of the acid used to attained the end point was recorded, the blank determination was carried out using the same procedure described above until the color changes from blue to transparent white, then the volume of acid used was noted.

iv. Calculation

$$Saponification\ value = \frac{56.1 \times T\ (V_o - V_1)}{M} \quad (3)$$

here, T= molarity of the standard KOH solution used, Vo=volume of acid used for the first titration with oil sample, V1=volume of acid used for the second titration of the blank solution, M= mass of the oil sample used.

E. Viscosity Determination

Viscosity is the measure of material resistance to flow, higher viscosity materials flows with great difficulty and a material with less viscosity flow more easily. Viscosity is important to diesels and biodiesels because it has impacts on the operation of some engine components such as the fuel pump. The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal notion of "thickness".

i. Procedure

400 cm3 of oil sample was poured into the cup of "Clandom Viscometer, Model VT – 03 Viscometer", the lowest number spindle was selected and screwed into the underside of the viscometer, the cup containing sample was carefully locked into position so that the spindle cone would be completely immersed in the sample, the machine was switched on and pointed deflection on the machine scale was observed for about ten

seconds and allowed to stabilize, after which the position of the pointer on the scale was read off, this gives the value of viscosity of the oil sample in centipoises.

F. Density Determination

I. Definition

Density is an important physical property of a material or any matter, as each compound and element has a specific density associated with it. Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume.

II. Procedure

- The mud balance was cleaned properly to avoid any contamination of the oil sample.
- Fill the already cleaned and dried cup to the top with the oil sample.
- Place the lid on the cup and set it with a gentle rotational motion. Be sure that some oil is expelled through the hole in the cup as this will ensure the cup is full and also will free any trapped air or gas.
- Cover the hole in the lid with a finger and clean all oil from the outside of the cup and arm. Then thoroughly dry the entire balance.
- Place the balance on the knife edge and move the rider along the outside of the arm until the cup and arm are balanced as indicated by the bubble.
- Read the mud weight and specific gravity at the edge of the rider towards the cup.

G. Production of Biodiesel

The process of producing Bio Diesel can be as simple or as tasking as you want it to be, though the more effort you go through, the more percentage of oil you will be able to convert to biodiesel, and the better quality biodiesel you will have as a result. The first step of the process is to reduce FFA content in vegetable oil by esterification with methanol and acid catalyst. The second step is transesterification process, in which triglyceride portion of the oil reacts with methanol and base catalyst to form ester and glycerol. The acid catalyst is generally sulfuric acid while the base catalyst is usually sodium or potassium hydroxide. Product from the reactions is separated into two phases by gravity. The upper portion is then purified by water washing process to meet the biodiesel fuel standards.

i. Esterification

Esterification is mainly the reaction between alcohols and carboxylic acids to make esters. It also looks briefly at making esters from the reactions between acyl chlorides (acid chlorides) and alcohols, and between acid anhydrides and alcohols.

The esterification reaction is both slow and reversible. The equation for the reaction between an acid RCOOH and an alcohol R'OH (where R and R' can be the same or different) is:

ii. Trans-esterification (alcoholysis)

Trans-esterification of oils (vegetable, used cooking oil) is the most well-known method of producing biodiesel. Trans-esterification, also known as alcoholysis is the reaction of a fat or oil (triglyceride) with an alcohol to form fatty acid alkyl esters, methyl and ethyl esters (which are excellent substitutes for biodiesel) and glycerol as shown in the reaction below;

