ENVIRONMENTAL IMPACT ASSESSMENT OF CIVIL ENGINEERING INFRASTRUCTURE DEVELOPMENT PROJECTS

W. K. Kupolati [a]
[a] Department of Civil Engineering, Tshwane University of Technology, Pretoria, South Africa.
[a] Corresponding author: kupolatiwk@tut.ac.za

 ISSN 1923-6654 (print)
ISSN 1923-6662 (online). Available at http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Abstract: The study involved environmental impact assessment of upgrading of existing flow station dealing with different civil engineering works such as road network, housing, water supply, to name a few. Data was collected from Federal Environmental Protection Agency (FEPA), Department of Petroleum Resources (DPR) Port Harcourt, Nigerian Meteorological Department (NMD), Lagos, Rivers State Ministry of Environment and Natural Resources (RSMENR), Port Harcourt, Ahoada West Local Government Area (AWLGA), Akinima, Rivers State and the Internet. Data collected was used to get an overview of the existing Environment. Relevant test of existing water, soil, noise and air samples were carried out. Comparisons were made with results of the test carried out and data of the area collected. Formal and informal interviews were also carried out with some of the inhabitants of the area. All these were done with the aim of assessing the impact the infrastructure had on the environment, and projection of the likely impact of the upgrading exercise. The study revealed that civil engineering infrastructure development projects impacted greatly on the environment especially in areas of noise pollution, water pollution, decrease in size of available land, etcetera. Based on the findings, recommendations were made for the elimination of the negative effects in some cases; and for amelioration of the effects in situations where it will be impossible to completely eradicate such effects.

Keywords: Environmental impact assessment, flow station, environmental pollution, civil engineering infrastructure, impact mitigation

I. INTRODUCTION

Our daily life environment in Nigeria relates to air, noise, sunlight, geological features, fauna, flora, landscape, etcetera. All these affect the economy of the country: if the environment is abused, daily life style (living and working conditions, etc.) will be affected; and this will in turn affect the economy.

As there is need to protect the environment in every possible way, it must also be noted that the need for the existence of infrastructure as an indispensable part of any economy cannot be over emphasized. As those infrastructures come into existence, there are resulting positive effects as well as adverse effects, which in many cases tend to out-number the positive effects; and yet not usually noticed. This inability to take cognizance of the adverse effects of civil engineering infrastructural development projects has become a source of worry to the environmentalists, civil engineers, and, indeed all stakeholders in the environment [1]. Infrastructure development projects are of many types, and their impact on the environment are also very many and vary in magnitude and form depending on the type of civil engineering project. According to the procedural guideline on Environmental Impact Assessment (EIA) by the Federal Environmental Protection Agency [2], infrastructure projects should include but not limited to: Industrial estate development projects; Canalization and flood relief works; Dams and Hydropower to hold water;; Oil and gas pipe line installations; Solid waste management and sanitation projects; and Industries.

The impact of these projects on the environment range from cumulative to long term and short term impacts; and include impacts on human beings and man made features, agriculture, effects on flora, fauna and geology, effects on land, effects on water, air and climate and, of course, the indirect and secondary impacts associated with the project. Environmental impact assessment may be said to be one of the vital steps required for careful planning and management of natural resources resulting from pressures placed on virtually all areas of the earth from the need to provide food, water, minerals, fuel, and other necessities for such increasing number of people. In other to properly assess environmental impact of civil engineering infrastructural development projects, it is necessary to perceive the environment from the point of the view of the entire physical setting, experiencing a complex array of interrelationships compassing life and development. Since the environment itself is multi dimensional in nature, it means that the circumstances that create (adverse) impacts on it are multi-dimensional; and therefore require some sort of multidimensional or multidisciplinary handling. It is therefore very necessary to involve as many disciplines as should be interested or connected to the environment as possible. These professionals will carryout comprehensive investigations prior to the actual project execution. These investigations are usually geared towards the matching of ecological and technological requirements of land use with the qualities of land and the effect of the proposed use of such land on the environment.

The process of construction of these infrastructures or even the existence of completed ones create some adverse environmental impacts which may or may or may not come to the notice of the lay man. It is this difficulty in observing the impact of infrastructures projects on the environment that has necessitated this study, which aims at adequately identifying the impacts of the projects on the environment.

The objectives of this study were: (a) Identification of the impacts of civil engineering infrastructures development projects on the environment;. (b) Discussion of the impacts in relation to the types and expanse of the infrastructural development project involved; and (c) Suggestion of the ways of averting such impacts.

