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Review

Applicable international environmental impact assessment laws for the Niger Delta Area of Nigeria

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The Niger Delta Area of Nigeria has undergone several alterations in her environment through various projects development including oil and gas exploration, dredging and mining activities. These activities have continued to impact the environment as relevant organs of the government deliberately down play the relationship between environmental degradation/pollution and project developments. Though, there are plethora of international laws and conventions, some domesticated in the country, the objectives of these laws in relation to assessing the environmental impact (in this case the Niger Delta Environment) as applicable to project developments will be brought to the fore. The specific objective hereto is to appraise selected International Environmental laws and the Nigerian Environmental Impact Assessment methodology in demonstrating how the Niger Delta Environment can be preserved for future generation. This paper affirms that Environmental Impact Assessment laws are strictly predicated on adherence of procedural requirements and not the requirement for proper utilization of resources, this notwithstanding, provides a veritable tool for environmental sustainability if properly applied.

Key words: International law, Niger Delta, environment, impact assessment.

INTRODUCTION

The natural environmental process as the need arises, needs to be altered from time to time to meet the comfort of emerging cultures, societies, species, developers and environmentalist. The point being made here is that such activities should not adversely or irreversibly alter the natural environmental process. This was corroborated by the World Commission on Environment and Development (WCED, 1987), which highlighted basic requirements for the sustainability of the Environment Development which meets the needs of current generations without compromising the ability of future generations to meet their own needs. The concept supports strong economic and social development, in particular for people with a low standard of living. At the same time, it underlines the importance of protecting the natural resource base and the environment. Economic and social well-being cannot be improved with measures that destroy the environment. Intergenerational solidarity is also crucial: all development has to take into account its impact on the opportunities for future generations. It is estimated that in

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one region alone in the Niger Delta, flaring is statistically likely to cause 49 premature deaths, 5000 respiratory illnesses among children, some 120,000 asthma attacks and 8 additional cases of cancer each year (Environmental Rights Action and the Climate Justice Programme, 2009). This is more worrisome when it is carried out in an uncontrolled approach, predicated by the pursuit for profit by the foreign investors engaged in developmental projects in the area, whereas these developments must be sustainable by meeting the needs and aspiration of the current generation without compromising the ability to meet those of future generations.

The adherence to standards, commencing from the project conceptual stage to actual construction has being an issue of concern. Though, there are applicable laws, regulations and conventions promulgated and adopted in Nigeria, the role these laws play in assessing the impact (positive or negative) to the Niger Delta Environment must be brought to the fore. This study will further x-ray the import of applicable international environmental laws midwifed by the United Nations and its relevant bodies and in particular Nigeria environmental impact assessment law of 1992 as it relates to the developmental projects and other allied activities in the Niger Delta.

The laws and regulations that are enacted and in operation by relevant authorities in the Nigerian context will be stated and reviewed as they are evoked for the protection of the Nigerian natural environment. This is anticipated to minimize and mitigate the deterioration of health quality, destruction of flora and fauna, pollution of water resources, destruction of traditional economic infrastructures within communities accommodating these super investments.

NIGER DELTA AREA

The Niger Delta, like most deltas in Africa, is a storehouse of bio-diversity, food, energy and mineral resources. As the world's third largest wetland, it is characterized by significant biological diversity, to bulk of proven oil reserves (culled from Niger Delta Development Commission NDDC) Master Plan. This makes the region a veritable economic and socio-cultural hub of human activities in Nigeria. The region, situated in the southern part of Nigeria and with the south by the Atlantic Ocean and to the east by Cameroon occupies a surface area of about 112,110 km^2. It represents about 12% of Nigeria's total surface area and its estimated population by 2005 was over 31 million persons (culled from NDDC Master Plan). Abieyi (2005) posits that the region is also endowed with potentials in fishery, forest products, large clay deposits and a good climatic condition that supports tourism and wild life. Further to this, is the thick evergreen forest which houses diverse animals and plant species and whose flora and fauna are dominated by extensive mangrove belts and water hyacinth. Regrettably, it has also become a source of intricate and perhaps excruciating conflicts, contradictions, environmental degradation and pollution from decades of prolonged and persistent oil and gas exploration and exploitation. The Niger Delta today is inundated with a maze of pipelines, delivery lines, flow lines, canals and slots, drilling sites, flare stations, geophysical prospecting transects, etc., making it a frontline of adverse changes and vulnerability (Opuaji, 2015). Peel (2009) corroborated this fact that petroleum operations have caused massive environmental pollution in the oil producing area of the Niger Delta. Specifically, there have been pipeline leakages, wells blow-outs and spillages which have had severe effects on land, water resources, the micro-climate and to residents. There have been unquantifiable environmental degradation and hazards, loss of valuable agricultural land and settlements to the burrow pits as well as impoverishment of the people (Okoli, 2008). The activities of these companies and their operations no doubt impact on the environment with the attendant alterations. In spite of the huge and damaging side effect of the various project development in the area, relevant organs of government have deliberately down play the connection between environmental degradation and pollution with project development (Powell, 1993). From the foregoing, the region environmental challenges has underscored the need for strong legal framework for impact assessment.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA): AN APPRAISAL

EIA attempts to determine the effects of modernization processes with agriculture, industrialization, urbanization, oil and other mineral exploration and exploitation, transportation, housing pattern and cultural heritage on the existing equilibrium relationship between the surroundings and its inhabitants between project conception and completion. The usual approach adopted is to obtain ecological baseline data, field and laboratory studies, interviews and consultations with individuals/representatives of the communities of the project area. Several techniques have become routine in the EIA process (Usman, 2001). These techniques include:

(1) Description of the natural environment with biophysical, chemical, ecological, hydrogeological/geological, socio-economic, health status, etc.
(2) Description of the processes, projects, etc., being proposed or already undertaken for a given environment.

(3) The effects of "developmental" processes, projects and related activities on the natural environment and proximal areas of influence.
(4) The spatial temporal content of the study area (that is, the environment) is a critical component in assessing impacts including all the areas likely to be potentially affected by the projects.

In order to bring in some order in the developmental processes, an aspect of EIA has evolved laws, regulations, treaties, ethics and standards that promotes the philosophy that the environment is not an abstract concept but represents a phenomena that must be sustained for the quality of life of human beings, including generations yet unborn. The existence of the general obligation of states to ensure that "developmental" and "modernization" activities within their jurisdiction and control conform to these international environmental regulations, laws, treaties, has resulted to the evolution and promulgation of associated laws such as National Environmental Standard and Regulations Enforcement Agency (NESREA, 2007) relating to the EIA process. NESREA is charged with the responsibility of enforcing all the environmental laws, guidelines, policies, standards and regulations in Nigeria. This is also in addition, to all international agreements, protocols, conventions and treaties on the environment to which Nigeria is a signatory (Ojile 2009). However, the challenge has been the lack of commitment by both relevant international organizations and the government to ensure the true applicability of these laws (Usman, 2001). There is no doubt that several assessment reports are produced for intended projects and associated exploitation activities with promises of potential economic benefits to the host community but not for the environment which guarantees the sustainability for the future (Adigun and Oniemola, 2009). In summary, environmental impact assessment attempts to determine the effects of developmental' projects on the existing equilibrium relationship between the environment and its inhabitants.

INTERNATIONAL LAWS, POLICIES AND REGULATIONS

Issues bordering on the protection of the environment cuts across several areas and disciplines, including political interests, economic interests, international relationships as well as interests in human right laws, international trade and international environment laws (Abdulkadir and Imam, 2009). The pronouncement of the Secretary General of the United Nations Organization, Ban Ki Moon, that "the world is still waiting for a solution that is long-term and economically viable" (http/www.reuters.org), clearly indicates that the search for a permanent solution remains on-going. In the light of this development, the study of the impact of the activities of man on the environment thus cuts across several disciplines of contemporary academic exercise. This underscores the major goal of international environmental laws which seeks to develop universally negotiated agreements that create effective international standards for environmental protection (Michael, 1992).

In 1992, a United Nation conference on Environment and Development (Rio Declaration on Environment and Development, 31 ILM 874, 1992) which developed five critical documents vi-za-vis Agenda 21, an action plan for sustainable development in the 21st century, the Rio declaration- principles on healthy environment and equitable development, the convention on biodiversity, the convention on climate change and a statement of forest principles. These five documents provides the legal and ethical framework for the preservation and impact monitoring of the environment from a global perspective (Ojile, 2006)

Much of contemporary international environmental law deals with issues such as the sustainable use of fresh waters, fisheries, forestry, and biological diversity (endangered species) (UNEP, 2010). An isolated developmental activity may have very little negative environment impact within a more or less confined space, e.g. regions, states, Local Government Areas (in the Nigerian context), but the cumulative effects and implications of such impacts may be much more adverse as time goes on and the spatial influence of the impact increases. For instance, sometime in the year 2012, the flood events of relatively high return periods occurred in the lower regions of the Niger-Delta river basin, (FEMA, 2012). Some experts (Orupabo and Hart, 2015) attributed these events to the release of waters from dams located at the upstream sections of the rivers Niger and Benue systems. The environmental impacts of the released waters from the dams were of little negative effect in regions at the upstream sections of the river systems. As shown in Figure 1, it was down-stream sections of these river systems (the Niger Delta communities) that were relatively negatively impacted upon and the spatial influence greatly increased due to the topography of the area.

In the same manner, phenomena such as oil spills as a result of technical accidents or sabotage may have increased influence away from the region of occurrence of the incidence and residual negative impacts be more severe in geospatial attributes and as time progresses. That the Niger Delta region of Nigeria groans from environmental degradation requires that certain assumptions underlying the immense neglect of the area's environment be confronted from a legal and ethical grounds that are rooted in sustainable development (Udoh, 2001).

It is on this basis that International Environmental Laws have had too much in common with International Human

Figure 1. Effect of flood in parts of Nigeria (National Emergency Management Agency (NEMA), 2012).

Rights Laws for the regulation of man's developmental activities that may negatively impact the environment.

An outline of some international laws, regulations and policies with their corresponding objectives and applicability are reviewed in this work. They have been severally applied to commonly identified developmental projects for regulating and protection of environments in other climes. These laws can promote the sustainability of the Niger Delta environment and in particular has implications from the immediate geo-spatial location of the activity (community, Local Government Area (LGA), state, region, etc.) to proximal communities at various epochs (that is, in time and space).

There are also Nigerian national laws derived from these international Laws. Between 1963 and 1990, Nigeria became signatory to a number of international laws, which led to the promulgation of these national laws targeted at protecting the Nigerian environment and in particular Niger Delta Region. They include but not limited to the following, Mineral Oil (Safety) Regulations Act 1963, Petroleum Regulations Act 1967, Oil in Navigable Waters Act 1968, Oil Terminal Dues Act 1968, Petroleum (Drilling and Production) Regulation Act 1969, Petroleum Amendment Act 1973, Associate Gas Reinjection Act 1979, and Harmful Wastes (Criminal Provisions) Act No. 42 of 1988 (Eneh, 2010; Amukam, 1997).

Environmental impact assessment is carried out within the framework of both local, national and international environmental guidelines and regulations. Some of these statutory international laws and regulations are summarized as the following.

World Bank Guidelines on Environmental Assessment (EA) 1991

The World Bank Operational Directive 4.00 of 1989 (Environmental Assessment) subsequently amended as Operational Directive 4.01 in 1991 deals on environmental impact assessment. EA is designed to be a flexible process that makes environmental considerations an integral part of project preparation and allows environmental issues to be addressed in a timely and cost effective way during project preparation and implementation. The bank requires the execution of an EA on a proposed industrial activity by a borrower as pre-requisite before granting any financial assistance in form of loans. These guidelines are published in the Bank's EA source book Vols. 1-3 of 1991. The critical issues raised are Biological Diversity, Coastal and Marine Resources Management, Cultural Properties and Hazardous, and Toxic Materials and international waterways.

International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines 1996

The World Conservation Union statutes have undergone several amendments from 1948 to the recent amendment of 2015. It provides the list of threatened animals and categorized them based on the relative risk of extinction; in addition, list of species that cannot be assessed due to insufficient data. This system is designed to determine relative risk of extinction and the main purpose of the list is to catalogue the species that are regarded as threatened at the global level, that is, at risk of overall extinction. It recognizes principally, that conservation of nature and natural resources involves the preservation and management of the living world, the natural environment of humanity, and the earth's renewable natural resources on which rest the foundation of human civilization.

Convention on the conversation of migrating species of wild animals (Bonn Convention, 1979)

This convention was adopted in 1979 and entered into force on November 1, 1983. It is also known as the Bonn

Convention, it recognizes that states must be the protectors of migratory species that live within or pass through their national jurisdictions, and aims to conserve terrestrial, marine and avian migratory species throughout their ranges. It is concerned with the promotion of measures for the Conservation and management of migrating species. Migratory species are vulnerable to a wide range of threats, including habitat shrinkage in breeding areas, excessive hunting along migration routes, and degradation of their feeding grounds.

Convention on Biological Diversity (1992)

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction. To this end, the objectives of this convention, are to be pursued in accordance with its relevant provisions. They include the conservation of biological diversity, sustainable use of its components and fair and equitable sharing of the benefits arising out of the utilization of genetic resources. Further to this, is an appropriate access to genetic resources through proper transfer of relevant technologies, using an appropriate funding approach.

Convention Concerning the Protection of the World Cultural and Natural Heritage Sites (or World Heritage Convention, 1978)

This convention set aside areas of cultural and natural heritage for protection. These are areas with outstanding universal value from the aesthetic, scientific and conservation point of view.

Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal (1987)

It came into force in Nigeria in 1989. This convention defines wastes that must be regulated and controlled in its trans-boundary movement, to protect human and environmental health against their harmful effects. It was to protect by strict legal control, human health and environment against adverse effect, which may result from generation and management of hazardous waste. One of the interesting attributes of this convention is that if wastes are smuggled into the territory of one state without the competent authority's consent, such waste can be returned back to the country.

United Nations Framework Convention on Climate Change (1992)

This convention aims to protect climate system for present and future generation. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted as the basis for a global response to tackle the challenge posed by climate change. With 195 parties, the convention enjoys near-universal membership. The ultimate objective of the convention is to stabilize greenhouse emission.

Geneva Conventions on the Continental Shelf and the High Seas (1958)

This treaty was assented by Nigeria on May 28, 1971. It contains rules designed to prevent or minimize oil pollution arising from exploitation of the continental shelf or its natural resources. It was used to mark the territory of the seas and its internal waters.

The International Convention for the Prevention of Pollution of the Sea by oil, 1954 (amended severally from 1958 through 1982 to 1992)

The international convention for the prevention of pollution of the sea by oil is a product of the deliberations of the Inter-Governmental Maritime Consultative Organization (IMCO). This treaty was assented by Nigeria on April 22, 1968. This regulation covers the obligation of state as it relates to the pollution of the marine environment from all polluting sources such as oil, nuclear related activities, etc. This convention applies to all ships, except tankers of under 150 tons gross tonnage and other ships of under 500 tons gross tonnage. All ships covered by this convention are to carry an oil record book in a form specified in the annex, to be completed whenever certain operations take place.

Convention for Cooperation in the Petroleum and Development of the Marine and Coast Environments of West and Central Africa, 1984

This treaty was ratified by Nigeria on August 5, 1984. It has the objective of protecting the marine environment of coastal zones and related internal waters falling within the jurisdiction of the states of the West and Central African region.

The United Nation Organization as an international organization meant to maintain the efficacy and efficiency

Table 1. Applicable International Environmental Laws and Regulations.

S/N	Laws/Regulations	Effective date	Summary of purpose	Responsible organization
1.	The Endangered Species (Control of International Trade and Traffic Act, No 11)	1985	Prohibits the hunting and Trading of animal Species	UNO
2.	World Bank Guidelines on Environmental Assessment (EA)	1991	Guidelines required to attract support from World Bank	World Bank
3	International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines	1996	Provision of list of threatened animals and categorize them based on the risk of extinction	UNO
4	Convention on the Conversation of Migrating Species of Wild Animals (Bonn convention)	1979	Promoting measures for the conservation and management of migrating species	UNO
5	Convention on Biological Diversity	1992	It aims at conserving biological diversity	UNEP
6	Convention Concerning the Protection of the World Cultural and Natural Heritage Sites	1978	It sets aside areas of cultural and natural heritage for protection	UNESCO
7	Basel Convention on the Control of Trans-Boundary Movements of Hazardous wastes and their Disposal	1987	It regulates and controls the trans-boundary movement of wastes	UNEP
8	United Nations Framework Convention on Climate Change	1992	It aims at protecting the climate system for present and future generations	UNO
9	Geneva Conventions on the Continental Shelf and the High Seas	1958	It is designed to minimize oil pollution	UNO
10	Convention for Cooperation in the Petroleum and Development of the Marine and Coast Environments of West and Central Africa	1984	To Protect the marine environment of coastal zones and related internal waters	AU

of International law recognizes the sovereignty and individuality of each state among the committee of nations (Ajayi and Ikporokpor, 2002). The states have exclusive jurisdictional control over its territory (that is, its environment). It is to this extent that many conferences, conventions, treaties and protocols were initiated to protect the world environment.

From the foregoing, Table 1 shows the applicable international laws and regulations as enunciated above. It showed the effective date of the promulgation of these laws, its purpose and responsible organizations. However, majority of these laws were established between 1985 and 1992. This period marked an increase on the awareness and advocacy of the danger and implication of certain activities on the environment including the Niger Delta area of Nigeria. The Niger Delta region of Nigeria is one area that epitomizes the dereliction in its true sense owing to the uncaring attitude of man to the environment. In the Niger Delta of Nigeria, the exploitation of rich oil and gas deposits in the vast swamps and the triangular-shaped coastal region, through which the River Niger and its tributaries discharge their waters into the Atlantic, has fast become a tragic experience for the vast majority of the population (Peel, 2005). The world body (United Nations) and its agencies rose to the occasion through the adoption of these relevant environmental laws. The Geneva Convention of continental shelf and high seas of 1958 was the oldest. It was observed that the Organization of African Unity (now African Union) has not done much in this regard as very few conventions and protocols geared towards the preservation of the environment have been adopted (Abdulkadir and Imam, 2009). This is despite the enormous impact on the environment especially as developing countries. International Environmental Laws relating to impact assessment are strictly predicated on the adherence of procedural requirements rather than guidelines on the utilization and exploitation of environmental resources. Douglas and Okonta summed up this issue quoting a report submitted to the World Conference of Indigenous Peoples on Environment and Development during the Rio Earth Summit in June 1992, by the kings, chiefs and community leaders of the Niger Delta which states “Apart from air pollution from the oil industries ‘emissions and flares day and night, producing poisonous gases that are silently and systematically wiping out vulnerable airborne biota and otherwise endangering the life of plants, game and man himself, we have widespread water pollution and soil and land pollution that respectively result in the death of most aquatic eggs and juvenile stages of life of fin-fish and shell-fish and sensible animals (like oysters) on the land, whilst on the other hand agricultural land contaminated with oil spills become dangerous for farming, even where they continue to produce any significant yields” (quoted in Okonta and Douglas, 2001). Having reviewed the content of some international environmental laws and agreeing with Akintayo (2006); these laws are broad and extensive as applicable to the Niger Delta area in Nigeria. The African Charter on Human and People’s Right (Ratification and Enforcement) Act Cap 10, Article 24 succinctly states that “all peoples shall have the right to a general satisfactory environment favourable to their development. In view of the importance of these international environmental laws and conventions as may be applied to the Niger Delta of Nigeria, most of these laws has not been ratified and domesticated by the country (Charles, 1984). This has raised serious moral and ethical questions about the Niger Delta Environment. Further to this, the corpus of international laws and conventions relating to the environment without the capacity provisions detailing out necessary ingredients of the subject matters makes it difficult to seek for justice and remedies when the environment is abused.