CH2-OOC-R1 R1-COO-R’ CH2-OH

CH-OOC-R2 + 3R'OH R2-COO-R'+ CH-OH CH2-OOC-R3 R3-COO-R' CH2-OH

Triglyceride Alcohol Esters Glycerol (Vegetable oil) trans esterification as an industrial process is usually carried out by heating an excess of the alcohol with vegetable oils under different reaction conditions in the presence of an inorganic catalyst. The reaction is reversible and therefore, excess alcohol is used to shift the equilibrium to the products side. The alcohols that can be used in the trans-esterification process are methanol, ethanol, propanol, butanol and amyl alcohol, with methanol and alcohol being frequently used. The reactions are often catalyzed by an acid, a base or enzyme to improve the reaction rate and yield. Alkali-catalyzed trans-esterification is much faster than acid-catalyzed trans-esterification and is most often used commercially (Ma, & Hanna, 1999; Ramachandran, Suganya, Gandhi, & Renganathan, 2013; Agrawal, 2007). The alkalis which are used include sodium hydroxide, potassium hydroxide, and carbonates. Sulphuric acid, sulfonic acids, and hydrochloric acids are the usual acid catalysts. After trans-esterification of triglycerides, the products are a mixture of esters, glycerol, alcohol, catalyst and tri-, di- and monogylcerides which are then separated in the downstream (Ma & Hanna, 1999; Freedman, Butterfield, & Pryde, 1986; Demirbas, A, 2005). The process of trans-esterification brings about drastic change in viscosity of the vegetable oil. The high viscosity component, glycerol, is removed and hence the product has low viscosity like the fossil fuels. The biodiesel produced is totally miscible with mineral diesel in any proportion. Flash point of the biodiesel is lowered after trans-esterification and the cetane number is improved. The yield of biodiesel in the process of trans esterification is affected by several process parameters which include; presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil.

iii. The effect of reaction time

The reaction time in the esterification and trans-esterification process because both processes experience an increase in conversion rate which increases the yield.

iv. The effect of reaction temperature

For both processes, the reaction temperature was close to the boiling point of methanol (550C - 600C). The top of the heating vessel should be covered to avoid evaporation of methanol during the esterification and trans-esterification process.

H. Biodiesel Production Process in Laboratory Environment

For this process, 250ml of jatropha oil will be used

- Filter oil remove particles or solid suspension.
- Heat oil to about 80oC - 100 oC to remove moisture: this is very important.
- Allow oil to cool to about 55oC
- Measure out methanol equal to 17% of the volume of oil used. For 250ml oil, 43ml of methanol is used.
- Measure out sulphuric acid: 1liter of oil to 1.5ml of sulphuric acid. For 250ml oil, 0.4ml is used.
- Mix methanol, sulphuric acid and oil for 2hours @ 55 oC - 60 oC.

- The mixture is left for 12hours.
- Prepare methoxide: 3% methanol by volume of the 250ml oil is measured: 2.5g of KOH is dissolved in the methanol.
- Add methoxide to oil and mix for 1hour.
- Pour the mixture into a separating funnel (two phase separation appears), allow glycerol to settle then drain of.
- Water wash the biodiesel with warm water and dry
- Determine the physical and chemical properties of the biodiesel.
- Carryout 3-27 test on biodiesel.

I. Production of Bio-Kerosene

Two methods were used in a quest to achieve this;

(i) Distillation of biodiesel

(ii) Blending of biodiesel with ethanol.

i. Distillation of biodiesel

In an aim to produce bio-kerosene, I distilled the produce biodiesel at a temperature range of (1750C - 3250C). This temperature range was used because it's the boiling point of fossil kerosene.

ii. Blending of biodiesel with ethanol

Blending of biodiesel with ethanol at different percentage;

E5B95 (5% ethanol, 95% biodiesel), E20B80 (20% methanol, 80% biodiesel), E50B50 (50% methanol, 50% biodiesel), E70B30 (70% methanol, 30% biodiesel).

iii. Flash point determination

The flash points of the blends are determined through the use of an Automatic flash point tester closed cup

Results and Discussion

Table 1: Results of the Analysis of Chemical and Physical Properties of Jatropha Oil

PROPERTIES OF JATROPHA OIL	Frequency
Free Fatty acid (FFA %)	14%
Acid value ($^{mgKOH}/_{g}$)	28
Pour point (^{0}C)	5.0
Viscosity @ 40 ^{0}C (cst)	36
Viscosity @100^{0}C(cst)	14.4
Density ($^{kg}/_{m^3}$)	920.4
Specific gravity	0.92
Saponification value($^{mgKOH}/_{g}$)	187

Table 2: Physiochemical Analysis of the Jatropha Oil Biodiesel

Jatropha biodiesel	Value
Pour point (^{0}C)	2
Viscosity (cst)	4.8
PH value	8
Density ($^{kg}/_{m^3}$)	874.73
Specific gravity	0.875

Table 3: Flash Point Analysis of the Various Biodiesel Ethanol Blends.