It is expected that: (d) the findings made at the end of this study will assist both the civil engineers and environmentalists to understand the environmental impacts of civil engineering infrastructural development project; (e) the work will be found useful in helping to avert, ameliorate or even eradicate such impacts where necessary.

As diverse as the impacts of civil engineering infrastructures are on the environment, the research intended to capture them in the whole entirely. After critical examinations, some problems were diagnosed.

The study was limited to observatory survey of the area to ascertain the extent of the impact on the environment on first hand basis; also, formal and informal interviews were carried out with the inhabitants of the area. Moreover, water; soil and air samples were collected. All samples collected were analyzed to ascertain the extent of pollution. Results were interpreted in accordance with the research objectives and deductions were made resulting in strategies needed for amelioration or even total eradication of these impacts on the environment.

The challenges faced included the attitude of people in positions that could provide relevant data; the biased response of people of the area due to fear; security of the facilities and financial constraints

Civil infrastructures are physical structures and facilities necessary for a country or an organization to function efficiently. For example, oil and gas infrastructures, buildings, airports, roads, highways, railways, water and energy facilities, electricity lines, dams and bridges, coastal and river protection works, sand fills, etc. The sizes of these projects depends mainly on the population and economic status of the country and the organization which intends to undertake them and sometimes also determined by the natural condition, which the project is expected to control or support, for instance in the case of dams and bridges.

Oil and gas exploration activities also rely to a large extent on civil engineering infrastructures project. Often, there is need for construction of access by clearing of land and movement of heavy trucks and equipment. These activities usually require roads some times constructed just for the purpose. During full operation there will also be the need for construction of helipads, airfield offices and site building e.t.c. (sectorial guidelines on oil and gas industries and projects) [3], [4] & [5].

II. MATERIALS AND METHODS

Topography / Soil Morphology

The topography of the oil field area is flat. The micro-relief is also flat but gradually role into numerous creeklets and lakes in the back swamps. The macro-relief of the whole topography gradually roles into the Orashi river that was a few kilometers west of the study area. The slope ranged from 0 to 30 in the whole study area. Topsoil in the flow station area has sandy loam and sandy clays, loamy texture, but areas around the waste pits have highly compressed clays. Gravel and granite chippings in both top and bottom soils contain crude petroleum and gas clay bottom soils. The two gas flare guns were located 100m from each other on highly compressed clay top and bottom soils. The very wide flare-pit-like area was open towards the forest and back swamps, thereby allowing very hot water and steam from the flare pit to the immediate and nearby forest environment.

Ambient air quality Assessment

The assessment was aimed at determining the concentrations of total suspended particulate (TSP), volatile organic compounds (VOC), carbon monoxide (CO), oxides of Nitrogen (NO_x) and sulphur dioxide (SO_2). These formed the core of criteria pollutants recognized as having potential impacts on human health, and which are normally prevailing in routine combustion, industrial processes and other common sources of air pollution.

Sampling locations were chosen to coincide with different types of activities around the flow station. These include the inlet manifold area, an open area within the premises, flow station site office, construction area, and adjourning roadside. The potential impact will be established by comparing site data with occupational health and general public exposure standards published by Federal Ministry of Environment.
The monitoring of the TSP over the air was taken using Casela singe-state samplers fitted with cellulose paper by a suction pump with flow rate in the range 10 – 20 liters per minute (1/pm) for approximately 8 hours. The flow rate of the suction pump was measured using an air flow meter calibrated to measure flow rates in the range 0.5 to 3.0 1/pm. The pump flow rate was maintained constant throughout the sampling time, enabling very accurate determination of the sample air volume. The total suspended particulate (TSP) matter collected on the filter is obtained by the difference between initial and final weights, before and after sampling, dried to constant weights in a desiccator filled with suitable drying agents. The filter weights are measured using a mettler microbalance with a sensitivity of 0.1mg. All filters used for sampling were stored in sealed polyethylene bags to avoid contamination prior to elemental analysis.
The determination of the elemental constituents of the TSP is required both as basis for evaluating its toxicity and for source appointment. Chemical analysis of the TSP was undertaken using a combination of atomic Absorption spectrophotometry (AAS) and Energy Dispersive X-Ray fluorescent (ED-XRF) analysis.
The potential impacts of all pollutants at the sites monitored were evaluated by comparing measured concentrations with recommended threshold limit valves (TLV) regulatory agencies [2].