CONCLUSION

Finally, environmental issues in the Niger Delta has provoked considerable interest both nationally and internationally particularly in the mid-1990s despite the availability of relevant international laws on the environment that are not strictly enforceable. The environment of the Niger Delta should no longer be seen as a mere object, but a co-subject with man’s activities. The region’s environment has majorly been plagued by extensive land degradation, water and air pollution mainly through oil and gas related activities such as seismic blasts, oil pipelines leakages, dredging, gas flaring and effluent discharges driven by the various multinational companies. In view of the net effect of these activities, Awajiusuk (2010) asserts that the Niger Delta can be seen as an environment cum ecosystem so mangled, raped and denuded that the area has been labelled by the most endangered delta in the world. However, the much talked about UNEP report on the Ogoni (in Niger Delta Region) environment clean up readily demonstrated the implication of international organizations intervening and bringing to the fore issues of the human activities on the environment and its impact assessment from the world view based on the relevant international laws, regulations, policies, and guidelines.

Conflict of Interests

The authors have not declared any conflict of interests.

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Review

Importance of soil physical characteristics for petroleum hydrocarbons phytoremediation: A review

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Petroleum and petrochemical hydrocarbons for some places are serious sources of environmental pollutants. To remediate these contaminants, phytoremediation, a relatively low cost and an environmental friendly technique is recommended more widely, now more than ever. Successful and effective applying of hydrocarbons phytoremediation depends mainly on the soil and plant types and conditions and microbial activities and the interactions between these three factors. Although for the last several decades, various plant and organism's species for the phytoremediation processes have been extensively studied, evaluating and characterizing soil properties, as an important objective for sustainable remediation and land use management, which had negligible considerations. An ideal soil for phytoremediation should have proper physical, chemical and biological characteristics to let the plant grow well and produce biomass as high as possible. It also should provide favorable conditions for microbial activities to perform efficient remediation. Soil physical characteristics such as texture, structure, water status and aeration are important factors affecting the microbial activities and consequently the degree of remediation potential. A better understanding of soil physical properties in conjunction with proper soil-plant-microbe management could be exploited to enhance the remediation of hydrocarbon contaminated soils and thus sustainable healthy environment.

Key words: Phytoremediation, petroleum, hydrocarbon.

INTRODUCTION

In the current industrial society, using petroleum as a primary source of energy and for petrochemical byproducts is inevitable (Bierkens and Geerts, 2014), but for some specific places these activities pose the major sources of soil and water pollution as well (Hentati et al., 2013). According to Macci et al. (2013), industrialization during the past decades caused an ever-increasing reliance on petrochemicals, and as a consequence, many sites have been significantly contaminated with petroleum and the petroleum-byproducts (Jesus et al., 2015 and Gennadiev et al., 2015). This is especially more serious around the petroleum and petrochemical complexes and refineries in the countries producing these materials and generally the overall industrialized regions.

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According to the EPA (US Environmental Protection Agency) the very hazardous chemicals like benzene, toluene, ethylbenzene, xylenes, and naphthalene are included in the petroleum hydrocarbons (Lehmann et al., 2006, Bojes and Pope 2007, Gao and Collins, 2009, Cook et al., 2010, Boonsaner et al., 2011, Fester et al., 2014, Germaine et al., 2015). These pollutants can affect soil physical characteristics like soil texture and structural status, compaction, saturated hydraulic conductivity, and penetration resistance (Hreniuc et al., 2015). When released on the surface soil, petroleum hydrocarbons, with a specific physico-chemical characteristics (Zahed et al., 2010) pushes soil toward a condition undesirable for proper and sustainable growth of plant and rhizosphere organisms activity (Gaskin and Bentham, 2010; Masakorala et al., 2014). Sources of spreading hydrocarbons also include storage tanks leakage, which only in 1994 was estimated to be around 250,000 numbers in the USA (Buswell, 1994). This means that presence of these contaminants in soil significantly reduce the quality of soil and thus minimize the germinating, growth and health of plants (Tang et al., 2010a). Therefore, remediation and removing of these materials from soil is necessary for the sustainable environmental health (Kang, 2014; Nichols et al., 2014). The petroleum contaminants are mixtures of solid, liquid and gaseous of hydrocarbon molecules with linear or polyaromatic structures (Moubasher et al., 2015); so not all compounds should be treated similarly and remediated by identical mechanism.

The source and degree of processing of the petroleum hydrocarbon adds an additional layer of complexity as, hydrocarbons may be in the form of crude oil or refined products such as gasoline, diesel or plastic byproducts (Kaimi et al., 2007; Barnes et al., 2009). Aging of the compounds in soil is another factor affecting the remediation phenomena (Wang et al., 2014). Phyto-remediation, make the use of plants to remediate contaminated soil, water or air and as an environmentally safe technique which is more than ever used in treatment or removing of pollutants from the contaminated sites (Tang et al., 2010b; Rascio and Navari-Izzo, 2011; Lotfinasabasl et al., 2013). Comparing to the destructive and expensive traditional methods (washing, excavating or thermalizing), this is a relatively low cost alternative, recently used for the remediation of a variety of environments (soil and water), contaminated with heavy metals and/or petroleum hydrocarbons (Semple et al., 2003; Ahn et al., 2008; Marek et al., 2009; Falciglia et al., 2011). However, using the phytoremediation technique maybe limited to a certain soil depth (up to the root zone area) and to a relatively low contaminants concentration. Phytoremediation is a collaborating soil, plant and organisms technique, in which plants, basically through the root systems clean, remediate or detoxify the polluted sites (Kamath et al., 2004; Isitekhale et al., 2013; Abhilash et al., 2014). The basic processes of phytoremediation include: transforming, stabilizing, assimilating, metabolizing or detoxifying of the hydrocarbon molecules.

Almost all of these procedures are depended on the interaction between the soil, plant and organisms (Zhang et al., 2010). In this regard, soil is the basic support for plant growth and a necessary medium for the organism's activity in almost all ecosystems; therefore a successful phytoremediation management tentatively relies on the power of this collaboration. According to Padmavathiamma et al. (2014) for the phytoremediation technique to be successful, answering the following questions are crucial; if the contaminants allow the species to be germinated or transplanted, if the species are able to inoculate with the presenting micro organisms and if the use of local versus exotic plants and microorganisms is possible. An important factor in this regard is that, phytoremediation efficiency is absolutely affected by the concentration of petroleum contaminants (Peng et al., 2009).

After delineating and expressing the type and extent of contaminated soil and also finding out the methods to quantify the petroleum substances (Gan et al., 2009; Liu et al., 2011; Zhang et al., 2012; Abdullah et al., 2014; Pinedo et al., 2014; Potashev et al., 2014; Zhang et al., 2014; Wolejko et al., 2016), the subjected soil should be characterized as the first step in planning remediation strategies (Mao et al., 2009). This step includes testing and analyzing soil physical, chemical and biological characteristics. These analyses bring details of the degree of succession for the techniques such as microbial-based, bio-stimulation (Haslmayr et al., 2014) and bio-augmentation or phytoremediation in the processes of hydrocarbon degradation (Ayotamuno et al., 2006; Towell et al., 2011).

It is basically the soil conditions which manage plant-microbe interactions (Alrumman et al., 2015), therefore an ideal soil for phytoremediation should have proper characteristics in order to, let the plant grow well and produce biomass as high as possible (Khan et al., 2013; Phillips et al., 2012). Soil physical properties such as texture, structure, aeration and water status are among the factors affecting root-organism activity and performance. It is also the root exudates that cause the soil to become firm resulting in, movement of oxygen into deeper soil layer, higher root growth, more micro-organisms' activity and thus more hydrocarbons degrading (Técher et al., 2011). Soil characteristics and plant-microbe interaction, significantly affect soil nutritional status, the quality and quantity of root exudates and consequently on bioavailability-remediation of petroleum hydrocarbons and heavy metals at the rhizosphere area (Técher et al., 2012). During the last three decades many researchers reported the importance of, different plant and organism species during the phytoremediation processes, but very little is mentioned about the soil part in this regard.

However, the efficiency of phytoremediation, degrading activities and performance of this technology greatly depend on factors like soil type, water status, nutrient bioavailability, soil temperature and aeration condition, salinity, sodicity and pH. Although, not well documented, evaluating and characterizing soil properties during phytoremediation processes can be a valuable help for decision making and finding possible use of different remediation techniques. In this review the role of a number of soils physical characteristics are being explained during the phytoremediation processes of petroleum hydrocarbon.

Soil texture (particle size and distribution), structure (pore size and tortuosity), consistency, bulk density (compaction), organic matter and moisture content, temperature status, and salt and nutrient content are some of the most important physical characteristics affecting root growth and development. Proper soil conditions allow roots to have the proper growth and thus having higher phytoremediation efficiency. For roots, the following morphological parameters are important: root architecture, structure, tensile strength, tortuosity, number, diameter, conditions (live or dead) and root hairs (Wang et al., 2013; Loades et al., 2013) which almost all, depends on soil physical (textural and structural) characteristics. In the following sections some of the important soil physical characteristics involved in the processes of phytoremediation of petroleum hydrocarbons are, being evaluated.

HYDROCARBONS (HC) AND SOIL QUALITY

Several studies have highlighted factors such as soil organic matter content, temperature, pH, salinity, nutrient availability (particularly nitrogen and phosphorus), soil moisture content, oxygen availability and redox potential, influencing the bioremediation and phytoremediation processes (Chaillan et al., 2006, Lone et al., 2008, Wang et al., 2012 and Waqas et al., 2014). In soil, plant seeds should be able to absorb water, to germinate at the first place then anchor, stabilize and support the plant afterwards. The microbes should also be able to biologically function in soil, in order to function as the remediation tool, but in this regard unfavorable soil conditions have diverse effects (Afzal et al., 2011). The mentioned parameters are examples of soil quality indices. Soil quality is an important factor for sustaining plant and animal productivity, maintaining/ enhancing water and air quality, and supports the life of people on the earth, now and in the future. Traditional strategies for improving soil quality includes increasing physical properties like aggregation or optimizing particle size distribution (Herrick et al. 2001), lowering salinity (Lawton, 2015; Kalliola et al., 2016), adjusting extremely low or high pH to more neutral values, increasing plant coverage (Laird and Chang, 2013) and enhancing microbial community activity in the rhizosphere (Lamers et al., 2012; Wang et al., 2013).

However, the quality of soil is continuously subjected to all kinds of environmental stress or produced by human activities such as production of petroleum hydrocarbons. With the growing societal and industrial demands this kinds of pollution is occurring through transportation, accidental spills and during petroleum refining operations. As reported by Pathak et al. (2011), petroleum hydrocarbon contamination is able to increase toxicity and thus lowering soil quality. According to Pathak et al. (2011) and Onojake and Osuji (2012) soil physical and chemical quality such as moisture status, pH, EC, and water holding capacity is significantly reduced by petroleum hydrocarbon contaminations. On the other hand attributes like soil textural, structural and water and air characteristics are important factors to accelerate or reduce the degradation of soil pollutants. In this respect, Pathak et al. (2011) stated that, the particle and pore size distribution by affecting soil aeration, bulk density, hydrocarbon movements (both vertical and lateral) and adsorbing/desorbing contaminants, significantly enhance or lower the degradation of pollutants. When contaminants like petroleum hydrocarbons are present on the soil surface, both biodegradative and non-biodegradative processes happen in soil. The non-biodegradative processes include draining due to irrigation, evaporation/volatilization, direct plant uptake and adsorption by soil particles or organic matter. Almost all of the non-biodegradative processes are in association with soil physical characteristics. Results in most of the studies show that, TPH loss through direct plant uptake is negligible because mixtures of petroleum hydrocarbons similar to diesel oil could not be taken up by the plant (Schwab and Banks, 1994; Reilley et al., 1996).

In this review the attempt is to relate the effects of hydrocarbon contaminations on soil physical characteristics as the major soil quality attributes.

PHYTOREMEDIATION OF HC AND SOIL TEXTURE

Relative quantities of sand, silt and clay form a soil textural class. Texture is a basic soil property which influences other characteristics such as water holding capacity, root growth and development and nutrient dynamics in soil. The amounts and sizes of different particles should, provide proper balance between the macro and micro pores for easy air and water movement, in soil and holding water as well. These physical properties have direct effects on the dynamic and fates of any elements in soil (Scherr et al., 2007; Abdel-Moghny, 2012). Clayey soils are more plastic and sticky and have more swell and shrinkage activity and the presence of petroleum hydrocarbon in it results in, more stickiness, binding and clogging. While sandy soils have less plastic and stickiness properties, so the mobilization of the contaminants would be easier in these course textured soils (Abdel-Moghny, 2012). Generally, coarser particles (sand) when mix with the fine clays and silt, build pore spaces with different shapes and sizes, then provide various routes and fates for the contaminants like petroleum hydrocarbons. Lee et al. (2002) showed that sand is able to recover about 73% of toluene and 84% of TCB when tested in a batch experiment. They also reported that, sandy soils are more effective for surfactant remediation than clay soils because the clay surface adsorption reduce surfactant effectiveness. Not only the diversity and abundance of the clay, minerals is an important factor in the remediation processes, but sometimes the fractions of fine particles in one specific texture control the procedure (Carvalho et al., 2015). Falciglia et al. (2011) investigated soil textural behavior (coarse, medium, fine sand, silt and clay size aggregate fractions) involved with artificially polluted diesel fuel, and thermally treated at different temperatures. They concluded that desorption efficiency is influenced by soil texture such that fine sandy soil showed the highest desorption of the contaminant, and a temperature of 175°C is good enough to reach low contaminant residual concentration of almost100 $mgkg^{-1}$ for all size fractions. For the clay, the highest desorption happened at temperature around 250°C (Falciglia et al., 2011).

In another study, limestone and granite with specific clay minerals showed higher duration for achieving the target remediation efficiency but schist with the highest fine fraction and no clay minerals, resulted in the lowest time necessary for remediation (Carvalho et al., 2015). Yanai et al. (2006) showed that along with coarser textural particles, low pH (between 5 and 6) and high concentrations, resulted in more Cd uptake by *Thalaspi caerulescens* plant. Soil amendments or conditioners like biochar (Sarkar et al., 2005; Qin et al., 2013) or zeolite (Wen et al., 2016) are also able to modify soil textural and structural and thus diverting the mobility of some heavy metal ions (Zn, Pb, Cu and Cd). This could be due to the influence of soil amendments on plant rhizosphere and thus on PAH bioavailability (Gana et al., 2009; Marchal et al., 2014).

Wang et al. (2012) and Waqas et al. (2014) also reported the effects of amendments like compost and sewage sledges and biochar on remediation of some PAHs. Soil texture, by controlling bioavailability of the plant nutrients and the contaminants would change the phytoremediation result (Figueiredo et al., 2016). This is because clay can bind molecules stronger than silt or sand therefore, the bioavailability of contaminants is lower in soils with higher clay contents (Abdel-Moghny, 2012). Sandy soils commonly have higher PAH mineralization comparing to silt and especially to the clay particles which could be due to the greater bioavailability of the contaminants in the sandy soils (Carmichael and Pfaender, 1997). Edwards et al. (1982) showed that soybean bioavailability and uptake of ^{14}C-anthracene from nutrient solution is higher than from soil, which could be due to more adhering of the PAHs to soil particle than to the water molecules. This also might be due to the chemical hydrophobicity of some contaminant substances in soil (Dettenmaier et al., 2009). According to Sterling et al. (2004a,b) in a modeling approach of simulating the changes in particle size distribution and density due to aggregation, clay and crude oil were categorized as cohesive particles and colloidal silica was classified as non-cohesive. To show the interaction between soil particle size, contamination and the functionality of microorganisms, Amellal et al. (2001) pointed that degrading bacteria are more active in the silt and clay particles in the uncontaminated soils, but when contaminated, the sandy texture soils showed higher microorganism's populations and activity.

In another study Huesemann et al. (2004) also showed that soils with low percentages of fine silt and clay demonstrated higher degradation rates of hydrocarbons. This could be due to the aeration porosity which in turn depends on soil texture. Sandy soils have a higher percentage of macro and the clayey soils produces more of the micro pores, so the clay soils are more susceptible to water logging which can adversely affect root respiration and microbial activity, therefore in the water lodging situation degradation of hydrocarbons would dramatically reduce. Regarding the phytoremediation of petroleum hydrocarbon, it can be concluded that, because the contaminants have weaker binding to the particles and both plant roots and organisms are more active in the coarser soil textures, there appear to be more performances in the coarse comparing to the finer textural classes.

PHYTOREMEDIATION OF HC AND SOIL STRUCTURE

Soil structure is "how the particles joint or bind together to form a larger piece of soil named lumps or aggregates". Soil structure as a dynamic property is subjected to change via various soil management practices such as tillage, crop rotation, irrigation, drainage and also to contaminations like petroleum hydrocarbons. Pores between the soil particles are occupied by air and/or water which control the functions such as seeds emergence and plant growth and number and kinds of organisms. Roots are only able to move through the spaces between the particles or aggregates, so the soil should have an aggregating structure such that the roots of the seedling which can easily penetrate into it. Spaces between the aggregates are macro while those between the individual particles of the aggregates are micro pores. Therefore, soil physical properties should not be any containment to the seed emergence and root growth processes, but the presence of contaminants like petroleum hydrocarbons in soil would disturb this habitat. In an experiment referring to the interaction between soil aggregation and hydrocarbon contamination Amellal et al. (2001) indicated that, more PAHs were found in the smaller size fractions (clay < 2 µm and fine silt 2 to 20 µm) compared to the sand and coarse silt. This accumulation and binding process is driven predominantly by the organic carbon content of the fractions (Tan et al., 2007; Guimara et al., 2013; Razafimbelo et al., 2013). The degrading microbes of PAHs were also distributed un-evenly through out the soil particles with different sizes (Razafimbelo et al., 2013). The collaboration of organic matter in soil for building aggregates in several land use managements had, variety of influences on the fate of PAHs, reported by Xiao et al. (2014). They reported that total PAHs were strongly bound to soil organic matter and since OM is an important binding agent for aggregation, the larger and more stable aggregates (naturally with more OM) contain more PAHs too. One of the important and promising ways to positively alter soil aggregation fractions and thus improving hydrocarbon degradation is the addition of binding agents to the soil. Commonly these agents could be very simple plant residues (different organic materials) with low density and when incorporated with soil it lowers the bulk density and increase porosity and oxygen diffusion and further help building water-stable soil aggregates. These materials include vermiculite (inorganically), and saw dust, wheat bran, hay and other grass residues organically enhance jointing soil particle together and consequently increase aeration, microbial activity and thus hydrocarbon degradation (Razafimbelo et al., 2013). In respect to soil aggregation and remediation processes some other complexities like root growth and functions, soil water status and chemical properties (i.e. salinity) should be considered. Roots while growing, release organic material into soil, stabilizing aggregates (Gurska et al., 2009 and Tejeda et al., 2013) but salinity by dispersing the aggregates that cause soil structural deterioration (Rengasamy and Olsson, 1991). Soil heterogeneity as an index of texture and structural status that alter mycorrhizal colonization and pollutant distribution in soil so, these can substantially change the plant response and functionality for phytoremediation (Langer et al., 2010; Liu et al. 2016). According to Liu et al. (2016) sedimentary heterogeneity has a significant effect on hydrocarbon accumulation, which in turn might have similar influences on release and remediation of these compounds. Soil aggregation regulates soil structural stability, root penetration and water and air infiltration which all are physical properties and are important for soil erosion and permeability (Bengough et al., 2006) and through this phenomenon the fate of hydrocarbons in soils may alter.