BLENDS	B100	B95E5	B80E20	B50E50	B30E70	B100
FLASH POINT(^{0}C)	175	125	98	52	25	13

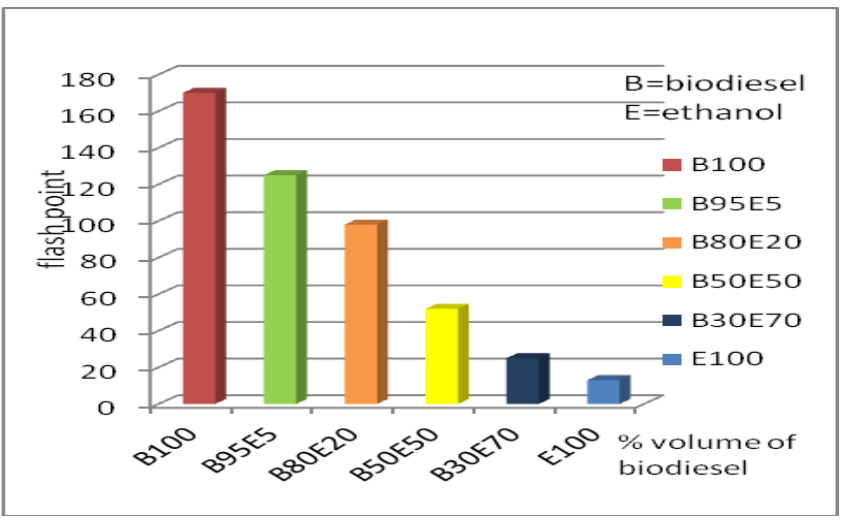

Figure 1: Chart showing Percentage by volume of Biodiesel to Ethanol

1.5 Discussion

The aim of this paper is to produce bio-kerosene from jatropha oil. The physical and chemical properties of jatropha oil and jatropha biodiesel are showcase in table 1 and 2 respectively. Initial method to produce bio-kerosene was to distill bio-diesel at the boiling point of fossil kerosene, but this method was not a success.

The second method was to blend bio-diesel with a solvent that will raise the cetane number of the bio-diesel to that close to kerosene, solvent such as acetone peroxide, alkyl nitrate and ethanol. Ethanol was chosen because of its availability compared to others.

Acetone peroxide wasn't used because it's an unstable solvent. Blending of ethanol with bio-diesel was a successful one as shown in figure 1, but solubility of the mixture is a problem. Ethanol solubility in bio-diesel reduces with increase in ethanol percentage. From table 3, the flash point of the blends reduces as the percentage by volume of ethanol increases. This shows that ethanol has a great effect on the flash point.

1.6 Conclusion

Pure bio-kerosene production might not have been a success, but with further analysis better solvent (non-fossil) could blended with bio-diesel to improve the cetane number, such that the flash point of the blend would very close to that of fossil kerosene.

Bio-fuels has shown to have advantages over fossil fuels because of low greenhouse gases emission when its being combusted. Blending of bio-diesel with fossil diesel reduces carbon emission.

Large scale bio-diesel Production Company would provide jobs and other source of fuels to reduce dependency on fossil fuel.

References

Agrawal, A/K. (2007). Biofuels (alcohols and biodiesel) Applications as Fuels for Internal Combustion Engines. Progress in Energy and Combustion Science, 33.3, 233 - 271.

Aldo, Okullo., Temn, A.K., Ogwok, P and Ntalikwe, J.W. (2011). Physico-Chemical Properties of Biodiesel from Jatropha and Castro Oi. International Journal of Renewable Energy Research, Vol.2. No. 1.

Bryan, R. Moser. (2009). Biodiesel Production Properties and Feedstock in Vitro Cell. Dev. Biol - Plant, 45: 229 - 266.

Chakraborty and Sarkar. (2008). Development of a Biofuel Lamp and it Comparism with a Kerosene Lamp . Journal of Energy in Southern African, Vol. 19. No. 2.

Demirbas, A. (2005). Biodiesel Production from Vegetable Oil via Catalytic and Non-catalytic Supercritical methanol Transesterification Methods. Progress in Energy and Combustion Scieence , 31(5), 466 - 487.

Falasca, Ulberich and weldman. (2006). Possibilities of Argentine to Produce Biokerosene for Aviation Under Sub-humid Dry to Acid Areas: Materials and Process for Energy. Communicating Current Research and Technology Developments.