Noise

Noise levels were measured within and outside the flow station. This was done by a cell precision integrating sound level meter. The instrument was adequately positioned to the wind and noise direction, to get an accurate noise level measurement. Noise level measurements were taken at: Flow station control room, Generator area, Flare site area, 1km from the station.

Microbiology

Water samples were aseptically collected into sterile bottles from various points within the study area. Also, soil samples were collected into sterile polythene bags as composite samples, at 0-15cm and 15-30cm depths, using a soil auger.
The following microbial analyses were carried out on the water and soil samples. (a) Total Heterophic Bacterial Count (THC) (b) Total Heterophic Fungal Count (THF) (c) Hydrocarbon Utilizing Bacterial and Fungal Counts (HUB) (d) Identification of the microbial isolates.
For the microbial counts, serial dilutions of the water and soil samples were carried out in sterile normal saline and 1ml of the appropriate dilutions were plated using the standard pour plate techniques. Nutrient Agar (Oxide) and Plate Count Agar containing 0.05% chloramphenical were used for the fungal assay. The bacterial plates were incubated aerobically at 35^0C for 5 days while the fungal plates were incubated at room temperature for 7 days. At the end of the incubation period, plates containing between 30 and 300 colonies were selected for estimation. Hydrocarbon utilizing bacteria and fungi count were determined as described by [6] and [7]. Crude oil was used as the test hydrocarbon. Bacterial and fungal identification were done as described in line with existing standards. The sampling point description for water microbiology is shown in Table 1.

Soil Sampling

Random soil samples were done within areas of the flow station. Random samples were collected from the Saver Pit, Heater, Oil Tank, Compressor, Generators, Waste Pit, and Gas Flare Burnt Forest. At each of the location, soil sample was carried out with the aid of Dutch auger. At each sampling station, three auger borings spaced at 5m apart were collected and examined. Samples were collected at depths of 0-15cm and 15-30cm at a particular sample area. The soil samples were physically examined to assess the environmental impact the soil was subjected to, at different locations at the flow station, and to identify whether or not there was pollution of the soil. The sampling point description is shown in Table 2 and 3.

Sample code	Site Description
WS1	Flare site water
WS2	20m downstream of flare site
WS3	Discharge pond
WS4	Saver pit
WS5	Flushing water
WS6	Storm water
WS7	Borehole located north of flow station

Table 1: Sampling points description for the flow station water microbiology sample.

Sample Code	Site Description
OS 1	Manifold Site within flow station
OS 2	Heater location within flow station
OS 3	Gun barrel within flow station
OS 4	Compressor within flow station
OS 5	Generator point within flow station
OS 6	Waste discharge point just outside flow station
OS 7	Saver pit within flow station

Table 2: Sampling point description of the flow station microbiology sample

Sample No.	Location
OS 1	API (saver pit)
OS 2	Heater
OS 3	Oil Tank
OS 4	Compressor
OS 5	Generator
OS 6	Water pit
OS 7	Gas Flare Burnt Forest

Table 3: Sampling point description for the flow station soil physical sample

III. RESULTS AND DISCUSSION

Ambient air sampling result

The results of the TSP monitoring are presented in Table 4. It showed that the ambient air quality was exceeded at some of the city locations (road side and by a hotel premises) within the town. Results indicated that TSP around the flow station and neighborhood exceeded the FM ENV threshold limit value of 250µ g/m^3 at only one locations (within the flow station facilities, where construction works were on-going). The flow station control room had the lowest measurement (being an air conditioned office). However, the results were all above the WHO threshold limit value of 40µ g/m^3

The potential impact of the ambient air quality can be measured when comparing measured ambient air mixing values with recommended limits for these pollutants recommended [2]. These were termed the threshold limit values (TLV) for each pollutant and are usually published for reasons of assessing compliance to air quality standards at locations under investigation. Results of the elemental concentrations of the TSP in parts per million by mass were presented in Table 5 while Table 6 showed the recommended TLV of some conventional pollutants by FEPA.

Toxicity indices of each receptor site sampled were computed by obtaining the ratio between field concentration and the threshold limit valve (TLV) for TSP, the national TLV of 250µ g/m3 was used, while literature based TLV for some heavy metals as presented above were used. Results are presented in Table 7. The results indicated that TSP exceeded the TLV at two out of the six location sampled; therefore posing as adverse environmental effect.