Compaction as a deteriorating soil physical and structural status is a process by which the bulk density of soil increase, pore space decrease, water and air movement and biological activities restricted. The basic phytoremediation processes such as removing, degrading, transforming, or stabilizing of the contaminants depend on the soil dynamic properties like aeration porosity which is known as an important index for soil structural status. Therefore, if compaction occurs some processes in contaminated soil like the rate and quantity of phytoremediation of petroleum hydrocarbons may be reduced. Water and air content which strongly are related to the soil texture and structural status, both known as the key factors involved in polyaromatic hydrocarbons (PAH) bioremediation. A well structured and aggregated soil enhances both movement and fate of the petroleum contaminants (Sterling et al., 2004). According to Pathak et al. (2011) the vertical movement of the petroleum contaminants is changed not only because of the alteration in aggregate density, but may be due to the reduced sediment aggregate porosity.

Lee et al. (2002) also mentioned that these effects might be because of the interaction between the petroleum substances and the soil particles and also due to the buoyancy effects of the contaminants in the substance-clay aggregates. Compact soil layers limit root growth and also adversely affect properties related to water and air movement in soil and around plant roots. A good structured soil provide proper condition for plant root growth and mutually increasing root activity which results in a good soil structure, with a dynamic situation for water, air and nutrients in soil. Petroleum hydrocarbons in a structurally hard and naturally weathered soil, according to Gerhardt et al. (2009), commonly causes the contaminants not to be readily bioavailable. This could be due to the hydrophobic characteristics of the petroleum components which retard mass transfer of air, water, and contaminants from particles to microorganisms in soil. The consequence results will be limiting the rate of uptake and metabolism of contaminants by microorganisms (Das and Chandran, 2011). The rooting depth and the mechanism by which, nutrients reach near the root surfaces (rhizosphere) are some limiting factors affecting the petroleum contaminants remediation in soil (Loades et al., 2013). Adversely, in a well structured soil, when plant roots grow well, root penetration ease inserting air and also exerting exudates and substances into the soil, thus physical structure improve and microbial populations and activities would be enhanced and so the remediation of the petroleum contaminants. Therefore, a more enhanced plant root growth provided by proper soil physical properties (Li et al., 2002 and Loades et al., 2013) and nutritional status (Lamers et al., 2012), sufficient moisture content (Quyum et al., 2002) and good oxygen transport to lower depths in the soil (Neira et al., 2015), stimulate petroleum-degrading microorganisms (Jing et al., 2007), and could then significantly accelerate phytoremediation of soils contaminated with petroleum hydrocarbons (Tang et al., 2010a).

According to Bharti et al. (2014), lack of soil structure, low water supply and nutrient deficiency are generally intensify metal toxicity and so, decline plant growth in the contaminated soils.

PHYTOREMEDIATION OF HC AND SOIL AIR STATUS

Aeration porosity is the pore spaces in soil filled with air of relatively similar content to the atmosphere, which the oxygen is necessary for microbe and plants to respire. In this process oxygen is taken up and carbon dioxide release and almost all physiological activities, especially root elongation is dependent to the aeration. Oxygen is also require for processes like aerobic respiration or aerobic biodegradation which is the breakdown of contaminant molecules via microorganisms.

Aerobic bacteria utilize oxygen providing electron acceptor for, partitioning organic matters into smaller compounds. In this process carbon dioxide and water is produced. Habe and Omori (2003) has comprehensively reviewed the processes of breakdown and metabolism of soil-PAH in aerobic bacteria. Albergaria et al., 2008 reported that airflow rate directly affect the mass transfer and vapor extraction of contaminants such as benzene, toluene, ethylbenzene, xylene, trichloroethylene and perchloroethylene, during the remediation process. They concluded that for the dry sandy soils (if clay and natural organic matter content can be neglected) at the equilibrium between the pollutants and the different phases, the higher airflow rate exhibited the fastest remediation (Albergaria et al., 2008, 2010). Adversely, when there are lacks of, O_2 in soil metabolic processes in plants disturb, and accumulation of toxic substances, low nutrients uptakes occur. Aeration generally can also control soil temperature, regulate soil moisture, improve drainage, stimulate microbial activity and improve overall soil tilth. Many of the plant–bacteria interaction are dependent upon soil aeration porosity (Tang et al., 2010a). In Soil contaminant bioavailability, the composition of root exudates, and nutrient levels are all directly depend on aeration porosity (Carvalho et al., 2015). These processes would be inversely affected by entering and presenting hydrocarbons into soil, but not in all soils and situations.

Therefore, there is no unique solution for decreasing/ increasing degradation or improving soil productivity because soil conditions vary between contaminated points. In one study Caravaca and Roldan (2003) showed that adding of hydrocarbon contamination to soil improved porosity by more than 15 times when compared to the control soil. This happened in the contaminated sites because more cracks in 100 to 200μm size range of soil, were produced and thus, over time lead to improve soil quality and increased microbial activity. In another experiment, Kaimi et al. (2007), by cultivating twelve plant species measured the changes in total petroleum hydrocarbon concentration, soil dehydrogenase activity and the number of aerobic bacteria and concluded that TPH concentration was more dependent to the soil dehydrogenase activity than to the aerobic bacterial number. Several experiments (Metay et al., 2007; Razafimbelo et al., 2013) showed that crushing soil aggregates would enhance respiration (higher CO_2), which results in additional carbon mineralization as SOC pool, physically protected in soil aggregation. In cases when oxygen is absent or limited, biodegradation can occur anaerobically. Contrary to aerobic biodegradation, anaerobic microorganisms use other available substances such as nitrate, sulfate, iron and manganese as their electron acceptors to break down organic compounds into smaller constituents, often producing carbon dioxide and methane as the final products.

Alternatively some anaerobic microorganisms can break down organic contaminants by fermentation whereby in this case, the organic contaminants act as the electron acceptors. At the situations like accidental oil spills or water submerged soil in paddy field, swamps water logging happen, soil aggregates either crash or clogged, then due to high concentration of contaminants and lack of oxygen, anaerobic biodegradation is inevitable. Due to a low cost and small requiring area, anaerobic biodegradation is being to replace aerobic biodegradation. In an experiment Carvalho et al. (2015) reported higher (≥99.3%) remediation rates in bioventing technique (comparing to no ventilation - bioventing), confirming the importance role of oxygen on remediation. This effect was more pronounced for granite (comparing to limestone and schist) with biggest difference in remediation time, when compared to techniques of no ventilation (Carvalho et al., 2015). Furthermore, anaerobic bioremediation can be used for deep soil layers since the process does not require oxygen.

PHYTOREMEDIATION OF HC AND SOIL MOISTURE STATUS

Soil moisture content is another important characteristic when phytoremediation of petroleum products is considered. Soil moisture status can alter hydrocarbon degradation through several direct and indirect mechanisms. Soil is a reservoir of water and becoming the main supplier of the essential water for plant growth. Soil water status is important because of its significant role in natural processes and phenomenon such as evapotranspiration, infiltration and drainage of water, diffusion of gases, soil temperature status, and movement of salts and nutrients.

In particular, Fernandez and Quigley (1985) for example showed that soil hydraulic characteristics can alter PAH adsorption sites, such that when the soil is too wet the adsorption is driven by soil organic matter content, while in the dry situations clay content has the major role to adsorb the substances (Chiou and Shoup, 1985). With the presence of hydrocarbons in soil, generally, the limitations will be poor moisture-holding capacity (due to hydrophobicity), low permeability (due to clogging) and nutrient deficiencies (because of adsorption and toxicity). In some cases when petroleum hydrocarbon in soil results in enhancing soil hydrophobicity, water repellency and in turn infiltration and depleting water from the root zone would occur. According to Onwurah et al. (2007) contamination of soil by total petroleum hydrocarbons and its components limit soil fertility status and consequently its productivity. This basically happen via the effect of phenomenon like, water repellency which is an important phenomenon in this regard. According to Quyum et al. (2002) the mechanism of increasing hydrophobicity is, through declining soil wettability which brings discontinuities in the hydrophobic coating, whereas the existence of hydrophilic surfaces of soil particles enhance the wettability. Adversely, dilution of hydrophobic substances showed a pronounce reduction in soil water repellency (Quyum, 2000)). As reported by Adams et al. (2008), increasing water repellency in petroleum contaminated soil caused a decrease in the soil field capacity.

Several other researcher have mentioned high water repellency in soils confronted with petroleum hydrocarbons (Edenborn and Zenone 2007; Sublette et al., 2010; Nieber et al., 2011). They mentioned that the reduction in the electrostatic interaction between soil particles and water enhanced by a thin film of low-polarity of the compounds (i.e., hydrocarbons), around the polar surfaces of the soil organic matter (SOM) and clays, could be the reason (Adams et al., 2008a and 2008b). When dry, a film of petroleum hydrocarbon covers soil particles, bind them together and on the surface, it form a crust (Marı´n-Garcı et al., 2016). Large hydrocarbon molecules at the soil surface persist and glue the soil particles to form crust. The smaller sized molecules penetrate and move to the lower soil layers, block soil pores and stop air movement resulting in inhibition of biodegradation processes. This also leads to inhibition of roots to absorb water for retrieving sap and supporting plant metabolism, thus phytoremediation would be decreased or completely stop.

According to Ying et al. (2013) dumping of raw petroleum substances into the marsh soils is able to alkalinize the soil, reduces its fertility and deteriorate soil physical properties. In this case, phytoremediation has the potential to simultaneously restore and remediate the petroleum hydrocarbon-contaminated to these wetland soils Ying et al. (2013). In most cases petroleum contaminants are rich in salts too, which after the aging of organic substances; the salt by itself will have more deterioration influence on phytoremediation. For example Thavamani et al. (2015) showed that, the poor plant growth and earthworm mortality in their study was due to an increase in salinity (calcium sulfate) which results from high surface evaporation and not residual soil TPHs.

PHYTOREMEDIATION OF HC AND SOIL TEMPERATURE

Some of the soil physical, chemical and biological properties like acidity and pH, soil moisture content and number of organisms directly influence degradation of the hydrocarbons. But sometimes enhancing or prohibiting plant and organism’s functionality, in soil would indirectly alter degradation procedures.

In this regard Njoku et al. (2009) reported that grown soybean in petroleum hydrocarbons contaminated soil can alter soil physico-chemical properties and as a consequence, degradation is enhanced. The plant root exudates by counteracting toxicity of the substances which would also provide proper conditions for a better plant growth (Hechmi et al., 2013). So, any action such as adding soil amendments or conditioners to petroleum contaminated soil could enhance and increase the rate and quality of remediation efficacy of the plants like soybean or maize (Njoku et al., 2008). Chaıˆneau et al. (2005) indicated that soil nutrient concentration for plant or microbial usage is another important parameter for degradation of contaminants like petroleum oil in soil. Temperature and moisture are the two most important factor controlling biological processes for nutrient movement and availability in soil (Sylvia, 2005). Thermal characteristics of soil have both direct and indirect influences on degradation of materials like petroleum hydrocarbons. Many different soil physical characteristics such as moisture, colour, slope of the land, vegetative cover and general soil tilth, control soil temperature. Higher soil temperature affects phenomenon such as viscosity and movement of the substances and thus enhances its chemico-physical and biological processes like volatilization. Indirectly, temperature can enhance micro-organisms and plant root growth and therefore is able to enhance degradation of the contaminants (Socolowski et al., 2010). Temperature which ranges for the growth and activity of almost all of the crops and organisms in soil is commonly restricted at the temperature lower than about 9°C and higher than 50°C. This effect is very much profound on seed germination, root and shoot growth, nutrient uptake and thus on crop growth (Socolowski et al., 2010). Generally the seeds are germinating above or below a certain range of temperature but this range may not be similar for the micro-organisms. These creatures functions well in the soil around 27 to 32°C.

PHYTOREMEDIATION OF HC AND SOIL ORGANIC MATTER

Soil organic matter (SOM) is a multi-functioning substance and an important element to regulate soil physico-chemical and biological properties. When soil is contaminated with any hazardous substance like petroleum hydrocarbon, the presence of SOM can altered the fate and dynamics of these contaminants. For example the behavior of soil microorganisms is an important factor for degrading SOM and the substances is related to any kind of stressor agents such as hydrocarbons in soil (Cruz-Hernandez et al., 2013; Oliveira et al., 2015).

According to Marinescu et al. (2010) soil organic matter adsorb petroleum contaminants and through this process reduce its mobility and forming non-extractable bound residues, harden the biocidal activity and thus, decreasing bioavailability of the components would happen. On the other hand plants exude soluble organic matter into soil then, in conjunction with organic matter, potentially increase the adsorption of the above mentioned contaminant (Arora et al., 2010; Cook and Hesterberg, 2013). Although, Fester et al. (2014) mentioned that microbes may adapt to prevailing conditions in contaminated soil, according to Pandey and Singh (2004) and Adesodun et al. (2005), physico-chemical properties of soils usually affect the organism's activities especially the metabolite functioning of soil microorganisms. Several reports have shown the influences of petroleum hydrocarbons on soil biological or physicochemical characteristics (Li et al., 2007; Chakraborty et al., 2012) may result in limited bioavailability for microorganisms. For assisting of the organic matter decomposition, presence of petroleum hydrocarbons in soil may have both positive and negative influences.

Sometimes, the hydrocarbons in soil stimulate the activity of organisms by providing their required food (carbon), so in this case degradation is being faster (Siddiqui and Adams, 2002). According to Masakorala (2014) almost all of the acclimated bacterial populations are active and vigorous in most contaminated soils, and especially at the vicinity of soil-root rhizosphere. As mentioned by Kaimi et al. (2006), Jing et al. (2007) and Kaimi et al. (2007), rhizosphere (important interface of soil and plant), is an important area which plays a vital role in phytoremediation of contaminated soils (Maletić et al. 2013). At the rhizosphere area microorganisms positively affect heavy metal mobility and thus to the availability of the ions for the plants by different mechanisms. These mechanisms include chelating agents, acidification, phosphate solubilization and redox changes, which all have potential to enhance phyto-remediation processes and efficiency. But, if a large amount with high toxic substances concentration of the hydrocarbons entered into the soil, it causes mortality of the microbes, so that the decomposition of the contaminants would be seized (Siddiqui and Adams, 2002; Khan et al., 2013; Fester et al., 2014).

However, the petroleum compounds may also interact with some other ambient abiotic factors (including soil bulk density, nutrient, moisture and oxygen concentration, temperature, EC, and pH of the soil) when determining organic matter decomposition (Blakely et al., 2002). According to Galitskaya et al. (2014), in testing several techniques, adding compost to the petroleum contaminated soil, significantly promote bioremediation in most cases. Respecting microorganism’s activity, the presence and amount (concentration) of the hydrocarbon substances is a crucial factor. As mentioned by Amellal et al. (2001), the distribution of microbes in the soil differ between, contaminated and uncontaminated soils. Abiotic factors can greatly influence the rate of crude oil biodegradation (Sonawdekar, 2012). As reported by Phillips et al. (2012) the biodegradation of petroleum hydrocarbons in loamy and sandy soil under proper SOM content and favorable degradation conditions of microorganism is, inversely proportional to the concentration of the contaminants. The hydrocarbons of crude oil were totally or partially biodegraded: low molecular weight n-alkanes were completely degraded by oil degraders while the high molecular weight n-alkanes are less degradable (Moubasher et al., 2015). Branched alkanes are resistant to biodegradation as, compared with n-alkanes and also aromatic hydrocarbons which are more resistant to microbial attack than n- and branched alkanes (Riser-Roberts, 1998).

Conflict of Interests

The authors have not declared any conflict of interests.

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Land use/cover change and perceived watershed status in Eastern Uganda

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This study assessed the current status of Awoja in Ngora district of Eastern Uganda. Remote sensing, household survey, In Pac S methodology and focus group discussions were used to acquire data from April to July, 2015. Landsat satellite imageries from 2007 and 2013 were acquired by USGS Earth Explorer to quantify land use/cover changes. Five land use/cover types were identified namely; (1) open water (2) wetland (3) tree cover (4) agriculture and (5) built up area. The findings indicate a fivefold increase in built up area by 154.27Km^2 and open water changed by 8.7 Km^2 and a reduction in wetland area by -1.0Km^2 tree cover by -48.07Km^2 and agriculture area by -11.4.0Km^2. The survey results indicated deforestation, wetland encroachment, poor attitude and over population as the main reasons for degradation. In Pac S methodology findings showed convergence in the perceived indicator of degraded watershed in terms of water and soil quality; vegetation type and species diversity among the lay people and technocrats. The focus group discussion findings indicated a negative trend in land use/cover change. There is need for a concerted effort to design an appropriate restoration strategy for Awoja.

Key words: Land use/cover, remote sensing, GIS and other methods.

INTRODUCTION

Whereas watersheds are recognised for their contribution to livelihoods, the main cause of degradation has been alternate human activities resulting into land cover change (Hari et al., 2015). A watershed is an area of land draining into a common body of water and is comprised of soil, trees, vegetation and water along with the people and animals that are the integral part of the system (Wani, 2008; Townsend et al., 2011). Land use/cover change is often used as a precautionary indicator of watershed status (Garroway et al., 2012; Filgueira et al., 2016). Watershed status refers to the position of affairs at a particular time, especially in terms of vegetation, water, soil and biota (Steven et al., 2012). Land use change is increasingly becoming a centre of debate in the current global change phenomena directly related to livelihoods (Víctor et al., 2013). This high rate of land use/cover

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change is escalating globally (Palmer, 2009; Townsend et al., 2011; Krumhansl et al., 2015). Additionally, population growth, increased conflict on resource use and limited alternatives are partly the reasons for this change (Turyahabwe et al., 2013; Qingqing, 2015; Junguo et al., 2016). The pressure on watershed resources has affected the original land use/cover. Land use/cover change is the intended employment of land management strategy placed on the land cover by human agents to exploit land cover and it reflects human activities like agriculture, mining among others (Zubair, 2006; Rawat et al., 2013; Bajocco et al., 2016). This change results into reduction in associated quality and availability of these resources (Tesfaye, 2011; Tsehaye, 2013). In India for instance, there has been an increase in land cover/use change specifically in built-up areas and sand bars by 88.8% (Rawat et al., 2013). On the other hand, in Egypt, land cover/use changes show significant decline in agricultural land among other land uses (Ibrahim and Mosben, 2015). Ideally, effective watershed management entails regulated off take of watershed resources to meet the socio-economic needs of the people without degradation and the interaction between water, biota and soil, stable in structure and functions (Qingqing, 2015). A healthy watershed must have clean air, water and biota for a well-balanced system that sustains many forms of life (Kevin et al., 2012).