Fernando. (2004). Developmentment of Novel Biofuel Blend Using Ethanol-Biodiesel-Diesel Microemulsion. Energy and Fuel, Vol. 18. Pp. 1695 - 1703.

Freedman, B., Butterfield, R.O., & Pryde, E.H. (1986). Transesterification Kinetics of Soyabean Oil 1. Journal of the American Oil Chemists' Society, 63(10), 1375 - 1380.

Ma, F., & Hanna, M.A. (1999). Biodiesel Production: a review. . Bioresource Technology, 70(1), 1 - 15.

Ramachandran, K., Suganya, T., Gandhi, N.N., & Renganathan, S. (2013). Recent Developments for biodiesel Production by Ultrasonic assist

Transesterification using different Heterogeneous Catalyst: A Review. Renewable and Substainable Energy reviews, 22, 410 - 418.

Covenant Journal of Engineering Technology (CJET) Vol. 1, No. 1, June 2017

An Open Access Journal Available Online

An Exploratory Study of Techniques for Monitoring Oil Pipeline Vandalism

Kefas Yunana, Sunday Olumide Adewale, Abraham Ayegba Alfa & Misra Sanjay

Department of Computer Science,
Nassarrawa State Univerisity, Keffi, Nigeria
faske03@yahoo.com
Department of Computer Science,
Federal University of Technology, Akure, Nigeria
adewale@futa.edu.ng
Department of Computer Science,
Kogi State College of Education, Ankpa, Nigeria
abrahamsalfa@gmail.com
Deaprtment of Electrical and Information Engineering,
Covenant University, Otta, Nigeria
Sanjay.misra@covenantuniversity.edu.ng

***Abstract*—** Wireless Sensor Networks are crucial substructure made up of microcontroller, sensing units and communication interfaces designed to enable the users possess the capability to measure, collect and responds to phenomenon within the surrounding been monitored. WSN are viewed as an edge between the physical and the virtual world. More so, the demand of fluid transportation from the production point to the region of end users has led to an increase in the number of pipelines that are fabricated globally. Pipeline infrastructure is generally regarded by many countries as a key element for national development, therefore shielding and observing the pipeline is essential for a successful economy. The current techniques in pipeline monitoring and surveillance include visual inspection, the use of Unmanned Aircraft, Ground Penetrating Radar, Fibre Cabling Technology, and Wireless Sensor Networks. This paper presents the various techniques, strengths and weaknesses when deployed for continuous monitoring of oil pipeline infrastructure.

Keywords - Wireless Sensor Networks, Pipeline, Oil, Pipeline Infrastructure, Monitoring

I. Introduction

The demand of fluid transportation such as oil usually from the production point to the region of end usage has given rise to the large numbers of pipelines fabrications and overlays. Many countries around the world depend on vast network of gas, oil and water pipelines for its economic development [1]. Pipeline infrastructure is often regarded by certain countries as a key element for national development [1]. As such shielding and observing the pipelines is essential for a successful economy. Pipeline infrastructure, looking at their essential spread all over a wide area, the poisonous and highly flammable fluid transported, it tends to present severe danger to the environment. More so, majority of oil pipeline infrastructures have been under incessant attacks by vandals over the years. This is the case of the oil pipeline infrastructure in Nigeria especially between the years 1976 and 1996. The NNPC authorities reported roughly five thousand incidents of oil pipeline damages for the period (2009 – 2011) leading to 10.9 Billion USD in losses [2]. Whenever oil pipeline leakages happened and undetected promptly; they have attendant negative consequences on economy, health and environment. In addition, there is loss of valuable product, increased cost of cleanups, service disruptions and massive repair expenses [3]. This paper presents the various pipeline monitoring techniques, strengths and weaknesses for monitoring of pipeline infrastructure.

II. Related Work

The Nigerian pipeline structure has been confronted by increased numbers of pipeline vandalism especially in the Niger Delta Region of the country. During the period of 2005 - 2015, a total of 16,083 pipeline damages were documented. Consequently, about 2.4 percent accounted for the pipelines ruptures while vandalisation activities were estimated at 15,685 breaks, which is about 97.5 percent of the whole incidence [4] as presented in Table 1.