Noise

The noise level varied between 54.20 dB(A) at 1km from the flow station to 109dB(A) at the Generator Area as shown in Table 8. All the points outside the flow station recorded levels that are below FEPA recommended limit of 90dB(A) for an 8 hour per day work exposure. Areas within the flow station showed levels that are quite above the FEPA limits. This showed that the activities of the flow station have negative impact on the environment. Table 9 showed the standard for noise exposure limits for Nigeria

TSP	Sampling site					
	Plant Gate	Control Room	Construction worksite	Inlet manifold	Open plant	Access road to flow station
(μ g/m^3)	28,000	65,000	560,000	225,000	135,000	142,000

Table 4. Table suspended particulate (tsp) measured at sites around the flow station

Sampling Sites	Plant Gate	Control Room	Construction Work Site	Inlet Manifold	Open Plant	Access Road to Flow station
Al	450	399	690	389	704	1102
Cr	128	190	109	90	203	200
Si	8739	9850	1208	650	1200	785
V	2263	3082	2263	5890	979	290
Ti	4280	2190	2780	2890	1209	2303
Ni	2930	1192	1293	1290	1378	1190
Fe	699	1389	2930	3984	2839	1290
Mn	2900	2936	2004	781	465	262
Ca	1190	8739	10289	1093	1920	2640
Mg	785	890	683	280	192	79
P	7839	9765	9517	6137	6137	3544
Na	639	984	783	83	73	4612
K	583	782	283	783	874	763
Co	790	882	66	873	930	1093
Cu	2590	3028	1530	6490	3743	2749
Zn	1209	1470	1379	387	183	2546
As	1648	1374	1537	2839	183	1932
Se	1844	87	183	162	126	127
Br	182	129	128	192	101	42
Pb	873	928	729	238	389	182
Cd	7544	8498	9404	8454	7548	4845

Table 5. Relative concentration of trace elements in tsp at sampling locations around the flow station: Elemental concentrations (ppm)

Microbiology

Water Microbiology

Results of the water microbial analysis revealed appreciable variations in the microbial loads of the water samples. Total heterotrophic bacterial count was observed to range from 104 to 105 cfu/ml, while total fungal densities were lower ranging from 0 to 103 cfu/ml. The observed bacterial densities fall within the range proposed for freshwater. Hydrocarbon utilizing bacteria count varied in from 103 to 105 cfu/ml while their fungal counterparts were observed to vary from 0 and 102 cfu/ml.

Pollutants	Time of Average	Limit
Particulate	Daily average of daily valves 1 hour	250 µ g/m^3 * 600µ g/m^3
Sulphur oxides (sulphur dioxide)	Daily average of hourly valves 1 hour	0.01ppm(26µ g/m^3) 0.1ppm (260µ g/m^3)
Non-methane Hydrocarbon	Daily average of 3 hourly valves	160µ g/m^3
Carbon monoxide	Daily average of hourly valves 8-hourly average	10pp (11.4µ g/m^3) 20ppm (22.8µ g/m^3)
Nitrogen oxides	Daily average of hourly valves (range)	0.04ppm – 0.06ppm
(Nitrogen dioxides)		(75.0µ g/m^3 – 113µ g/m^3)
Photochemical oxidant	Hourly valves	0.06ppm

Source: [2]
* = Concentration not to be exceeded for more than once a year

Table 6: Nigerian ambient air quality standard

It was generally observed that the hydrocarbon utilizers densities were far greater than 1% of the total heterotrophs (Table 11), a quotient which has long been established by [8] as index of hydrocarbon pollution or recovery potential. This implied that the locations have been previously exposed to hydrocarbons to the extent that appreciable hydrocarbon derivatives gene pool has been established in this area, which is expected to favor a speedy natural cleanup during hydrocarbon pollution. Also, fourteen (14) bacterial and nine (9) fungi species were identified from the water samples (Table 12). Most of these isolates, especially those belonging to the genus *Pseudomonas* are renowned for their versatility and their roles in the bioremediation of hydrocarbon polluted systems have been extensively documented.