In Uganda, land use/cover change is an environmental challenge (Mbogga et al., 2014; USGS, 2015). The rate of land use/cover change was estimated at 7% in 1990 and now stands at 11% with eastern Uganda registering the highest rate of 20% (UBOS, 2011; Mary et al., 2014). Awoja watershed in Kyoga Water Management Zone of eastern Uganda with an area of 10 km^2 is a key watershed degradation hotspot with a perceived degradation rate of 76% as compared to 63% from Lake Victoria crescent and 41% in the south western farmlands of Uganda (NEMA, 2008; Nelson et al., 2013). In the last two decades, several strategies including sensitisation, training, tree planting, establishing soil and water conservation structures were put forward by both the government and development partners to protect and restore the degraded watersheds (Ministry of Water and Environment, 2013; World Bank, 2013;). Most of these strategies were geared towards improving the livelihoods of the communities living in the watersheds. In eastern Uganda, two such projects were implemented between 2007 and 2013. The projects implemented were Farm Income Enhancement and Forest Conservation (FIEFOC) and the Community Based Wetland and Biodiversity (COBWEB). The FIEFOC Project provided assistance to private forest owners to plan for and manage their forests, especially those located in watersheds. This was through restoration planting (MWE, 2009). The COBWEB aimed at restoring biodiversity (Crested crane, shoebills) in Lake Bisina, Awoja watershed area. This was through restoration planting including training on tree nurseries establishment, establishment of alternative sources of income for the community through ecotourism, initiation of a Savings and Credit Cooperative Organisation (SACCO). All these were aimed at restraining the community from over exploiting the watershed.

Awoja watershed supports over 1,700,000 individuals that derive their livelihood from it, with a contribution of over USD 200 as earnings from papyrus harvesting and mat making per household annually (IUCN, 2005; Richard et al., 2009). In spite of this, the watershed continues to face increasing degradation, even with government and development partner efforts to restore it. Although, studies conducted within Awoja watershed indicate failure in restoration efforts due to high population growth and increased demand for watershed resources, little is known about the magnitude of this change in terms of land use/cover (Mutekanga et al., 2013; Mbogga et al., 2014). Unless the extent of degradation in Awoja is known then will government and development partners devise appropriate approaches for restoration. This paper addresses this gap and avails empirical evidence on the status of Awoja watershed in Ngora district in Uganda and shows the extent to which it has changed. The findings contribute to the achievement of the Sustainable Development Goal 15 and its agenda that addresses degradation by ascertaining land use/cover change of Awoja for appropriate restoration.

MATERIALS AND METHODS

Description of the study area

This study was conducted in Awoja watershed of eastern Uganda basing on its high degradation rate in the last two decades of 20%, as compared to the national average of 11% (MWE, 2013). Additionally, it had the highest perceived degradation rate of 76% as compared to 63% from Lake Victoria crescent and 41% in the south western farmlands of Uganda (Nelson et al., 2013). Specifically, Ngora district was selected because it occupies a greater part of Awoja watershed. It also piloted the two restoration intervention projects by the Farm Income Enhancement and Forest Conservation (FIEFOC) and the Community Based Wetland and Biodiversity (COBWEB).

Ngora district is found in North Eastern Uganda which lies approximately between latitude 1°10’ North and 1°35’ North and longitudes 33°30’ East and 34°20’ East as shown in Figure 1. Ngora is bordered by the districts of Kumi in the east, Serere to the West, Soroti in the North West, Katakwi in the North and Pallisa district to the South. It covers a total area of 715.9 km^2, with 177 and 331 km^2 (19%) as land and open water bodies, respectively. The main water bodies include Lake Bisina, Lake Nyaguo, Lake Meito and Lake Nyasala. Over 93% of the households are engaged in agriculture with a population density of 267.5 persons/km^2, higher than the national average of 174 persons/km^2 (UBOS, 2015).

The sub counties of Mukura and Kapir were chosen because they were the implementing sub counties, besides having the

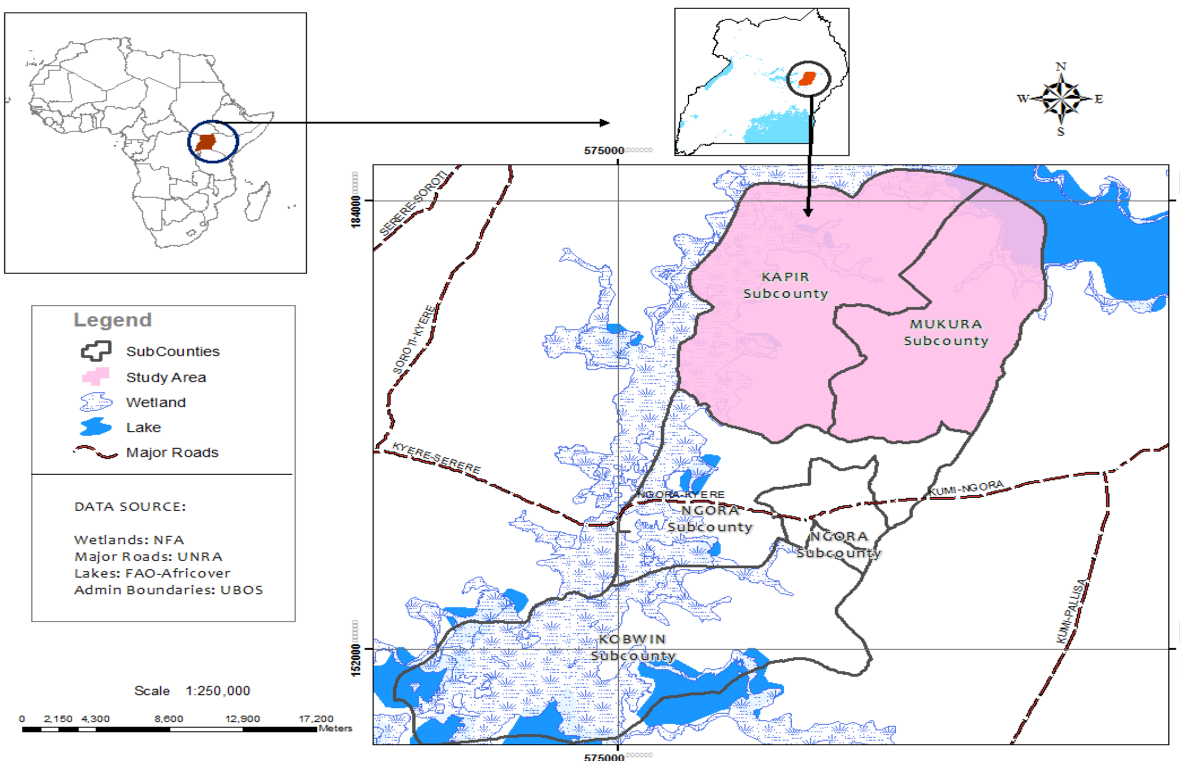

Figure 1. Map of the study area.

highest average household numbers of 5.3 and 5.2, respectively above the national average of 4.7 (UBOS, 2015). The parishes of Moru-Kakise and Mukura were chosen purposively because they were the implementing parishes for both COBWEB and FIEFOC interventions. The four villages of Kakor and Omitto in Omitto parish (Kapir) and Ariet and Puna of Moru- Kakise parish (Mukura) were chosen randomly out of the 8 implementing villages.

Data collection and analysis

Research design

This paper uses an ex post facto cross-sectional research design to acquire both quantitative and qualitative data used in the analysis. This research design best suits investigations where an intervention has taken place and data is collected at one point in time.

Quantification of watershed land use/cover changes

Remote sensing

Suitable processing of Land sat ETM Images covering the whole of Ngora district and part of Lake Kyoga (path 171, Row 59), of two time periods (May, 2007 and May, 2013) during the period of April – July 2015 was carried out. This was acquired from USGS Earth Explorer (Scaramuzza, 2011; USGS, 2015). The two time periods were considered before and after the two projects' implementation in order to establish the changes that may be attributed to these two projects. The change in land use/cover is shown in Figure 2. The down loaded images were processed and enhanced with ERDAS 2014 software to aid information extraction and analysis. Land cover change analysis, were performed on the processed images using ENVI 5.3 software (Rawat et al., 2013). The corrections made were meant to reduce inconsistencies in the satellite images which are inherent in the images because of differences in acquisition conditions including variation in sun zenith angles. Supervised classification method with maximum likelihood algorithm was performed to obtain land use/cover types. The classification was adopted from a similar study by Rawat et al. (2013). Five land use/cover types were identified and used in this study, namely; (1) Open Water (2) Wetland (3) Tree Cover (4) Agriculture and (5) Built up area. Post-classification detection method was employed to develop change detection matrix. Quantitative area data in square kilometers and their percentages, overall land use/cover change as well as gains and loss in each category between 2007 and 2013 were compiled as shown in Table 1.

Ground truthing using global positioning system (GPS)

The classified images were validated in a ground truthing exercise that involved the use of a GPS to collect geographic coordinates for each vegetation cover type. To improve the image classification accuracy, validation exercise was held.

Household survey

A household survey was carried out in the two restoration sites of

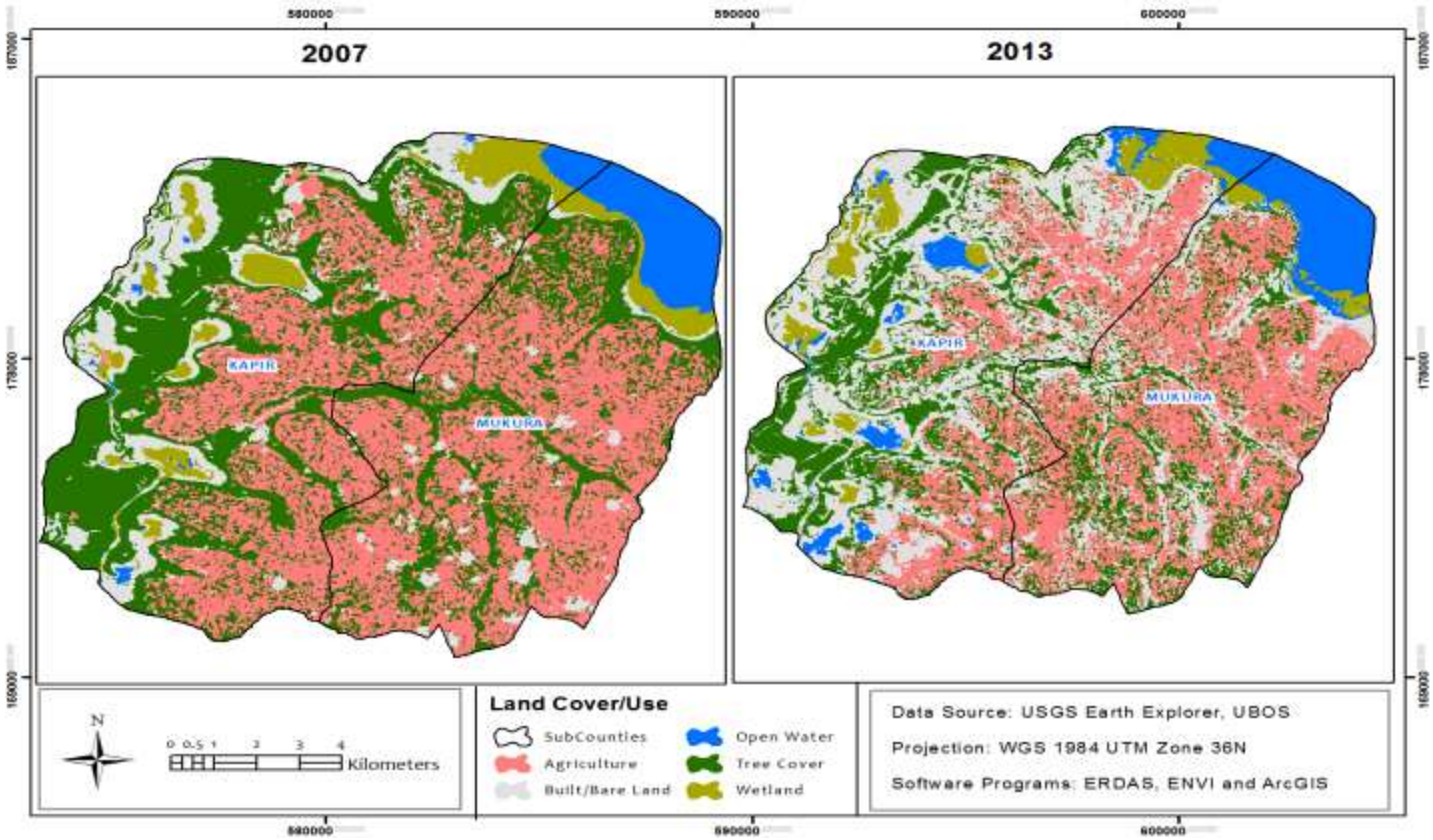

Figure 2. Land cover/use change from year 2007 to 2013.

Table 1. Area and percentage change in different land use/cover categories between the time periods of 2007-2013 in Awoja watershed.

Land use/cover categories	2007	2013	Change in land use/cover categories (2007-2013)	
	Area (km^2)	Area (km^2)	Area (km^2)	Change (%)
Open water	15.73	24.43	8.70	55.33
Wetland	16.24	15.24	-1.0	-5.1
Tree cover	139.63	91.56	-48.07	-34.46
Agriculture	223.35	109.35	-114.	-51.05
Built/bare area	41.1	195.39	154.27	375

FIEFOC (Mukura) and COBWEB (Kapir). This aimed at generating information from the household members that participated. The sample size was determined using Krejcie and Morgan (1970) formula, commonly used for determining sample sizes when the numbers of participating households are known.

$$s = X^2NP(1-P) \div d^2(N-1) + X^2P(1-P)$$

Where s = required sample size; X^2 = the table value of Chi-square for 1 degree of freedom at the desired C.L (3.841); N = the population size; P = the population proportion (of 0.50 since this would provide the max. sample size); d = the degree of accuracy expressed as a proportion (0.05)

Four villages of Ariet and Puna in Moru Kakise parish and Omitto & Kakor in Omitto parish were randomly selected out of the eight implementing villages, that is, two from each sub county. The household members interviewed were selected through simple random sampling so as to have equal chances of being chosen from the list provided by the chair persons of the groups. On average, each group had 65 and 75 households for FIEFOC and COBWEB Projects, respectively. A total sample size of 56 and 63 households for FIEFOC and COBWEB Projects were selected. In total, 112 and 126 households in Mukura and Kapir, respectively, from the four villages chosen, were interviewed. Each household was represented by a respondent who was either the head of the household or any member of the household who was knowledgeable on the group activities. The unit of analysis was the household. Structured and semi structured questions were asked on the causes of degradation of Awoja.

Data analysis

The data collected from the survey was entered into SPSS version 21 in order to perform statistical analysis. Descriptive statistical techniques afforded the researcher the opportunity to generate frequencies in order to know the main causes of degradation from the multiple responses.

Qualitative data on perceived status of the watershed and historical trends

In Pac S methodology

This was employed to generate information on the perceived indicators of a degraded and a healthy watershed between the two categories of respondents, that is, the lay people and the scientists. The scientists were purposively selected based on their participation in the projects and technical knowledge of the watershed. These selected individuals were from Ngora District Local Government (NDLG) Environment and Natural Resources sector, Sub County Local Governments of Kapir and Mukura who participated in the projects. In addition, the lay people were purposively identified with the help of group leaders from the membership list presented by the chairpersons of the watershed user groups. This was done based on the knowledge of the watershed and time spent in the watershed area. A total of four FGDs were held, two in each sub county for each category. The number of participants was 6-12 per FGD who were asked semi structured and open ended questions on their perception on watershed status indicators. The variables assessed to ascertain the state of the watershed were: water smell, water colour, soil quality, species diversity and vegetation type. The responses were recorded using a voice recorder and later transcribed. The summary of their responses are shown in Table 3.

Focus group discussion

The FGDs were held to generate information on the historical trends of Awoja watershed before independence to date. Participants were purposively selected from members of the projects based on their knowledge of the watershed land use/cover change, duration of residence in the watershed, sound memory of the key milestones in Awoja and utilisation of watershed products. The FGD comprised of mainly adult men and women between 60 - 85 years of age who were able to understand and vividly remember the dynamics of Awoja watershed. The members were identified with the help of group leaders from the membership list presented by the chairpersons of the watershed user groups (Golafshani, 2003). This choice was aimed at enriching the discussion with facts and memorable experiences as far as milestones in the management and status of Awoja are concerned. Four FGDs were held, one in each village. The villages were randomly sampled from the eight participating villages. The 6-12 participants per FGD were asked open ended questions on the status and trends of Awoja till the point of saturation was reached (Yin, 2006). The responses were recorded using a voice recorder and later transcribed.

Observation

During the field work, observations were also made to verify the information given by the respondents on the current state of Awoja watershed.

RESULTS

Spatial and temporal changes in watershed use/cover

For the period of 2007 to 2013, there were marked increase in change of built up areas and open waters in Awoja watershed as shown in Table 1 and Figure 2. The increase in the built up area was found to be fivefold the size it was in 2007. Built up area in 2007 covered 41.12 km^2 and by 2013 it had increased to 195.39 km^2. This change of 154.27 km^2 accounted for 375% rise in the built up area. The area of open water increased from 15.73 to 24.43 km^2, representing a 55.33% increase of 8.7 km^2. These changes are evidenced in the significant reduction in land under tree and vegetation cover.

Conversely, a reduction in land use/cover was registered mainly in the tree cover and agricultural land categories. The tree cover change reduced from 139.63 to 91.56 km^2 representing a 34.46% decrease. The agricultural land cover category reduced by 114 km^2 (from 223.35 to 109.35 km^2)' a reduction of 51.05%. However, the least change of 5.1% (1 km^2) was noticed in wetland use/cover category which reduced from 16.24 to 15.24 km^2.

Household survey

From the 237 households interviewed, 85.2% indicated that the main cause of degradation in Awoja watershed was defforestation, 80.6% mentioned wetland encroachement as the cause, 63.7% reported it was poor attitude, 55.3% over population and the least mentioned was political interference standing at 2.5% of the responses as shown in Table 2.

Perceived indicators of a degraded and a healthy watershed

From the FGDs held, the perceived status of a watershed was: rich in witch weed (emoto), elapanit", "ikodokodo", "ijeelo", the presence of hard pans, stunted growth of plants, disappearance of some wetland species like water fowl, shoebills, the crested crane, scanty Acacia species, bare soils, un clear waters of lake Bisina, unappealing water smell, the highly eroded banks and low water level

Table 2. The number of respondents and the percentage case on the causes of degradation.