Table 1: Nigeria oil pipeline vandalisation activities (2002 – 2012) [5]

System of Pipeline	Pipeline Route	No. of Incidents
2E/2EX	Port Harcourt – Aba – Enugu – Makurdi – Yola	8,105
2A	Warri Benin – Suleja/Ore	3,295
2B	Atlascove – Mosimi – Satellite – Ibadan – Ilorin	2,440
2C-1	Warri – Escravos	74
Gas	Trans – Forcados	55

In practice, the NNPC save guard the oil pipelines and installations through the police anti-pipelines task force, the Nigeria Security and Civil Defence Corps (NSCDC) and private security providers such as the Chukan Security Solutions Limited and members of the neighbouring communities against vandals ([6], [7]). Several other techniques have been developed for pipeline

infrastructure monitoring which are discussed in this section.

A. Satellite Monitoring

Presently, Satellites are designed to monitor pipeline right of way for ground motion, encroachment and leakage. Synthetic aperture radar (SAR) has been used to provide Radar Satellite RADASA images to show the presence of vehicular, earthmoving equipment and leakages. There is limited application for real-time monitoring purposes and unsuitable for overcrowded urban areas [8].

B. Visual Inspection

This technology is utilized to monitor aboveground pipelines using image and video sensors to observe the pipeline infrastructure vicinity. The image and video sensors are positioned relatively at huge sensing ranges in order to provide clear visibility which enable them to detect and localized the state of the pipeline [9]. But, it is limited to underground pipelines applications only [12].

C. Ground Penetrating Radar

Ground Penetrating Radar (GPR) has been used to accurately pinpoint buried pipeline leakages without digging. The GPR can be used with other portable devices which make them easily moved, deployed and maintained. The major shortcomings of this technology are: rigorous human participation and unsuitability for real time monitoring [10].

D. Unmanned Aerial Vehicle

The research carried out by [11] on the use of Unmanned Aerial Vehicle (UAV) for pipeline system monitoring involves the use of a drone (or unmanned aircraft) controlled remotely with pre-programmed flight plans. The use of the UAV for monitoring and surveillance has indisputable advantages such as dynamic nature, independent operation and high signal rate. However, a number of limitations make the technology unreliable. Firstly, the technology is applicable for only over ground pipelines. Secondly, it is unsuitable for continuous monitoring [11].

E. Optical Fibre Technology

The work of [12] on the use of optical fibre to monitor pipeline infrastructure show that an optical fibre is a cylindrical dielectric wave guide which is made from a silica glass or a polymer material. The optical fibres attached to pipeline infrastructure have the capacity to enlarge or shrink by small amounts according to the temperature or strain variations.

A part of the light generated by the sensor placed on the fibre is modulated according to the amount of the expansion or contraction (that is, a change in the sensor length), and then the sensor reflects back an optical signal to an analytical device which translates the reflected light into numerical measurements of the change in the sensor length. These measurements actually reveal the extent of strain or temperature along the monitored infrastructure [12].

The use of the fibre optic sensing technology offers the capability to measure temperature and strain at thousands of points along a single fibre, which is specifically interesting for infrastructure such as oil pipelines. However, the use of fibre optic poses a number of challenges including:

a) Damage in any section of the pipeline could put the network of

fibre optic out of service in that location.

b) Installation difficulty
c) Retro filling in the case of damage to the fibre can be difficult, uneconomic and can cause blind spots in the system [13].

F. Pipeline Infrastructure Monitoring Using Wireless Sensor Networks

The study by [14] was aimed at utilizing the network of sensors to monitor critical pipeline infrastructure. Consequently, a general architecture of pipeline monitoring system was developed which was later simulated to measure the performance. The strength of the monitoring system lies in its ability to monitor pipeline infrastructure at real-time. One major drawback of the system is the limited and fragile battery power. However, with modern batteries technologies alongside algorithms, these nodes can go to sleep when there is no activity which possibly increases the battery life of nodes.

G. Strengths and weaknesses of Wireless Sensor Networks

The strengths and weaknesses of WSNs deployed for the period for monitoring oil pipelines in Nigeria as advanced by several researchers are presented in Table 2.