IV. CONCLUSIONS

Mitigation / Amelioration measures
Air Quality

a) Construction work involving excavation of soil should not be done at the peak of dry season in order to avoid excessive release of dust into the atmosphere thereby increasing suspended particulates above threshold limit.
b) The efficiency of gas flares should be improved towards total combustion through regular maintenance for release of smokeless flares and reduction of the quantity of gas being flared, which is the ultimate goal of the upgrading exercise.
c) Bush burning around the flow station should be avoided in order to prevent fire outbreak, which could lead to unexpected emergencies.
d) All gas pipeline fitting must be tight fitted and maintained using the current technology in oil and gas industry.
e) Safety rules must be displayed in all the designated hot places that could result in explosion and fire out break.
f) Workers should be encouraged to wear appropriate PPE at designated locations in the flow station.
g) Regular over hauling of the heavy equipment and reduction in particulate discharge using screener.

Pollutant	TLV (μ g/m^3)	Plant Gate	Control Room	Construction Work Site	Intel Manifold	Open Plant Area	Access Road to Flow station
		Toxicity Index Per Sampling Site (C$^+$/TLV)					
TSP	250	1.12	0.26	2.24	0.9	0.54	0.568
Cr	25	0.001	0	0.002	0.001	0.001	0.001
V	1	0.634	0.2	1.268	1.325	0.132	0.041
Co	2.5	0.088	0.023	0.015	0.079	0.05	0.062
Pb	1.5	0.163	0.04	0.272	0.036	0.035	0.017
Zn	125	0.003	0.001	0.006	0.001	0	0

C$^+$ = Concentration of Pollutant measured at sampling site, TLV = threshold limit value (Regulatory Limit for Impact)

Table 7: Toxicity index of major air toxics around the flow station

Sampling locations	Noise levels dB(A)
Flow station control room	90.2
Generator Area	109
Flare site Area	96.2
1 km from the flow-station	54.2

Table 8. Noise level around the flow station

Duration per Day, Hour	Permissible exposure limit dB(A)
8	90
6	92
4	95
3	97

Source: [2]

Table 9. Noise Exposure Limits For Nigeria

Physical Soil Sampling Result

After a physical assessment of the soil samples, Table 10 showed relevant observation.

Sample No	Depth (cm)	Location	Drainage	Remarks
OS1	0 – 15	API (saver pit)	Poorly drained	Abundant crude oil spillage impacted
	15 - 30	API (saver pit)	Very poorly drained	Grass cover showed brown scotched patches
OS2	0 – 25	Heater	Poorly drained stagnant water due to compressed clay in sub soil	Grass cover on topsoils. No visibly seen oil spills.
	15 – 30	Heater		
OS3	0 – 15	Oil Tank	Well drained	No visible oil spills, very thick layer of sand planted to grass
	15 – 30	Oil Tank	Well drained	
OS4	0 – 15	Compressor	Well drained	Top and bottom soils were compressed clay mixed with gravels, No visible oil spillage.
	15 - 30	Compressor	Well drained	
OS5	0 – 15	Pumping Generator	Moderately drained	Concrete floor with concrete surface drains soils were compressed clay and gravels.
	15 - 30	Pumping generator	Poorly	Red iron oxide mottles visibly
OS6	0 – 15	Waste pit	Poorly drained	Very abundant crude oil spills showing very bad pollution;
	15 - 30	Waste pit	Poorly drained	Frequent human faecal materials seen. Top and Bottom soils were dry.
OS7	0 – 15	Gas flare (Burnt forest)	Poorly drained	Sand clay loam and loam with abundant charcoal and dead roots, Burnt vegetation and topsoil.
	15 - 30	Gas flare (Burnt forest	Poorly drained	Hot water and steam in inundated areas.

Table 10. Result of physical assessment of soil sample at the flow station

Sample code	THB (cfu/ml)	THF (cfu/ml)	HUB (cfu/ml)	HUF (cfu/ml)
OSW 1.	6.0 x 10^4	1.0 x 10^2	5.2 x 10^3	nil
OSW 2.	3.1 x 10^5	7.0 x 10^3	2.1 x 10^5	2.1 x 10^1
OSW 3.	3.6 x 10^5	2.0 x 10^3	2.3 x 10^4	1.5 x 10^2
OSW 4.	4.0 x 10^4	2.1 x 10^2	1.6 x 10^4	nil
OSW 5.	2.5 x 10^5	7.1 x 10^2	6.4 x 10^4	1.3 x 10^1
OSW 6.	6.0 x 10^5	1.3 x 10^2	5.2 x 10^4	2.1 x 10^1
OSW 7.	9.6 x 10^5	6.2 x 10^2	2.5 x 10^4	nil