Causes of degradation	Responses		Percent of cases
	N	Percent	
Deforestation	202	21.3	85.2
Wetland encroachment	191	20.2	80.6
Poor attitude	151	15.9	63.7
Over population	131	13.8	55.3
Poor awareness	111	11.7	46.8
Poor water and soil conservation practices	96	10.1	40.5
Lack of enforcement	59	6.2	24.9
Politics	6	0.6	2.5
Total	947	100.0	399.6

all pointing to degradation.

Additionally, the abundance of mud fish, small sized tilapia and absence of Nile perch further confirms that the lake Bisina which is part of Awoja watershed is degraded (Filgueira et al., 2016). The presence of small fish, few, thin and miserable cows, poor quality pasture, scanty woodlots and slow regeneration of Acacia trees further confirmed the degraded status of Awoja as shown in Table 3.

Focus group discussion

The historical trend generated from the discussions held, is shown in Table 4. The status of Awoja watershed is worrying. At independence during Obote I and II regimes, its status was fairly good. Its management had been under colonialists much as it was given to the Uganda government. Additionally, both regimes of Obote exhibited improved management through popularized extension services. During the regime of Amin and Museveni, lawlessness set in and the presence of wars and cattle wrestling marked the beginning of total dependence on natural resources with limited alternative source of livelihood. This was coupled with high population, corruption, returning of war affected people from the internally displaced people's camps (IDPs) and inadequate law enforcement.

DISCUSSION

The research findings show the land cover changes in Awoja watershed area in Ngora district, North Eastern Uganda for the period 2007 – 2013. The spatial and temporal changes presented are the basis for discussion. As earlier mentioned, the built up area increased fivefold by 154.27 km^2 signifying a 375% rise. This is explained by the high population increase of 12,119 and 13,312 for Kapir and Mukura sub counties from the period of 2002 and 2012 according to the national population and housing census. The number of individuals in the age bracket 18 years and above are highest in Kapir and Mukura, registered at 9,197 and 12,498, respectively (Ngora district development plan, 2015), implying the young couples will have to establish their homes hence the increase in the built up areas as they settle. Consequently, the need to establish trading or urban centers for provision of basic commodities such as sugar, salt in the watershed led to clearing land areas to build houses. Whereas, in Uganda, according to Kaggwa et al. (2009), agriculture is the principle cause of watershed degradation, this study differs from the watershed restoration sites in Kapir and Mukura sub counties in Ngora. The findings are also not in agreement with a study carried out by Tesfaye (2011) in Ethiopia, that asserted that agriculture is the main cause of watershed degradation. However, it concurs with Ibrahim and Mosben (2015) findings in Mansoura and Taikha watershed areas of Egypt that showed an eight fold increase in the built up areas from 28 to 255 km^2 from 1985 to 2010 that largely contributed to watershed deterioration The decline in land use/cover size in tree cover and agricultural land categories of 48.07 and 114 km^2 respectively was because agricultural land was taken over by settlement. Part of the area which was taken up for settlement and urbanisation was formerly for agriculture hence the decline in area under agriculture. Therefore, those involved in agriculture have abandoned it for petty trade like motorcycle riding (boda boda) and selling of basic household items like salt, match boxes, cloths while others are engaged in alternative sources of income such as baking chapatti and brewing (waragi), thereby diverting the youth who search for quick money.

This is further backed by responses from upto 85.2% interviewed individuals who stated that Awoja watershed had undergone degradation over the years due to deforestation, followed by wetland encroachemnt

Table 3. Perceptions on the status of Awoja watershed.

Variable	Degraded watershed (Lay persons)	Degraded watershed (Scientists)	Healthy watershed (Lay persons)	Healthy watershed (Scientists)
Water smell	Smelly	Poor water quality	Clear	Clean water, presence of water lilies, Nile perch, big sized tilapia, regeneration of papyrus
Soil quality	Very loose light soils easily blown by wind, very little harvest from such soils	Reduced yield, poor light soils	Dark sandy loamy soils , Earth worms are frequently found	Absence of species of animals like Antelopes, Rabbits, Foxes, Hyenas & Terrestrial tortoises, vegetation and trees like (Fagara: eusuk), Acacia species, Albizzia species, Grass (``ecici'',`` ekode'')
Water colour	Greenish in colour, brownish with dirt (silt)	De-oxygenated water rich in algae bloom	Whitish	Oxygenated and Colourless
Species diversity	Lung fish, crocodiles, frogs, leeches, snakes (puff udder), “Ailiilin”-(white festive ducks), pigs, big rat, ducks.	Destroyed vegetation, biota and water. Abundance of mud fish	Hippopotamus, sheep, goats, lizards, cows, squirrels, snakes (cobra), cat fish, Nile perch, tilapia, “abubusia”, “adolia”, “elibi”, “ekolia”,	Vegetation with vigorous growth, rich biota and clean water, abundance of Nile perch and Tilapia, shoebill and presence of created crane
Vegetation type	Abundance of Aleo vera species, star grass, witch weed (emoto), “ekeriau”, “elapanit”, “ikodokodo”, “ijeelo”, “ikarama'', “igirigiro''	Scanty Acacia trees, bare soils that cannot support large hard ,scanty vegetation, dry wetlands	Papyrus, water lily, spear grass, “ewaat”, “lab lab”, sedges, all crop types	Green vegetation rich in biodiversity, abundance of spear grass, nutritious and healthy pasture

(80.6%), poor attitude (63.7%) and over population (55.3%). Political interference was rated least (2.5%) as one of the casues of degradation. The perceptions on the reason for degradation seem to be consistent with the trends recorded during this study for the spatial and temporal analyses of land use/cover change from satellite imagery. The gradual substitution of agriculture with urbinasation and settlement was reported during the FGDs to have intensified from the mid 1980s to date.

In Pac S methodology results showed convergence in perceived indicators of watersheds status among the lay people and the scientists. The current status of Awoja watershed depicts degradation from the perceived indicators. The responses on vegetation types indicated that, papyrus and spear grass were rarely seen and the species of organisms were not many like they existed half a century ago, hence a degraded Awoja. The focus group discussions equally showed a negative trend in the status of Awoja watershed despite several interventions by government and development partners (Mbogga et al., 2014). The degradation was mainly due to conflicts for watershed resources use, stemming from 3.1% population growth in the country (UBOS, 2015). Furthermore, the failure by the elders to perform rituals for rain making coupled with inadequate law enforcement are to be blame for this trend in the degradation of the watershed.

Conclusion

This study provides evidence on the state of land

Table 4. Historical trends of Awoja watershed.

1962 - 1970 Obote I	Colonialists transferred management to Uganda government, abundant tree (big) and vegetation cover with high biodiversity, low population, less pressure on natural resources , respect for the wetlands which were used as communal grazing lands and adequate professional extension services were provided
1971 – 1979 Amin's regime	Lawlessness sets in, deteriorating conditions of woodlands, vegetation, water, soil and fish catch, flood hit Lake Bisina and people could not cross to Katakwi on foot, abundance of lung fish and hunger was experienced with provision of relief food (yellow posho) by government and World Food Program, extension services on natural resources were paralysed, population increase, conflicts over land rose as the value of money began to depreciate
1980 - 1985 during Obote II	Improved extension services, increased tree cover and food production, rule of law resumed and beginning of conflict on watershed resources with increase in population.
1986 - 1992 Museveni regime	Genesis of civil war and cattle rustling, people resorted to use of hand hoes as opposed to ox ploughing and famine set in, most of the IDPs depended on watershed resources since the cattle were stolen (rustled)
1993- to date	Annual rate of degradation was increasing, there was typhoid outbreak, formulation of policies and laws on management of watershed like Environment Act, Forest Act, Water Act, emergence of many NGOs, beginning of corruption in the resource management, loss of respect for local leaders, lawlessness among the local people increased, increased number of offences related to watershed resource use, those from IDP came back home and began to encroach on wetlands, with massive tree cutting for brick making, charcoal burning and firewood for subsistence and commercial uses, population increase and increase in land conflicts. The rate of degradation is very high.

use/cover changes in Awoja watershed in Eastern Uganda from 2007 to 2013. The major causes of watershed degradation being deforestation, wetland encroachment, poor attitude and over population as the communities clear more land for settlement and utilise the watershed resources. This study thus deviates from a similar study by Kevin et al. (2012), who found out that 37% of the change in land use at Gaspereau watershed was as a result of agriculture and not urbanisation. Unless, appropriate watershed restoration strategies are designed through afforestation, law enforcement on culprits and continuous sensitisation of the watershed community on the causes of degradation, all individuals whose livelihoods depend on Awoja will continue to suffer effects of degradation. There is need to advocate for non-consumptive projects as alternative sources of income order to reduce on the pressure.

Conflict of Interests

The corresponding author indicates that she was a service provider for FIEFOC project but never worked in the study area hence did not influence the quality of this research.

The co-authors have not declared any conflict of interest either.

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Characterization and classification of clay minerals for potential applications in Rugi Ward, Kenya

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The applications of various clayey minerals are related to their structural, physical and chemical characteristics. The physical and chemical properties of the clayey minerals dictate their utilization in the process industries and beneficiation required before usage. The study aimed at establishing the potentiality of clayey minerals from the study area, and the possibility of exploring and exploiting them in order to spur industrial development and promote economic self reliance of Kenya as a nation. The plasticity, particle size, surface area, chemical and mineralogy composition, morphological, thermal analysis and other physical properties were studied using various techniques. The clay samples composed of albite (5-16.7%), kaolinite (11.4-36.2%), microcline (15.2-35.3%), quartz (24.3-68.1%), hornblende (7.6% in samples from Ngamwa only), and other mineral impurities in small amounts. Ngamwa clayey materials consist of high impurities of chemical oxides such as TiO_2, MnO, MgO and Fe_2O_3. Generally, quartz and iron were the major impurities present in the samples from the concerned sites. The findings shows that clayey minerals from the study area can be exploited for commercial production of ceramic products after beneficiation using low cost and environmental friendly techniques in order to reduce the levels of iron, quartz, and other impurities to acceptable levels.

Key words: Kaolin, Impurity minerals, shrinkage, plasticity index, surface area, quartz.

INTRODUCTION

Clay is a naturally occurring material composed of layered structures of fine-grained minerals which exhibit the property of plasticity at appropriate water content but becomes permanently hard when fired (Heckroodt, 1991; Njoka et al., 2015). The clay material is formed from chemical weathering processes on the earth's surface, and contributes about 40% of the fine grained sedimentary rocks (mudrocks) which includes mud stones, clay stones and shales. Clay minerals are generally composed of aluminum silicates which are formed by tetrahedral and octahedral sheets that are linked together through sharing of apical oxygen atoms (Madejova, 2003). The formation of clay minerals is dependent on physicochemical conditions of the immediate weathering environment, nature of the starting materials and other related external environmental factors (Wilson, 1999),

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thus resulting into various types of clay materials. Consequently, the application potential of any clay mineral type in nature will depend on its chemical composition, structure and other inherent properties (Landoulsi, 2013). On this regard, clay minerals are classified into different groups as follows; Kaolinite, Smectite, Vermiculite Illite and Chlorites.

Kaolinite group which includes clay minerals like kaolinite, hallosite, nacrite and dickite, is a 1:1 type clay mineral. It is composed of one layer of silica and one layer of alumina, which is formed under acidic conditions through advanced weathering processes or hydrothermal changes of feldspars and other alluminosilicates (Miranda-Trevino, 2003). The chemical formula of kaolinite is $Al_2O_3.2SiO_2.2H_2O$ (39% Al_2O_3, 46.5% SiO_2 and 14.0% H_2O) and its structure possesses strong binding forces between the layers which resists expansion when wetted (Miranda-Trevino, 2003; Trickova, 2004). The cation exchange capacity (CEC) of kaolinite is less than that of montmorillonite due to its low surface area and low isomorphous substitution that result from its high molecular stability (Aroke, 2013; Murray, 1999) and this contributes to its low plasticity, cohesion, shrinkage and swelling. However, the material can adsorb small molecular substances such as lecithin, quinolone, paraquat, diaquat polyacrylonitrite, some proteins, bacteria and viruses (Williams and Environmental, 2005). Industrial uses of Kaoline includes; manufacture of paper, paint, rubber, ceramic, plastic and pharmaceutical products, catalyst for petroleum cracking and auto exhaust emission catalyst control devices, cosmetics base and pigments (Olaremu, 2015). Furthermore, kaolin is incorporated as an anti-cracking agent in the manufacture of fertilizer prills, as a carrier for pesticides, manufacture of white cement where it contributes alumina without iron, and in the production of glass fiber as a low-iron and low alkali source of alumina. On pharmaceutical applications for example, Kaopectate and Rolaids are used as the main ingredients for the original formulation of anti-diarrhea medication. Kaolin can be used to decontaminate aflatoxins, plant secondary metabolites, pathogenic microorganisms, heavy metals and other poisons in the animal diets which could be harmful to the digestive system through firm and selective binding of these noxious agents (Trckova, 2004). However, long term exposure to kaolin causes development of radiologically diagnosed pneumoconiosis. Kaolin that is heavily stained with ferric iron results to red or deep red colouration that is evenly widespread on ceramic bodies upon firing in an oxidizing environment. These iron stained clays can be used for coloured clay products but have no potential in high-grade ceramic applications. Therefore, brightness is the critical property in most high-value applications of kaolin (Chandrasekhar, 2006). Naturally, kaolin may be accompanied by other mineral impurities such as feldspar and mica, quartz, titanoferous, illite, montmorillonite, ilmenite, anastase, haematite, bauxite, zircon, rutile, silliminate, graphite, attapugite, halloysite and carbonaceous materials (Ramaswamy and Raghavan, 2011), thus reducing its industrial usefulness. On this regard, mineralogical analysis coupled with visual assessment of the colour is crucial when sampling for kaolinites, and then complemented by beneficiation trials and product evaluation. However, the later processes are both expensive and time consuming. Preliminary characterization stage ensures that inferior samples are screened out so that resources can be directed towards investigation of samples with most commercial potential. This stage also enables the quantification of toxic elements and/or micronutrients (Fe, Sb, As, Cd, Co, Cu, Pb, Hg, Ni, Se, Te and Zn) whose levels depend on their geological history.

Smectite, which includes montmorrilonite, beidellite, nantronite, saponite and hectorite, are 2:1 layer clay minerals formed from the weathering of soils, rocks (mainly bentonite) or volcanic ash and belongs to a group of hydroxyl alumino-silicate (Erdogan, 2015). The variation of physical and chemical properties of bentonites within and between deposits is caused by differences in the degree of chemical substitution within the smectite structure, the nature of the exchangeable cations present, type and the amount of impurities present (Christidis and Warren, 2009). Minerals associated with smectites include quartz, cristobalite, feldspars, zeolites, calcite, volcanic glass and other clay minerals such as kaolinite (Abdou, 2013). The groups of smectite clays are distinguished by differences in the chemical composition pertaining substitutions of Al3+ or Fe3+ for Si4+ in the tetrahedral cation sites and Fe2+, Mg2+ or Mn2+ for Al3+ in the octahedral cation sites. Smectites have very thin layers and small particle sizes which contributes to high surface area and hence a high degree of absorbency of many materials such as oil, water and other chemicals (Marek, 2010; Amel, 2013). Additionally, smectites have higher cation exchange capacities, swelling and shrinkage properties than other clays. The variable net negative charge on smectites structural layers attracts water molecules into the interlayer area thus causing expansion, and the amount of swelling is related to the type of interlayer cation present. For example, the sodium rich smectite clays expand more than those containing calcium ions (Odom, 1984). Na-montmorillonites contain one water layer in the interlayer position and Ca-montmorillonites consists of two water layers which account for the basal spacing on the x-ray diffraction pattern of 15.4 Å for Ca-montmorillonite and 12.6 Å for Na-montmorillonite (Murray, 1999). Soils dominated by these types of minerals form a wide range of cracks upon drying up and the resultant dry aggregates are very hard hence making the soil difficult to till (El-Maarry, 2013).

These soils are stable in arid, semi-arid or temperature climate and they form smooth gels when mixed with the right amount of liquids. Smectites are valuable minerals for industrial applications due to their high cation exchange capacities, high surface area, surface reactivity, adsorptive capacity and catalytic activity (Odom, 1984). This group of clays has found applications in bonding foundry sands, drilling fluids, iron ore pelletizing, agriculture (as carrier material for pesticides, fertilizers and for coating seeds), paper making, paints, pharma-ceuticals, cosmetics, plastics, adhesives, decolorization and ceramics (Christidis, 1998). The material is also used as clarifying agents for oils and fats, chemical barriers, liquid barriers and catalysts (Abubakar, 2014). Preparation of some high technology materials such as pillared clays, organoclays and polymer/smectite-nano ccomposites involves purification and physicochemical modifications of pure smectite (Ray and Okamoto, 2003). However, the commercial bentonites should contain not less than 60% smectite.

Vermiculite is a hydrated magnesium aluminium-iron silicate which possesses 2:1 type of clay minerals (Tang, 2012). It has a layer charge of 0.9-0.6 per formula unit, and contains hydrated exchangeable cations primarily Ca, and Mg in the interlayer (Schulze, 2005). The high charge per formula unit gives vermiculite a high cation exchange capacity and causes this clay type to have a high affinity of weakly hydrated cations such as K^+, NH_4^+ and Cs^+. Upon rapid heating at a temperature of 900°C or higher, the water in raw flakes vermiculite flashes into steam and the flakes expand into accordion-like particles (Hillier, 2013), a phenomenon known as exfoliation (Belhouideg and Lagache 2014). The expanded or exfoliated material is low in density, chemically inert and adsorbent has excellent thermal and acoustic insulation properties, is fire resistant and odourless. The common applications of exfoliated vermiculite include making of friction light weight aggregates, thermal insulator, brake linings, various construction products, animal feeds and in horticulture (Chad and Stachowiak, 2004; Ucgul and Girgin, 2002; Lescano, 2013). Incorporation of vermiculite in fertilizers makes them more efficient in releasing nutrients and hence making the fertilizers more economical to the consumers (Abdel-Fattah and Merwad 2015). The layered structure and the surface characteristics of vermiculite enable them to be used in products such as intumescent coatings and gaskets, treatment of toxic waste and air-freight. The expansion of vermiculite on heating generates sufficient internal pressure which can be utilized to break hard rock during tunneling work (Ahn and Jong, 2015). Vermiculite ores contain variable amounts of other minerals such as feldspars, pyroxenes, amphiboles, carbonates and quartz that are formed along with vermiculite in the rock and occur as major components, as well as minor components such as phosphates, iron oxides, titanium oxides and zircon (Lescano, 2013). Some impurities like asbestiform amphibole minerals found in vermiculite have toxicity impact on human health as they lead to development of diseases such as malignant mesothelioma, asbestosis or lung cancer; hence, characterization of clays is important in order to identify such impurities.