Table II: Oil Pipeline Monitoring Techniques Compared

Researcher	Technique	Strengths	Weaknesses
Gary and Alfred, 2003	Satellite Monitoring	Ability to monitor entire pipeline Right of Way	Unsuitable for real-time monitoring. It is applicable for over ground pipelines only.
Yuanwei and Eydgahi, 2008	Acoustic	Detection of minimum noticeable leaks. Non-interference with the pipeline operation. The topology of the pipeline is made too simple with acoustic sensors	Custom-built for the pipeline structure. Localization method is ineffective for complicated topologies of pipeline.
Jasper, 2011	Visual Inspection	Support available commercial cameras in monitoring	Unsuitable for underground pipelines Different cameras are usually required for individual line-of-sight.
Bimpas *et al*., 2011	Ground Penetrating Radar	Ability to precisely locate underground pipelines with no digging required. It can cover quite a number of miles.	Unsuitable for real –time monitoring. Involves rigorous human participation.
Jakub, 2014	Unmanned Aerial Vehicle (Drones)	High signal rate and ability to move around along pipeline vicinity	Unsuitable for underground pipeline and continuous monitoring.
Rajeev *et al*., 2013	Fiber Technology	It provides real-time monitoring of pipeline infrastructure. Able to cover long distances.	Expensive in nature, fibre damage can render the system in operational. It must be installed across the entire length of the pipeline.
Nader and Imad, 2008	Wired and Wireless Sensor Network Architecture	It is suitable and reliable for wired and wireless sensors deployment in monitoring pipeline infrastructure	There was no clear architecture illustrating how the individual sensor nodes will be deployed and what parameters to be measured for a specified fluid.

III. Methodology

A. Wireless Sensor Networks

The latest enhancements in the area of Micromechatronics and Microfabrication technology have been shown in the accessibility of less expensive, and low power sensors connected to form sensor network. A modern-day sensor is typically made up of a sensing device, on-board memory, micro-controller, and a transceiver [15]. Wireless Sensor Network (WSN) is a self-powered computing device which normally comprises a processing unit, a transceiver and both analog and digital interfaces in which various sensing units, primarily sampling physical data such as humidity and temperature are accommodated [16]. Typically, the two sensor fields used to monitor two different geographic regions are connected their base stations through to the Internet as illustrated in Fig. 1.

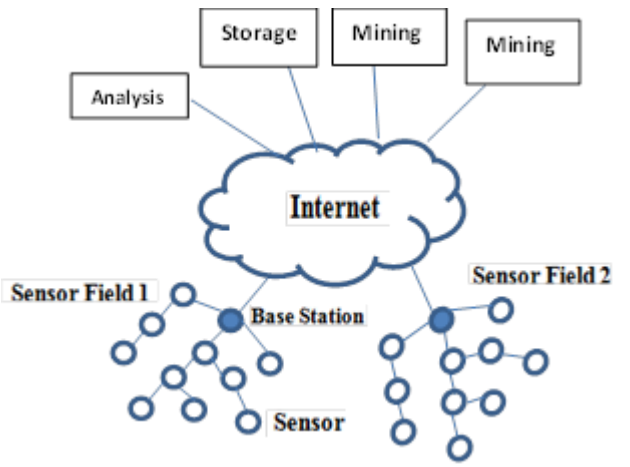

Fig. 1 Wireless Sensor Networks [12]

In general, WSN are obviously capable of functioning whenever other nodes in the network are deactivated. The potential damages arising from deactivation of certain sensor nodes can be overlooked by utilizing other available nodes alternatively. Often, the use of numerous sensor nodes in the network provides sustained connection in order to enable the sensed information to be conveyed seamlessly via the network to the required destination [17].

The sensors have the ability to instinctively organize themselves into an adhoc-network, which implies no need of any pre-existing infrastructure when compared to cellular networks such as the Global System for Mobile Communications (GSM) [18]. It offers decisive advantages over existing technologies used in monitoring the environment through the collection of physical data [17].

A transducer refers to a machine which transforms energy from one quantity to the other. A sensor can be viewed as a kind of transducer because of its capability to transform energy in a surrounding to electrical form of energy which can be forwarded to a computer for further

analysis. The stages involved in the sensing activity are given in Fig. 2. Whenever the sensors capture data, the corresponding signals are not usually ready for processing; instead they go through the phase of signal conditioning phase.