Table 11. Result of the microbial densities of the water samples collected from flow station area

Bacteria Isolates	Fungi Isolates
Pseudomonas aeruginosa, Klebsiella	Daldenia spp. Paecilomyces spp.,
Pneumoniae, Alcaligenes feacalis, Proteus	Cladosporium ssp., Scopulariospsis
Vulgaris, pseudomonas pseudomallei, Chromobacterium violacium,	Brevicaulis, Mucor mucedo,
Micrococcus hiteum, Streptomyces spp.,	Microsporium gypseum, Cunninghamella spp., Batrytis spp., Microsporium
Bacillus cereus, Bacillus subtilis.	Audovinii.
Eschericia coli, Enterobacteria cloacae.	

Table 12. List of bacteria / fungi isolates from the water samples

Conclusion Continued:

Water Quality

a) Construction and land preparation should not be done at the peak of the rainy season because of flood discharge and over land run off.
b) Dredged spots during pipe laying construction should not be piled up too close to water and farmlands.
c) Good toileting system should be facilitated by appropriate latrine design and maintenance at the flow station.
d) Liquid waste, sanitary wastes and chemical waste should not be discharged into water stream.
e) Dredges slots should not be prevented from entering farmland directly.
f) Suitable portable water should be provided for the communities in order to enhance high standards and personal and community hygiene.
g) Good horse keeping should be maintained during fuelling / re-fuelling of machineries to minimize oil spill.

Noise

a) Workers around the flow station should be provided with appropriate personal protective equipment (PPE), especially earmuffs and be compelled to put them on at designated places.
b) Buffer zones should be created in area were the noise level is high.
c) Silencers should be attached to machinery that make too much noise.

General Conclusion

The aim of research was to identify and determine the environmental impact of civil Engineering infrastructural development projects. This was done through the utilization of the project by a Nigerian oil firm. The project was the upgrading of a flow station in Ahoada local Government Area, Rivers state. An Assessment of the existing environment was done through desktop; field and laboratory methodologies. Positive and negative impacts were deduced and comparison was made between the results of the assessment and national and international guidelines on the environment. From the assessment of the flow station environment, it was found that the environmental impacts can be managed within reasonable standards and acceptable limits by applying appropriate mitigating measures.

ACKNOWLEDGMENT

The author wishes to acknowledge with thanks the establishments who willingly provided relevant data for the research. These included: Nigerian Meteorological Department (NMD); Federal Ministry of Environment (FMENV); Department of Petroleum Resources (DPR), Port Harcourt; Rivers State Ministry of Environment and Natural Resources (RSMENR), Port Harcourt; Ahoada West Local Government Area (AWLGA), Akinima, Rivers State and the communities around Oshie flow station especially Akara-Olu community in Ahoada West Local Government Area (AWALGA), Rivers State. Mr. Inuwa Iworima was also very supportive in offering necessary support in terms of data collation and liaison with the communities and organizations.

REFERENCES

[1] W. K. Kupolati: Environmental impact of infrastructural development project. An unpublished paper presented at the monthly lecture series of the Institute of Environmental Engineering, Nigerian Society of Engineers, 2000.

[2] Federal Environmental Protection Agency (FEPA): Guidelines and standards for

Environmental Pollution Control in Nigeria, 1991
[3] Federal Environmental Protection Agency (FEPA), Decree 58, 1988.
[4] Federal Environmental Protection Agency (FEPA), Decree 86, 1992,.
[5] African Development Bank, 1992, Environmental Assessment Guidelines
[6] A. L. Mills, C. Brevil and R. R. Colwell (1978): Enumeration of Petroleum Degrading Marine and Estuarine Microorganism by the most probabile number method. Can.J.Microbiology., Vol. 24, pp. 552 – 557.
[7] G. J. Muikins – Philips and J. E. Stewart (1974): Distribution of Hydrocarbon utilizing Bacteria in North Western Aflantic waters and coastal sediments. Can. J. Microbiol., Vol 20, pp 955 – 962.
[8] IPS (1997). Environmental impact Assessment of Akri/Oguta field Development programme A Report submitted to SPDC by RSOST.

ABOUT THE AUTHOR:

W. K. Kupolati is with the Department of Civil Engineering, Tshwane University of Technology, Pretoria, 0001, South Africa. (Corresponding author: mobile phone: +27733106085; fax: +27(0)123825226; e-mail: kupolatiwk@tut.ac.za.