Illite clay mineral group is also called clay micas. Mica is a group of phyllosilicate minerals with crystalline structure that can be split or delaminated into thin sheets that are platy, flexible, clean, elastic, transparent to opaque, resilient, reflective, refractive, dielectric, chemically inert, insulating, light weight and hydrophilic (Unal and Mimaroglu, 2012). The atoms of mica minerals are bonded together into flat sheets which allow a perfect cleavage of the minerals to produce tough sheets that occur in a variety of colours including brown, green, black, violet or colourless and often with a vitreous to pearly luster (Amrita et al*.,* 2011). Studies have shown that there are over 30 members of mica group, but six forms that are found in nature and commonly used in microscopy and other analytical applications consist of muscovite, biotite, phlogopite, lepidolite, fuchsite and zinnwaldite (Orlando, 2002).Three members (illite group) which includes illite, glauconite and muscovite are referred to as clay minerals because they exhibit characteristic properties of clay, with illite mineral being the most common. Illite is formed from weathering of potassium and aluminum rich rocks like muscovite and feldspar under alkaline conditions. Illite group is a 2:1 layer silicate clay mineral which is non expansive because the space between the crystals of individual clay particles is filled by poorly hydrated potassium cations or calcium and magnesium ions which hinder water molecules from entering the clay structure. The cation exchange capacity of Illite ranges between 20-40 meq per 100 g. The colour of the minerals ranges from grey white, silvery white to greenish grey. The illites find application in structural clay industry and in agro minerals due to high potassium content (Njoka et al*.,* 2015; Van, 2002). Mica clay ores contain a variety of impurities which includes quartz, feldspar, kaolin and pyroxene (Capedri et al., 2004). Presence of these minerals in mica ores will impact upon the industrial value of these deposits and the processing complexity thus reducing or increasing its value depending on the applications (Gaafar, 2014).

Chlorites are hydrous aluminosilicates that are arranged in a 2:1 structure with an interlayer (Wiewiora, 1990). They incorporate primarily Mg, Al and Fe cations and to a less extent Cr, Ni, Mn, V, Cu and Li cations in the octahedral sheet within the 2:1 layer and in the interlayer hydroxide sheet. They also exhibit a large substitution of Si by Al cations in the tetrahedral sheet (Ako, 2015). The colour of chlorites varies from white to almost black or brown with a tint of green where these optical properties are coupled to the chemical composition of chlorite (Saggerson, 1982). Knowledge of

Figure 1. Locally made clay products.

the chemical composition of chlorite is important in the study of phase relationships in low and middle grade metamorphic rock (Albee, 1962).

Considering the diversity of clay mineral groups in nature, the initial mineralogical and chemical examination of clay ores can be used to indicate the suitability of the material for different applications. In Kenya, there are several industries which can utilize the readily available and cheap clay raw materials after beneficiation in order to support industrial growth and relieve the government off the burden of importing such products. The improved industrial utilization of clay minerals in the country will depend mainly on the quality and durability of the material, and for this to be realized, there is need for rigorous studies on this resource. Unfortunately, very little attention has been given to clay characterization and mineralogy in Kenya despite the growing demand for clay products and the possibility of creating jobs through cottage industries. Currently, the local communities in Kenya are relying on the indigenous knowledge to make some clay products whose quality is hard to determine and neither does it meet the export standards as shown in Figure 1.

The objective of this study was to carry out the mineralogical, physical and chemical characterization of Rugi clay deposits in order to highlight its potential application and encourage more studies on this unexploited field.

MATERIALS AND METHODS

Study area

The ceramic clays occur in Tabaya-Karundu Valley in Rugi ward which is lowland in Nyeri County. The valley has a west-east orientation and covers an area of about 38 ha. The region experiences average temperatures ranges of 12 - 27°C with low temperatures in the month of June and July and highest temperatures in the months January-March and September-October. The average rainfall lies between 500 mm and 1500 mm per annum with bimodal rainfall pattern where long rains occur between March and May and short rains between October and December. Within the valley, there are two major excavation sites for ceramic clay that are close to each other but fall in different administrative units namely, Mweru and Karundu. The former site (Mweru) lies in Mweru sub location at an altitude of 1441 m above sea level on latitude 0° 36.474’ S and longitude 37° 6.828’ E, whose soil appearance is black/brown (Figure 2).

Karundu lies in Karundu sub location at an altitude of 1445 m above sea level, latitude 0° 36.400’ S and longitude 37° 6.799, and the soil appearance is grayish white (Figure 3).

The two sites are located less than 200 m off the Nairobi-Mukurwe-ini highway, and both lie on a swampy ground. The soils within the sites are typically waterlogged with the water bearing viscous appearance and issuing a smell characteristically indicative of the presence of humic acids. Phagmites (*Typha* spp.) are the dominant vegetation on the sites, and in areas where excavation was abandoned, the local community grows a thriving crop of arrowroots. A third excavation site locally known as Ngamwa lies a little lower than Mweru and Karundu sites. Ngamwa lies at an altitude of 1427 m above sea level on latitude 0° 36.504’ S and longitude 37° 7.913 E, with soils bearing a light brown coloration and coarse texture. This site is farther (2 km) off the highway than the first two sites, it is impassable and inaccessible due to the poor terrain, and there was virtually no evidence of recent excavation activity compared to the other sites.

Sampling techniques

Three sites namely, Karundu, Mweru and Ngamwa were chosen using purposive sampling technique to collect samples. The collection and preparation of clayey samples was carried out as described by Njoka et al. (2015). The quality and resolution of the obtained results was improved by performing pretreatment of the samples in order to remove the organic matter and other unwanted materials. Spectroscopic grade chemicals were used in the present investigation.

Instruments used and procedures

The following instruments were used in the present work. PG-990 Atomic absorption spectrophotometer, Analytikjena model contra 700, IRAffinity-1 FTIR Spectrophotometer, Shimadzu, Perkin Elmer Model TGA7, Thermal gravity analyzer, Transmission Electron Microscope JOEL.JEM-1210 (120KV, MULTISCAN CAMERA), Bruker AXS D8 Advance diffractometer, Quantachrome NOVA 1200 Gas sorption analyzer**.** The procedures used by Njoka et al. (2015) and El-Geundi et al. (2014) were adopted in the present study, and the Atterberg limits were determined as described by Melo et al. (2012).

RESULTS AND DISCUSSION

Table 1 presents the consistency limits and physical properties of clayey raw materials from Rugi ward. The consistency limits were determined in order to identify,

Figure 2. Mweru site.

Figure 3. Karundu site.

classify and predict the fine-grained soil behavior. Liquid limit, plastic limit, plastic index and linear shrinkage of the clayey raw materials collected varied from 40.00-64.00, 19.00-36.00, 18.00-29.00 and 9.00-14.00 respectively. These results showed that the collected clayey materials were inorganic clays except the samples from Karundu site at the depth of 0-20 cm which was inorganic silt. The average values of the plastic index of the samples from

Table 1. Physical properties of clay samples.

Sample site	Depth (cm)	Atterberg limits (%)					Texture classes of clay					
		Liquid limit	Plastic limit	Plastic index	Linear shrinkage	Inferences	% Clay	% Silt	% Sand	% Gravel	Plasticity ratio LL/PL	Inferences
	0-20	40.0	19	21	11	Inorganic silt	4	21	60	15	2.11	Silty sand
Karundu	20-40	44	26	18	9	Inorganic clays	33	17	48	2	1.69	Clayey sand
	40-60	44.5	25	19.5	9.28	Inorganic clays	49	17	33	1	1.78	Clayey sand
	0-20	44	25	19	10	Inorganic clay	28	15	55	2	1.76	Clayey sand
Mweru	20-40	53	26	27	12	Inorganic clays	25	11	49	15	2.04	Clayey sand
	40-60	53	31	22	10	Inorganic clays	31	20	41	8	1.70	Clayey sand
	0-20	63	32	31	13	Inorganic clay	49	19	29	3	1.97	Sandy clay
Ngamwa	20-40	64	36	28	14	Inorganic clays	56	18	23	3	1.78	Clayey sand
	40-60	60	31	29	14	Inorganic clays	55	17	26	2	1.93	Clayey sand

Karundu, Mweru and Ngamwa were 18.8, 22.7, and 29.33 % respectively. The results revealed that clayey raw material from Karundu have medium plasticity while those from Mweru and Ngamwa possess high plasticity. Furthermore, results from Ngamwa indicated that the clay soil has a finer (more clayer) texture as revealed by its higher value of plasticity index in comparison to the clayey materials from Karundu and Mweru. The high plasticity clayey materials from Ngamwa might be due to high levels of mineral oxide impurities such as TiO_2, MnO, MgO and Fe_2O_3. Clay identification chart using plastic limit and plasticity index parameters was used to identify the type of clayey minerals present in the samples. According to the clay chart, the results obtained in all sampling points were slightly lower in kaolinite than for pure kaolinite clays. The difference might be contributed by the presence of sand and silt in the samples. The plasticity ratio of 5.9, 2.16 and 1.59 indicates montmorillonite, illite and kaolinite respectively. Results obtained in the present investigation are very close to what is expected for kaolinite clays except those from Karundu samples at the depth of 0-20 cm and Mweru at the depth of 20-40 cm which were close to that of illite clay. However, the obtained results are suggestive of the presence of both kaolinite and illite clayey minerals in the samples in question. The values of linear shrinkage ranged between 9.00-11.00, 10.00-12.00 and 13.00-14.00 for Karundu, Mweru and Ngamwa respectively. High linear shrinkage value in clayey samples from Ngamwa was attributed to the amount of available clay minerals in the samples whereas the slightly low shrinkage values obtained from Mweru and Karundu samples was associated with the presence of high amount of quartz which tends to decrease the magnitude of shrinkage. Clayey mineral samples from the study area consist of 4-56, 11-21, 23-60 and 2-15% of clay, silt, sand and gravel respectively. The clayey mineral samples which were collected at Karundu (0-20 cm) and Ngamwa (0-20 cm) were silty sand and sandy clay respectively. The high level of gravel from Karundu (0-20 cm), Mweru (20-40 cm) indicated high level of quartz.

The oxides analysis results using XRF and AAS are presented in Table 2. The data obtained for Al_2O_3, SiO_2, CaO, TiO_2 and Fe_2O_3 were used to determine whether XRF and AAS analytical methods produced comparable results. Analysis was done using statistical programme for social sciences (SPSS) version 20 at p= 0.05, and confirmed using excel and manual approaches. The correlation values obtained were as follows; Al_2O_3 (R = -0.16, p=0.968), SiO_2 (R= 0.824, p=0.006), CaO (R= 0.446, p= 0.229), TiO_2(R= 0.173, p=0.655) and Fe_2O_3 (R= 0.609, p=0.081), while the standard errors of the estimates for Al_2O_3, SiO_2, CaO, TiO_2 and Fe_2O_3 were 4.63, 8.58, 0.18, 2.07 and 5.88 respectively. These results revealed that there was no significant

Table 2. Chemical composition of clay samples using XRF and AAS (%). Please provide the respective depths

Sample site	Depth (cm)	XRF									AAS										
		MgO	V_2O_5	Al_2O_3	SiO_2	CaO	TiO_2	MnO	Fe_2O_3	K_2O	Al_2O_3	SiO_2	CaO	TiO_2	MnO	Fe_2O_3	K_2O	MgO	Na_2O	LOI	Conductivity in Hs
Karundu	0-20	ND	ND	25	71	0.29	1.3	ND	2.3	ND	15.38	78.33	0.28	0.02	0.07	2.30	4.40	0.20	0.28	4.17	28.8
	20-40	ND	0.2	32	45	0.49	5.8	1.9	14.4	1.9	28.34	58.54	0.28	0.47	0.05	1.61	1.44	0.26	0.36	5.12	28.7
	40-60	ND	0.08	40	54	0.51	2.2	ND	4.40	ND	17.18	60.61	0.47	2.28	0.08	6.40	1.66	0.33	0.65	8.97	27.8
Mweru	0-20	ND	0.1ND	27	41	0.53	5.5	0.2	24.40	1.8	20.13	71.02	0.82	2.25	0.10	9.80	2.80	0.60	1.02	8.08	108.8
	20-40	ND	0.1	33	59	0.31	1.2	0.05	6.70	ND	13.50	84.27	0.24	2.62	0.06	2.56	0.76	0.22	0.19	4.08	105.2
	40-60	ND		33	49	0.50	6.6	ND	9.57	1.1	21.64	54.37	0.54	3.10	0.07	4.05	1.10	0.56	0.42	9.63	111.0
Ngamwa	0-20	ND	0.1	34	33	0.1	4.2	ND	17.9	0.33	29.10	49.39	0.54	2.64	0.09	11.60	0.55	0.56	0.35	10.06	21.8
	20-40	ND	0.1	30	30	0.1	3.4	ND	13.9	0.26	27.90	47.15	0.30	3.07	0.08	10.60	0.40	0.41	0.18	14.94	22.0
	40-60	ND	0.08	30	29	0.09	3.2	ND	13.0	0.2	30.30	44.70	0.27	2.41	0.07	11.10	0.40	0.40	0.20	13.80	22.5

correlation for all the oxides since their p- values were above critical value (0.05) except for SiO_2 which showed a strong positive correlation (R=0.82) at p-value =0.006 (below critical value). The F-value for SiO_2 was 14.81 at p=0.006 (less than critical value) indicating that there was no statistically significant difference in the precision when the two methods are used. The t-value for SiO_2 was 3.85 at p= 0.006 (less than critical value) confirming that there was no statistically significant difference in the silica results obtained using the two methods. Also a close scrutiny of the results revealed that several metal oxide were not detected by the XRF analytical method in some samples whereas they were detected in those samples by the AAS method. AAS usually exhibit superior sensitivity and low detection limit than XRF spectroscopic method. Therefore, based on above reasons, AAS results were used for analysis.

The average percentage of Al_2O_3 in clay mineral samples from Karundu, Mweru and Ngamwa were 18.96, 18.42 and 29.10 respectively and those of Fe_2O_3 were 3.44, 5.47 and 11.10 respectively. This revealed that the quantity of Al_2O_3 was less than 30% while that of Fe_2O_3 was more than 1% in all the samples studied. Clay with a composition of 5% or more of Fe_2O_3 are used as red firing clays, those with between 1 - 5% Fe_2O_3 are B tan –burning clay and those containing less than 1% Fe_2O_3 are used as white firing clays (Murray, 2007). Thus, these clays do not meet the conditions necessary for refractory fired clays, manufacture of high grade ceramic products such as white porcelain and glossy papers and other products that require clay with less than 1% iron content and at least 30% Al_2O_3. The presence of other oxide impurities like CaO, MgO etc. might also reduce the suitability of clayey mineral samples for refractoriness. The average quantities of Loss on Ignition (LOI) value obtained from clayey minerals from Karundu, Mweru and Ngamwa were 6.087, 7.263 and 12.933% respectively. Notably, there was high values of LOI of clay samples from Ngamwa which might imply that, they possess finer grains, high content of Al_2O_3 and could be more compact compared to those from Mweru and Karundu. The relatively higher LOI values in clayey mineral samples from Mweru compared to Karundu were associated with high percentages of impurities, water and organic matter in the samples. The low values of alkaline oxides (K_2O, Na_2O) in clay mineral samples from Ngamwa in comparison to those from Mweru and Karundu implies presence of low percentage of flux minerals. Ngamwa clayey minerals showed a high percentage of Fe_2O_3 which might increase the action of alkaline flux that results into a lower melting temperature and an increase in the abundant liquid phases thus making the material difficult to crystallize.

The results of inorganic elements present in clay samples are summarized in Table 3. The average concentration in mg/kg of various elements obtained were; Karundu {Na (0.0243), Ca (0.0229), K (0.0427), Mg (0.0228), Fe (2.207), Mn (0.006), Zn (0.0016), Cu (0.0013), Cr (0.0094), Pb (0.001)}; Mweru {Na (0.0353), Ca (0.0364), K(0.0401), Mg (0.00364), Fe (1.25), Mn (0.0077),

Table 3. Composition (mg/kg) of inorganic elements in the clay samples.

Sample site	Depth (cm)	Na	Ca	K	Mg	Fe	Mn	Zn	Cu	Cr	Pb	Al	Sb	Co	Cd	Conductivity (μs)	pH
	0-20	0.0117	0.0210	0.0405	0.021	2.38	0.006	ND	ND	0.0126	0.0002	0.752	ND	ND	ND	28.8	5.14
Karundu	20-40	0.0499	0.0213	0.0508	0.0213	2.67	0.0120	0.0044	0.0044	0.0011	0.0011	1.798	ND	ND	ND	28.7	5.17
	40-60	0.0114	0.0263	0.0368	0.0262	1.57	ND	0.0005	0.0005	0.0037	0.0017	1.613	ND	ND	ND	27.8	5.21
	0-20	0.0178	0.0298	0.0460	0.0298	1.23	0.0157	0.0039	0.0066	0.039	0.0008	1.705	ND	ND	ND	108.8	4.45
Mweru	20-40	0.0386	0.0552	0.0258	0.0552	1.49	ND	ND	ND	ND	0.0004	1.107	ND	ND	ND	105.2	4.32
	40-60	0.0496	0.0241	0.0486	0.0241	1.03	0.0073	0.0058	0.0058	0.0058	0.0012	1.701	ND	ND	ND	111.0	4.35
	0-20	0.0140	0.0427	0.0262	0.0427	6.67	0.0146	0.0028	0.0030	0.0030	0.0014	1.942	ND	ND	ND	21.8	5.35
Ngamwa	20-40	0.0076	0.0431	0.0282	0.0431	7.18	0.0162	0.0027	0.0047	0.0047	0.0012	1.93	ND	ND	ND	22.0	5.37
	40-60	0.0162	0.0443	0.0347	0.0443	8.60	0.0181	0.0034	0.0034	0.0034	0.0024	2.84	ND	ND	ND	22.5	5.38

Zn (0.00393), Cu (0.0032), Cr (0.0095), Pb (0.0008)], Na (0.0243), Ca (0.0229), K (0.0427), Mg (0.0228), Fe (2.207), Mn (0.006), Zn (0.0016), Cu (0.0013), Cr (0.0094), Pb (0.001)}; Ngamwa {Na (0.0126), Ca (0.0434), K (0.0297), Mg (0.0434), Fe (7.483), Mn (0.0163), Zn (0.00297), Cu (0.0037), Cr (0.00683), Pb (0.001667)}. The high levels of iron in all clay samples collected might be associated with the black, brown or grayish white colour that was observed in clay mineral samples from the study area. This colouration will have a negative effect on the degree of brightness of the products manufactured using clay minerals from the study area as shown in Figure 1, hence reducing their quality. However, the final product quality can be achieved by reducing the levels of iron and other impurities present to acceptable levels by employing low cost and environmentally friendly techniques. The average pH of clay samples from Karundu, Mweru, Ngamwa were 5.17, 4.37 and 5.36 respectively, and all fall within the pH range of 4.0 to 9.0 for chemically inert kaolinites, implying that the kaolinites present in the studied clay samples are chemically inert. The average conductivity of clay samples from Karundu, Mweru, Ngamwa were 28.4, 108.3 and 22.1 μS respectively. The high value of conductivity of clay samples from Mweru is associated with low pH observed. However, the electrical conductivity has a linear relationship with cation exchange capacity, particle size distribution, mineralogy, organic matter content, porosity and water content of the soil sample. High electrical conductivity relates to clay minerals like the smectite group that exhibits high cation exchange capacity (CEC) thus, the low electrical conductivity observed in the clay samples from Kurundu and Ngamwa imply presence of clay minerals with low CEC like the kaolinite group. Low electrical conductivity can also be brought about by high levels of quartz and low levels of clay mineral content.