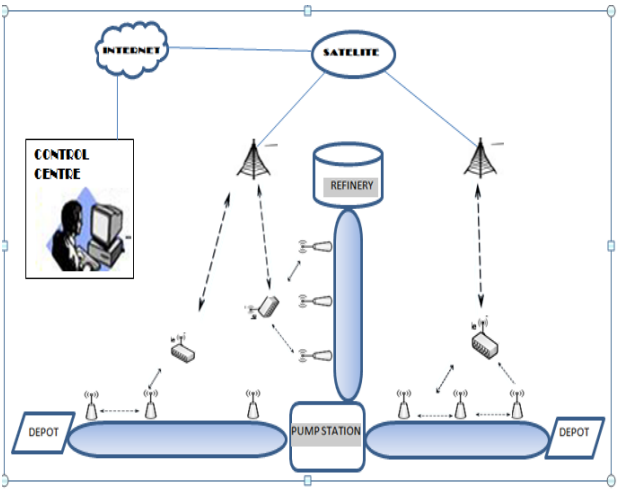

Fig. 2 Data acquisition and actuation [19]

In ensuring the safe operations of the pipeline infrastructure, regular monitoring of the pipeline is essential. Existing methods are limited in their capability to provide constant and continuous monitoring. As such the use of WSN seems promising because the individual sensors attached to the nodes in a WSN system can help with the various measurements such as the flow rate, pressure and temperature readings taken along a defective pipeline and then transmitted through Satellite links to the control Centre for immediate attention. The WSN architecture for a pipeline monitoring system is shown in Fig. 3.

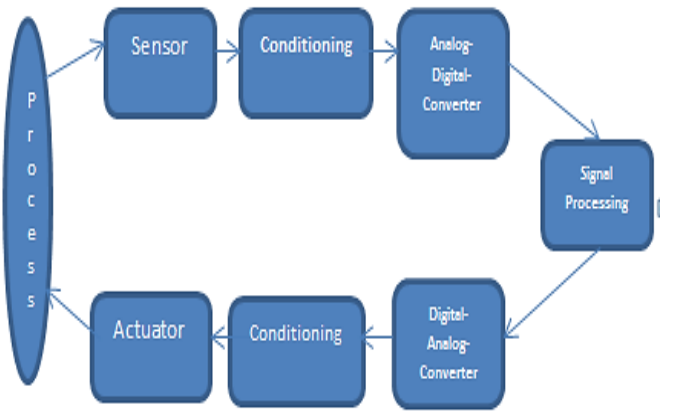

Fig. 3 Pipeline monitoring architecture using WSN [14]

IV. Results

This exploratory study exposes the weaknesses of the existing monitoring methods and presents WSN technique as an alternative for pipeline infrastructure monitoring. WSN as presented in this paper involves the collection of individual sensor nodes which are interlink by wireless communication units. The individual nodes as attached to a pipeline segment has the responsibility of gathering data from the pipeline surrounding and sending the sensed data via communication links to the control Centre.

When compared with other reviewed monitoring techniques, WSNs are capable in solving the reliability issues of some of the existing methods and also provide real-time monitoring of the pipeline with the aim of reducing or minimizing vandalisation activities in Nigeria and the world at large. Unlike in the existing methods, several nodes can be deployed in WSN which makes the network to offer sustained connectivity even if certain nodes failed to function.

The sensors have the ability to instinctively organize themselves into an adhoc-network, meaning that they do not require any pre-existing infrastructure as compared to cellular networks like the GSM. They consist of decisive advantages as compared to other previous technologies that were used to monitor the environment through the collection of physical data.

V. Conclusion

This paper highlighted the issues of oil pipeline vandalism and breaks causing major leakages; and degradation in economic, health and environment. WSN was identified to be highly favourable in remedying the failures of present-day security measures and techniques for protecting oil pipelines and installations. WSN is a self-powered computing device which normally consists of a processing unit, a transceiver with analog and digital interfaces, whereby various sensing units, primarily sample physical data such as humidity and temperature. In terms of cost and effectiveness, WSNs are suitable for securing and monitoring the vast oil installations in Nigeria and forestall incessant issues of pipeline leak detection and prevention because of sensing capability of these network devices to act promptly at real-time when the need arises.