The average results of BET (Brunauer, Emmett and Teller) surface area for Karundu, Mweru and Ngamwa were; 35.222, 47.222, and 34.222 m^2/g respectively. The BET surface area for pure kaolinite ranges between 10-20m^2/g. The results obtained in the present investigation suggest the presence of kaolinite in the samples as was observed in the physico-chemical properties analysis. The high kaolinite values obtained compared to those of pure clay is associated with the levels of impurities like quartz, sodium, magnesium ions in the samples. The high level of very small size quartz which are smooth, uniform and non-porous might be present in the region thus contributing to high surface area. This is supported by the high amount of quartz (Karundu, 31.3%, Mweru, 68.1% and Ngamwa, 24.3%) which was present in the samples. Na^+ and Mg^{2+} saturated systems can contribute to a higher surface area compared to other elements. In the present study, the average level of Na^+ in the samples from Karundu, Mweru and Ngamwa were; 0.0242, 0.0353 and 0.0126 respectively while Mg^{2+} values were found to be 0.02283, 0.03636 and 0.04336 respectively. The high values of quartz, Na+ and Mg^{2+} in the samples from Mweru could have contributed to the high surface area

Table 4. BET surface area results.

Sample site	Depth (cm)	BET surface area (m^2g)/	Pore volume cm^3/g	Pore size (A°)	Nanoparticle size (A°)
			Single point adsorption total pore volume of pores less than 917.424 A° at PP/PO=0.97843255	Adsorption average width	Average particle size
Karundu	0-20	35.222	0.2.601	130.7983	1895.316
Mweru	20-40	47.222	0.11311	130.7915	1890.176
Mweru	40-60	46.6703	0.167204	143.3070	1285.618
Ngamwa	0-20	31.722	0.10301	129.8985	1891.376
Ngamwa	40-60	34.222	0.40201	133.7981	1888.276

observed. The lower BET surface area of the samples from Ngamwa might be associated with high level of weathering of kaolinite in the surface soils or authigeic formation of large kaolinite which could be as a result of less inhibition of crystal growth by organic matter (Melo et al*.,* 2001). The average values of pore volume and pore size for Karundu, Mweru and Ngamwa were 0.20601, 0.167204, 0.40201 cm^3/g and 130.7983, 143.307, 133. 7981 Ǻ respectively. The average particle size of nano particles for samples from Karundu, Mweru, Ngamwa are 1895.316, 1285.618 and 1888.276 Ǻ respectively. The high value of pore volume for samples collected from Ngamwa could imply that, the clay from this region have a better crystalline kaolinite in comparison with the other two sites studied (Table 4).

The representative X-ray diffractogram for the clay samples from Karundu site is shown in Figure 4. The d-spacing reflections at; 4.18545, 3.53312, 2.59849, 2.50075, 2.32134, 2.21881, 2.11127, 1.96630, 1.78147, 1.66399, 1.56111 and 1.48185 revealed the presence of kaolinite in the sample. The presence of albite, microcline in the samples was revealed by d-spacing reflection at 3.21200, 3.23012 respectively. The reflection at 3.30796, 2.52836, 2.21881, 2.11127, 1.80485 and 1.66399 showed that quartz was present in the sample. Generally, the reflections of quartz were the strongest in comparison with other peaks thus indicating dominance and high crystallinity of this mineral in the samples compared with other minerals. The peaks of illite and huminic acid at d-spacing 3.32000 to 3.35000 and 3.33000 respectively were not established due to the fact that the principle reflection of quartz (3.30796 Ǻ) occurs almost at the same position.

Clay and non-clay minerals in the samples from Mweru site were identified using XRD method and a representative X-ray diffractogram is shown in Figure 5.
The presence of kaolinite clay mineral was revealed by reflection at d- values of 4.17788, 3.52252, 2.31787, 2.21856, 2.10941, 1.96249, 1.66034, 1.5524 and 1.48023. The d-spacing at 3.20419 and 3.24103 revealed the availability of albite and microcline respectively in the sample. Quartz was identified by reflections at 3.30114, 21.21856, 2.10941, 1.96249, 1.80478, 1.66.95.

Figure 6 shows a representative X-ray diffractogram of the clay sample from Ngamwa site. The availability of the kaolinite in this sample was indicated by the reflection at 4.18303, 3.53124, 2.32200, 2.21872, 2.11326, 2.50119, 1.98008, 1.65982, 1.54713 and 4.8144. The d-spacing at reflection 3.21062 and 3.24012 indicated the presence of albite and microline respectively in the sample. Quartz was revealed by reflection at 3.30495, 2.54130, 2.22412, 2.111464, 1.97273, 1.81135 and 1.66119. The percentage composition of the minerals in the clay samples as revealed by XRD results is shown on Table 5.

The percentage composition of Albite was in the range (5.3-16.7), Kaolinite (11.4-36.2), Microcline (15.2-35.3) and Quartz (24.3-68.1). Kaolinite was the only clay mineral detected in the samples with appreciable amounts for industrial applications (greater than 10%). For kaolinite mineral to be utilized industrially, other accessory minerals like albite, microcline and quartz should be reduced to acceptable levels through appropriate beneficiation techniques.

The identification of different types of clay minerals was achieved by the use of absorption bands due to structural OH and Si-O groups that were obtained from the FT-IR spectrum. The types of cations that are linked directly to the hydroxyls influences the OH absorption bands and this is important for the determination of cation distribution around hydroxyls. The interpretation of the FT-IR spectrums in Figures 7 to 9 was done using the available literature (Madejova, 2003; Vaculikova and Plevo va, 2005; EmDadul, et al*.,* 2013). A close examination of the obtained FT-IR spectrums revealed the presence of kaolinite clay minerals in all the samples that were investigated and this confirms the XRD results. The four bands in the ranges, 3620.55-3621.39, 3651.92-3653.75, 3670.01-3670.85 and 3690.31-3694.17cm^{-1} confirmed the presence of kaolinite in the samples. The presence of sharp doublets at around 3620.55-3621.39 and 3690.31-3694.17 further revealed the presence of kaolin group in the sample. The absorption bands at the range of 3620.55-3621.39 was assigned to the stretching

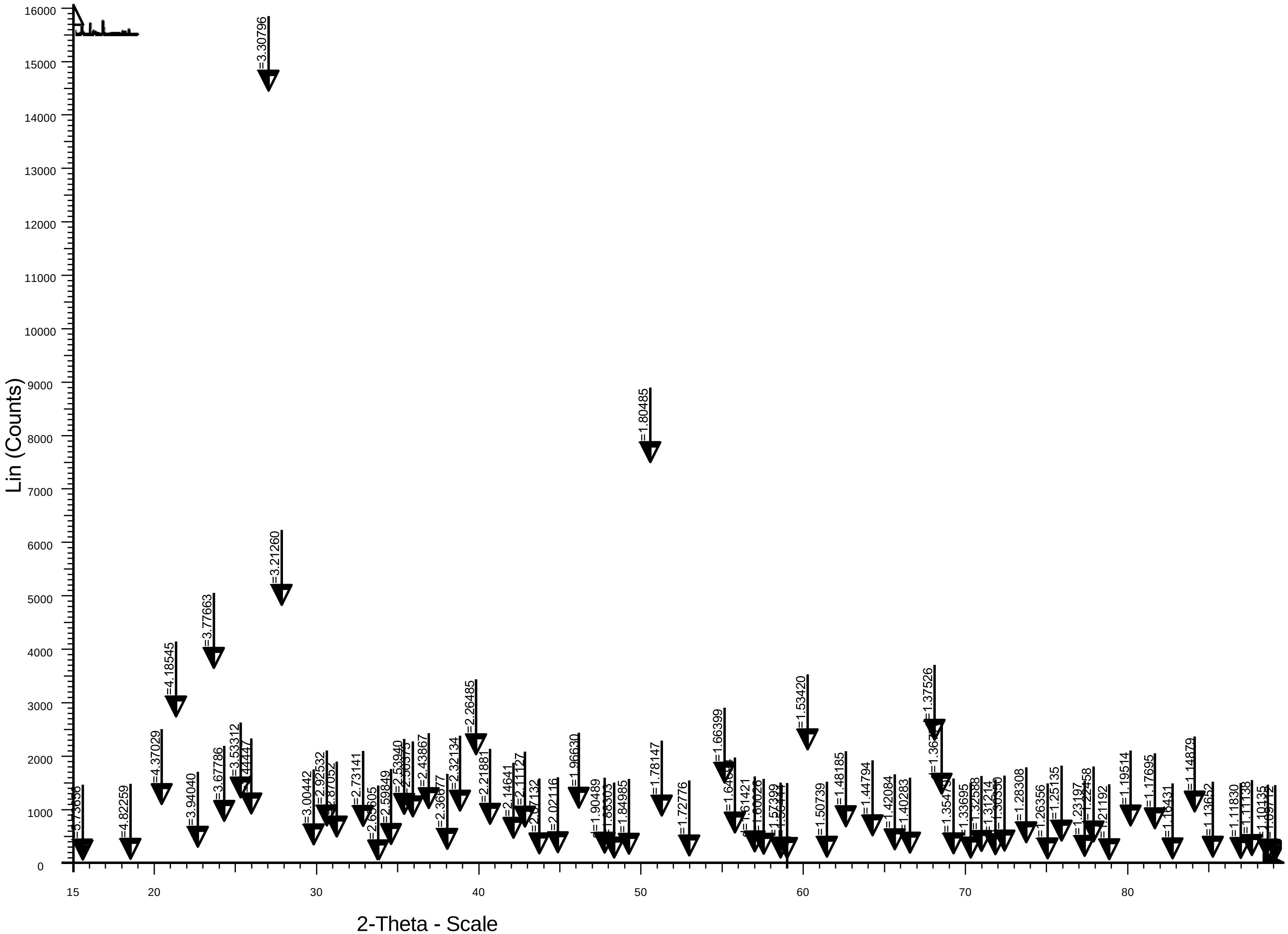

Figure 4. X-ray diffractogram for the clay samples from Karundu site.

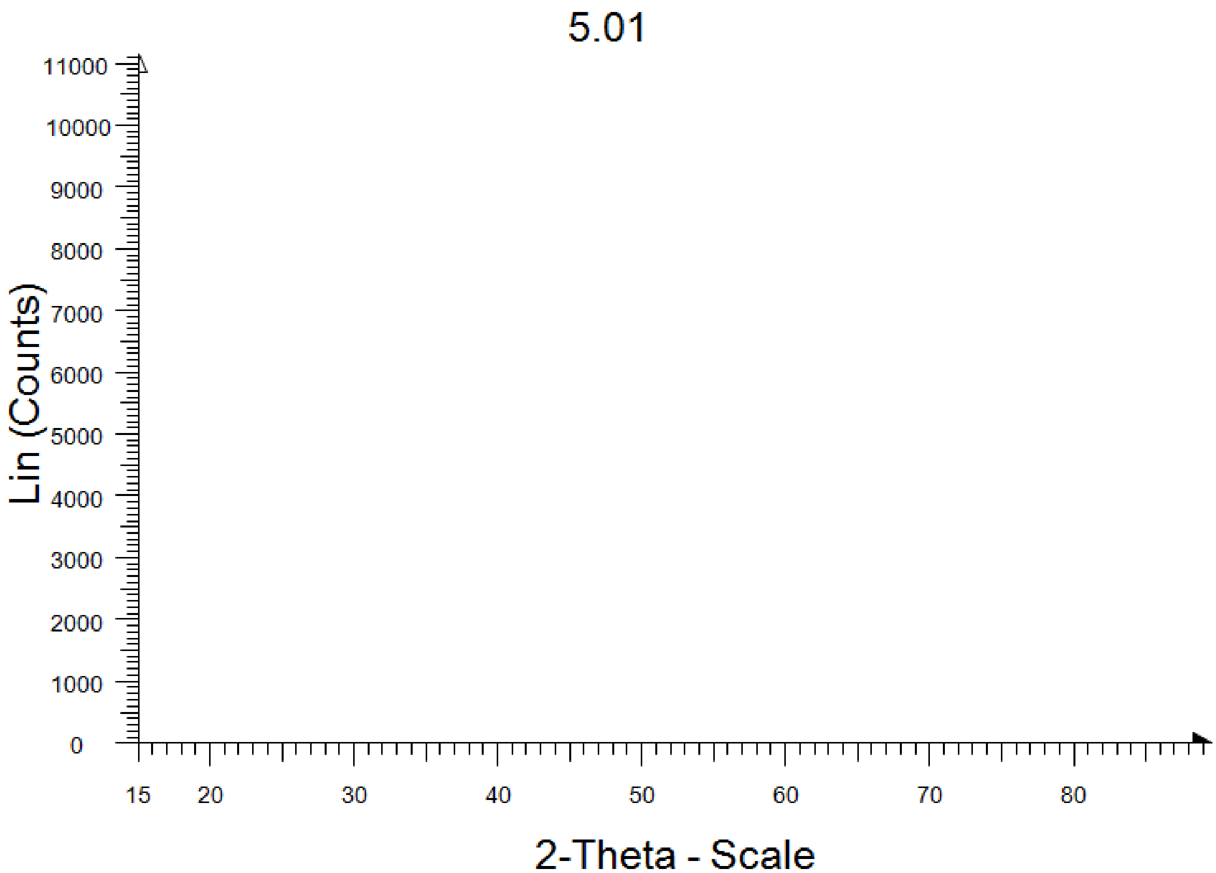

Figure 5. X-ray diffractogram for the clay samples from Mweru site.

vibration of internal surface OH groups which is located between the tetrahedral and octahedral surface of the layers and it forms hydrogen bonds with the oxygen of the Si-O-Si bonds on the lower surface of the next layer which is weak. The strong band at around 3690.31-3694.17 cm^{-1} was attributed to the in-phase symmetric stretching vibrations while the two weak bands at around 3651.92-3653.75 and 3670.01-3670.85 cm^{-1} were due to the out-of plane stretching vibrations. The bands observed at the range of 911.40-914.30 cm^{-1} were either due to vibrations of the inner surface or OH bending groups which is common to kaolinite containing samples, while occurrence of bands at 936.48-936.58 cm^{-1} are as a result of surface OH groups. The bands at the ranges 691.15-695.37 cm^{-1} and 752.27-754.20 cm^{-1} are attributed to the surface hydroxyls while the ones at 1006.89-1113.94 cm^{-1} can be associated with Si-O stretching vibrations of kaolinite. The bands occurring at the ranges 3645.36-3652.75 (OH stretching), 911.40-913.33 (shoulder), 780.24-795.67 and 747.86-753.23 (doublets) cm^{-1} indicated the presence of illite in the sample and they represent Al-Mg-OH deformation. The strong stretching bands ranging between 909.06-1112.97 and slightly less intense bending bands at406.97-794.95 cm^{-1} revealed the presence of Si-O bonds in all the samples studied. The bands observed at 460.35-4621.87 and 522.96-524.96 cm^{-1} (Si-O asymmetrical bending vibrations), 692.47-695.37 (Si-O symmetrical bending vibrations) 780.24-789.06 and 794.95-795.67 cm^{-1} (symmetrical stretching vibrations) and 1081.15-1099.47 cm^{-1} (Si-O symmetrical stretching vibrations due to Al for Si substitution) indicated the presence of quartz in the samples. The bands ranging from 590.92-604.03 cm^{-1} can be attributed to O-Si-(Al)-O bending vibrations and revealed the presence of microcline feldspar in the samples which accords the results from XRD. The four OH stretching bands (3669.00, 3656.00, 3642.00 and 3623.00cm^{-1}) were associated with the presence of hornblend in the sample. The bands observed at the ranges of 3411.10-3417.43, 2851.88-2957.97, 1031.96-1102.37, 1633.59-1650.36 and 1338.84-1350.17 cm^{-1} indicated humic acid was present in the sample which is in line with observation at the sampling sites. The bands recorded at the range of 2852.88-2957.97 was attributed

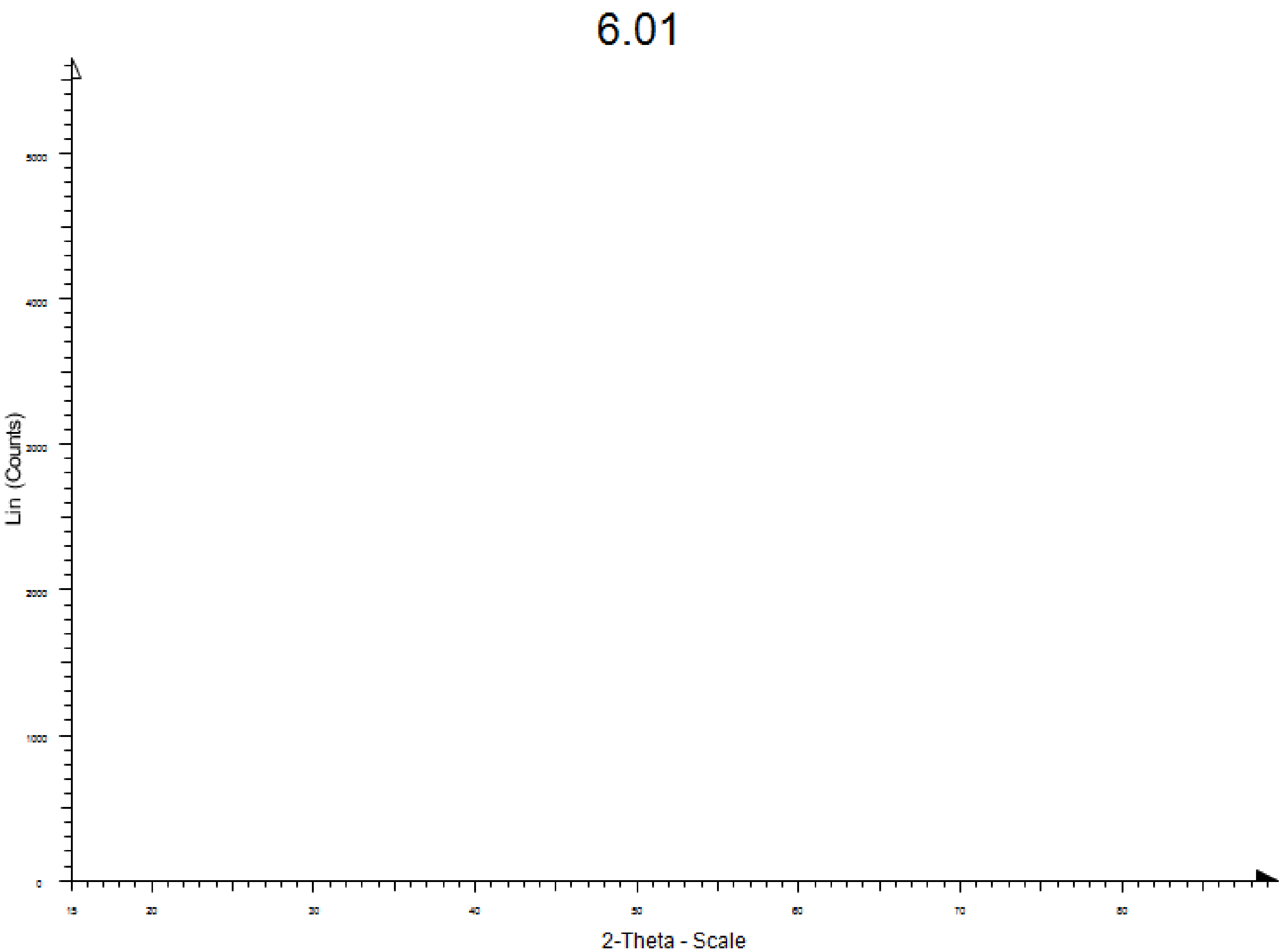

Figure 6. X-ray diffractogram for the clay samples from Ngamwa site.