References

[1] J. Imad, M. Nader, and S. Khalid, "A Framework for Pipeline Infrastructure Monitoring using Wireless Sensor Networks," Article, College of Information Technology, United Arab Emirates University, UAE, pp. 2-5 (2007)

[2] E. Ugwuanyi. (2013) Steaming Vandalism theft in downstream sector. [Online]. Available at http//the nation online.net/new/business/energy/steaming-vandalism-theft-in-downstream-sector-2/

[3] A. S. Osunleke, H. A. Gablar, and S. L. Miyazaki, Mathematical Modelling Approach to Pipeline Leaks Detection, Location and Control," In: 3rd International Workshop on Computational Intelligence and Applications, IEEE SMC, Okayama

University, Japan, pp. 1-3 (2007)

[4] O. O. Ogbeni. (2012) Fuel Pipeline Vandalism in Nigeria. [Online]. Available at http:www.chatafrik.com/articles/economy/item/1287-fuel-pipline-vandalism-in nigeria.html

[5] A. I. C. Okoli, and S. Orinya, "Oil Vandalism and Nigeria's Security," Global Journal of Human Social Science, Political Science, vol. 13, no. 5, pp. 67-75 (2013)

[6] M. Cyril. (2014) Security Expert suggests ways to tackle Pipeline Vandalism, oil theft, Daily Newswatch. [Online]. Available at www.mydailynewswatchng.com/security-expert-suggests-ways-tackle-pipeline-vandalism-oil-theft

[7] Pipeliners 1st Quarter. (2013 March) An in-house Quarterly Newsletter of the PPMC/NNPC, 7-8

[8] L. B. Gary, and E. C. Alfred. (2012) Real-Time Monitoring of Pipelines for Third-party. [Online]. Available at https://www.netl.doe.gov/File%20Library/Research/Oil-Gas/Natural% 20Gas/ 10211TechStatusAssess-Final.pdf

[9] A. Jasper, "Pipeline Potential Leak Detection Technologies: Assessment and Perspective in the Nigeria Niger Delta Region," Journal of Environmental Protection, vol. 2, pp. 1057-1059 (2011)

[10] M. Bimpas, A. Amditis, and N. Uzunoglu, "Detection of Water Leaks in Supply Pipes Using Continuous Wave Sensor Operating at 2.45GHz," Journal of Applied Geophysics, vol. 70, no. 3, pp. 226-236 (2010)

[11] O. Jakub," Intelligent Algorithms for Monitoring of the Environment around Oil Pipe Systems using Unmanned Aerial Systems," M.Tech Thesis, Czech Technical University in Prague (2014)

[12] P. Rajeev, J. Kadikara, W. K. Chiu, and T. Kuen, "Distributed Optical Fibre Sensors and their Applications in Pipeline Monitoring," Key Engineering Materials Journals, vol. 558, pp. 424-434 (2013)

[13] M. S. Ali, M. Nicole, N. C. David, and J. A. Carl, "Smart Wireless Sensor Networks for Leak Detention in Water Pipelines," Journal of Sensor and Actuator Networks, vol. 3, no. 2, pp. 65-66 (2014)

[14] K. Yunana, "Pipeline Infrastructure Monitoring using Wireless Sensor Networks," M.Tech Thesis, Federal University of Technology, Minna, Nigeria (2015)

[15] S. I. Sitharama, P. Nandan, V. P. Vir, N. Balakrishnan, and D. O. Chuka, Fundamentals of Wireless Sensor Networks Programming: Applications and Technologies. New Jersey: John Wiley & Sons Inc. (2011)

[16] S. Kazem, M. Daniel, and Z. Taieb, Wireless Sensor Networks Technology: Protocols and Applications,

New Jersey: John Wiley and Sons Inc., Hoboken (2007)

[17] M. Nader, and J. Imad, "A Fault Tolerant Wired/Wireless Sensor Network Architecture for Monitoring Pipeline Infrastructures," In: 12th International Conference on Sensor Technologies and Applications, IEEE Computer Society Press, pp. 1-6 (1995)

[18] P. Jacques. (2008) Wireless Sensor Networks for Marginal Farming in India [Online]. Available at http://www.researchgate.net/profile/Jacques_Panchard/publication/37462966_Wireless_sensor_networks_for_marginal_farming_in_India/links/09e41510058fd3e5d5000000.pdf

[19] D. Waltenegus, and P. Christian, Fundamentals of Wireless Sensor Networks: Theory and Practice. Chichester, West Sussex, United Kingdom: John Wiley & Sons Ltd (2010)