Table 5. Percentage composition of clay and non-clay minerals in the sampled clays.

Site	Albite	Clinochlore	Hornblende	Hematite	Kaolinite	Magnetite	Microcline	Quartz
Karundu	16.7	-	-	-	16.6	-	35.3	31.3
Mweru	5.3	-	-	-	11.4	-	15.2	68.1
Ngamwa	11.4	-	-	-	36.2	-	20.4	24.3

to CH_2-CH_3 stretching, while those at 1633.59-1650.36 and 1338.84-1350.17 cm^{-1} indicated humic acid was present in the sample. The bands which appeared at the range of 2851.88-2957.97 was attributed to CH2-CH3 stretching while those at 1633.59-1650.36 and 1338.84-1350.17 cm^{-1} was attributed to COO- asymmetric and symmetric stretching respectively. Presence of the humic acid could contribute to the decrease in the amounts of Si and Al contents in the clay structure due to decomposition of the Si-O-Si by acidolytic attacks.

Thermal analysis

The representative thermographic curves for the samples studied are shown in Figures 10 and 11. These curves

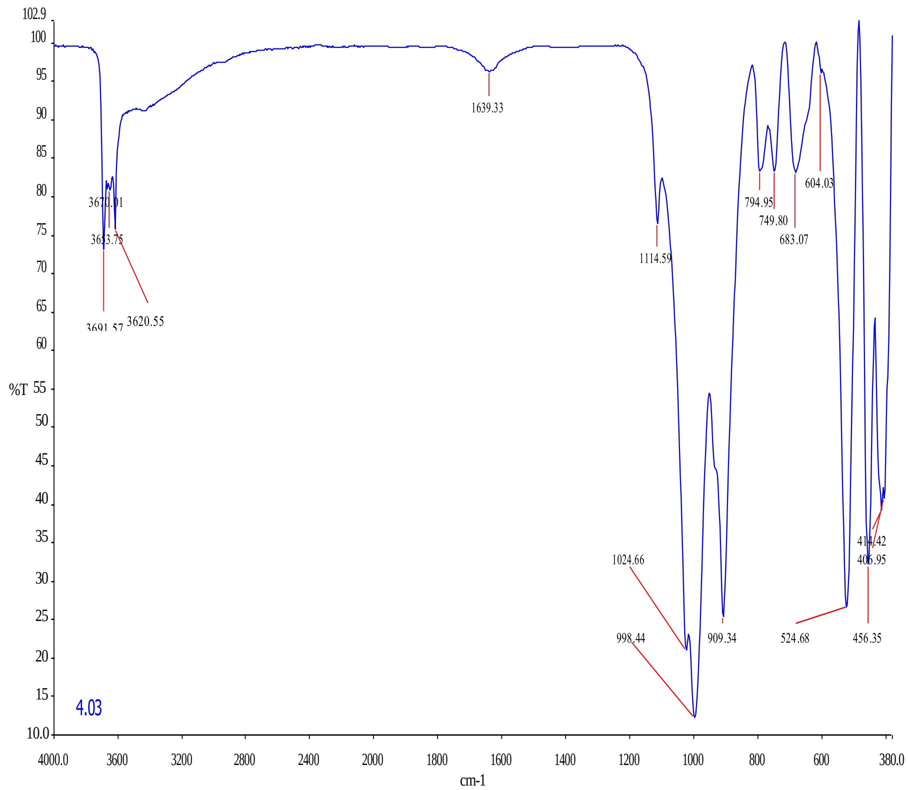

Figure 7. FT-IR Spectrum (Karundu site).

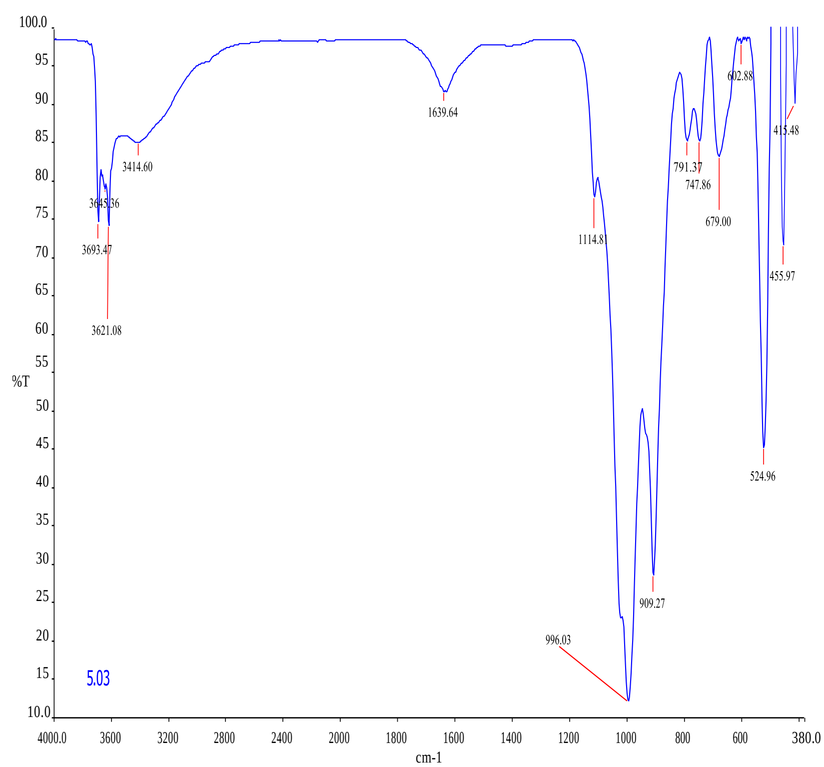

Figure 8. FT-IR Spectrum (Mweru site).

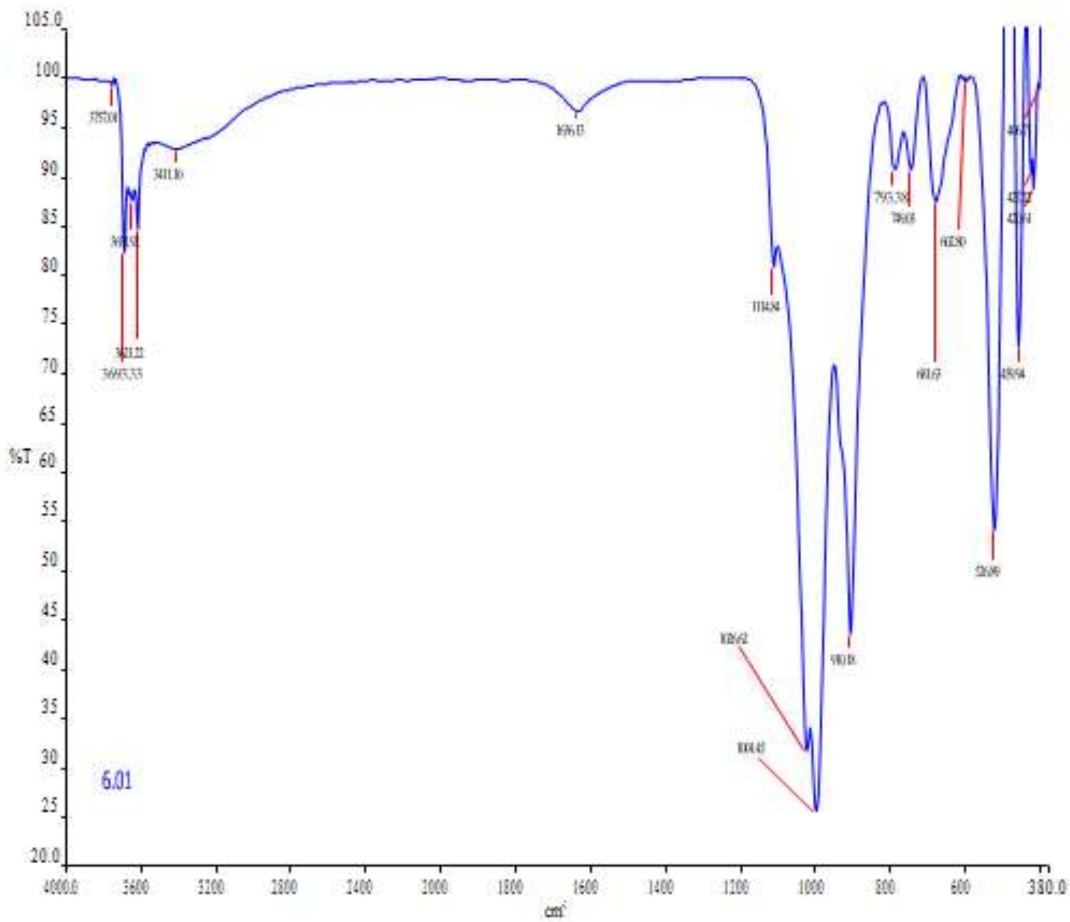

Figure 9. FT-IR Spectrum (Ngamwa site).

contain useful information regarding various temperature ranges which is indicative of where the processes of dehydration, dehydroxylation and phase transformation of various clay minerals studied takes place. A close examination of the curves revealed that only 3.125% of free water, adsorbed water and volatile products are lost between the temperature ranges of 25-200°C. The loss in weight of 10.625% between the temperature ranges of 200 to 500°C was attributed to the loss of the products resulting from organic reaction. The dehydroxylation process which resulted to the loss of 0.875% of structural water took place between the temperature range of 500 to 800°C. About 0.625 of hydroxyl water was lost from 800 to 900°C which completed dehydration process. A combustion reaction between inorganic oxygen and organic carbon took place from 900 to 1000°C. The symmetrical and smooth thermal curve in the interval from 400 to 800°C suggested the presence of kaolinite in the samples. The representative of SEM micrographs of the clay minerals samples is presented in Figures 12 and 13. The presence of almost pseudo hexagonal shapes and very small flattened platelets observed in these figures shows the presence of kaolinite. On further examination of SEM micrographs, the larger clay mineral particles seems to consist of much smaller platelets which indicates that the clay sample is made up of very fine particles. The presence of quartz was revealed by almost rounded and also V-shaped platelets with brighter luminescing and this confirms the results of XRD and FT-IR.

Conclusion

The clayey mineral samples are kaolinitic in nature, having more than 10% kaolinite and contain different types of impurities which make it less useful. The major impurities species are quartz and iron with minor ancillary cations such as Mn^{2+}, Mg^{2+}, Na^{+} and K^{+} etc. The identification and quantification of impurities in the clay samples from the study area makes it easier for future researchers in the selection or modification, and sequentialization of beneficiation process with the objective of reducing impurity levels to acceptable limits

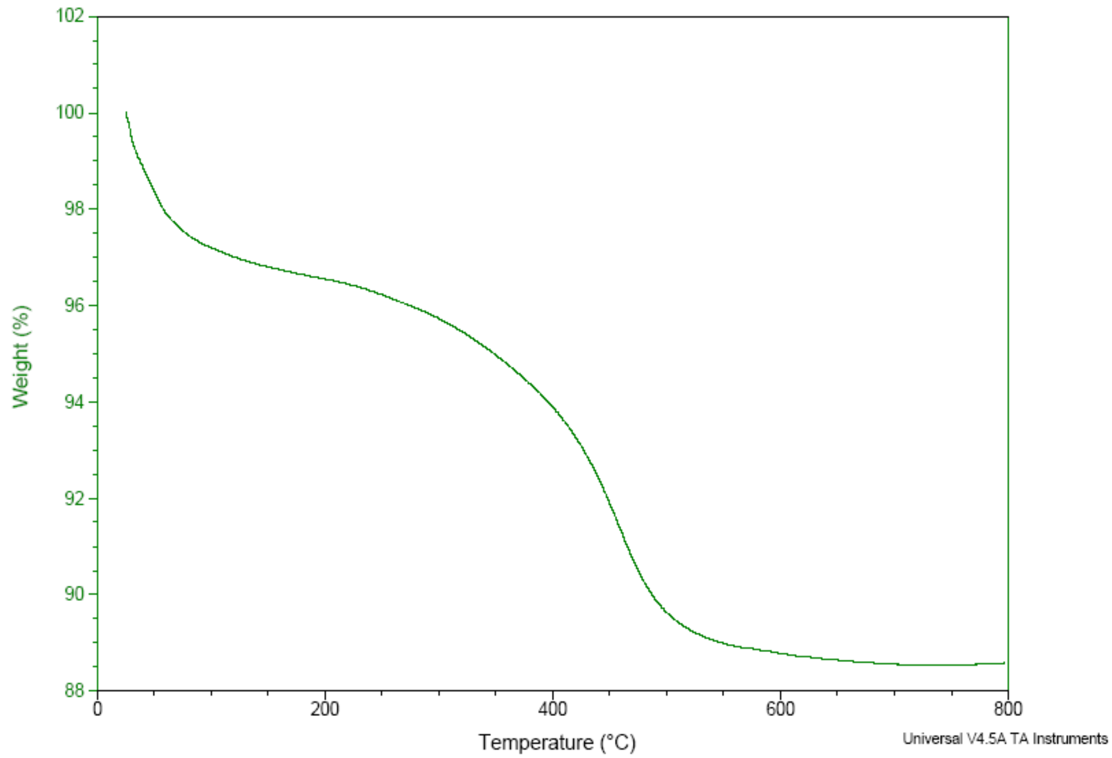

Figure 10. Representative thermographic curve A.

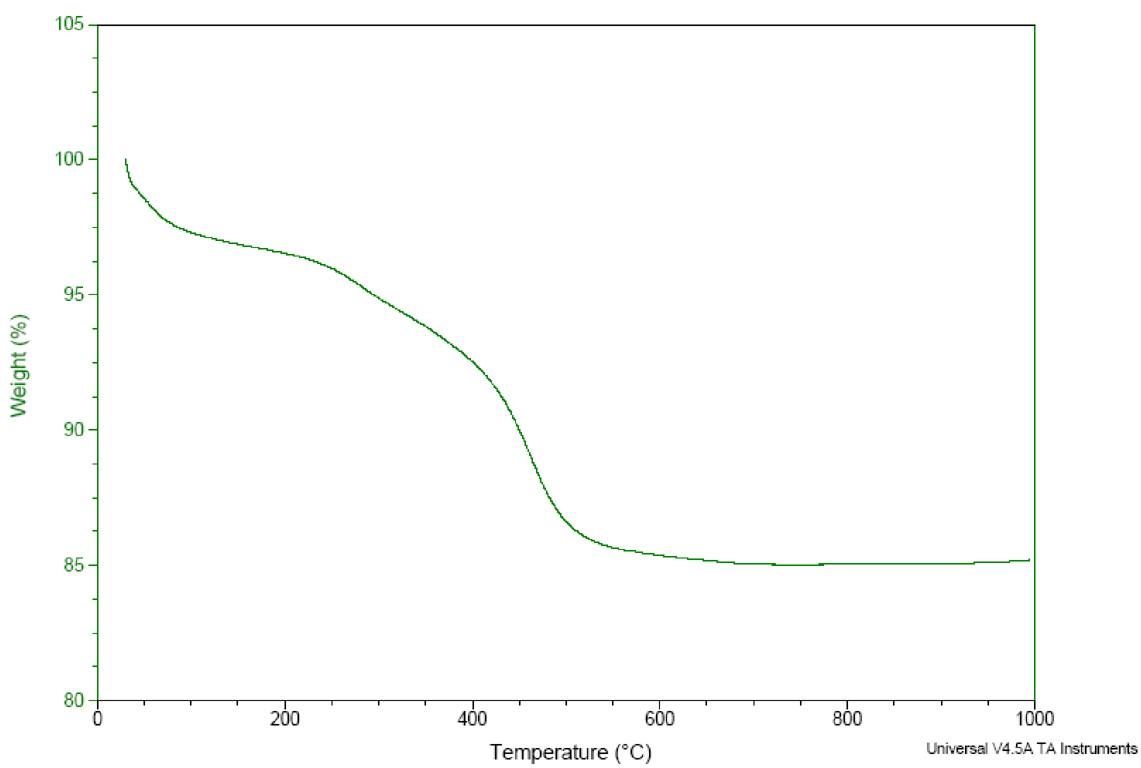

Figure 11. Representative thermographic curve B.

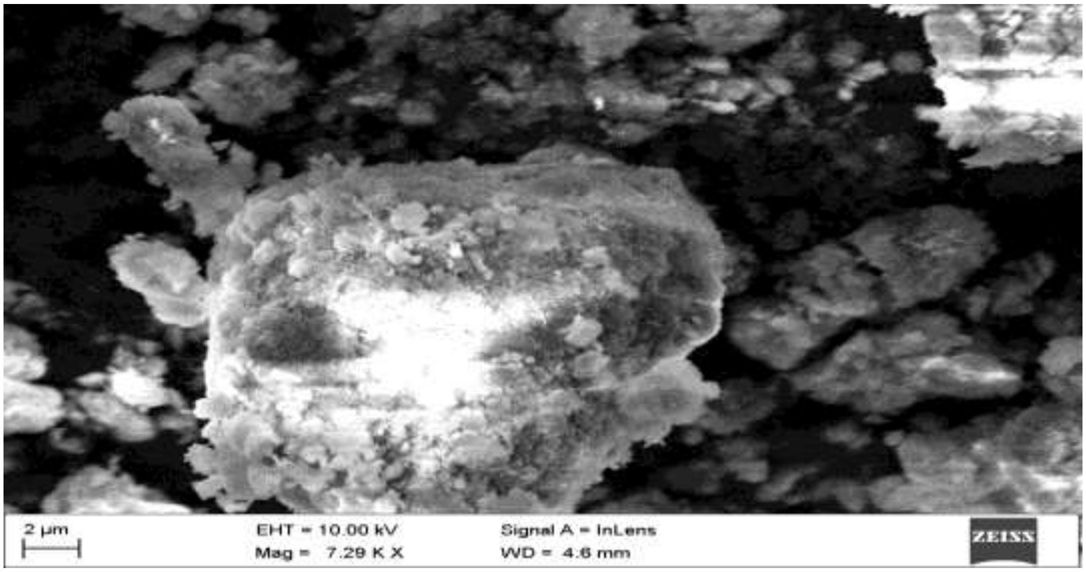

Figure 12. SEM micrograph A.

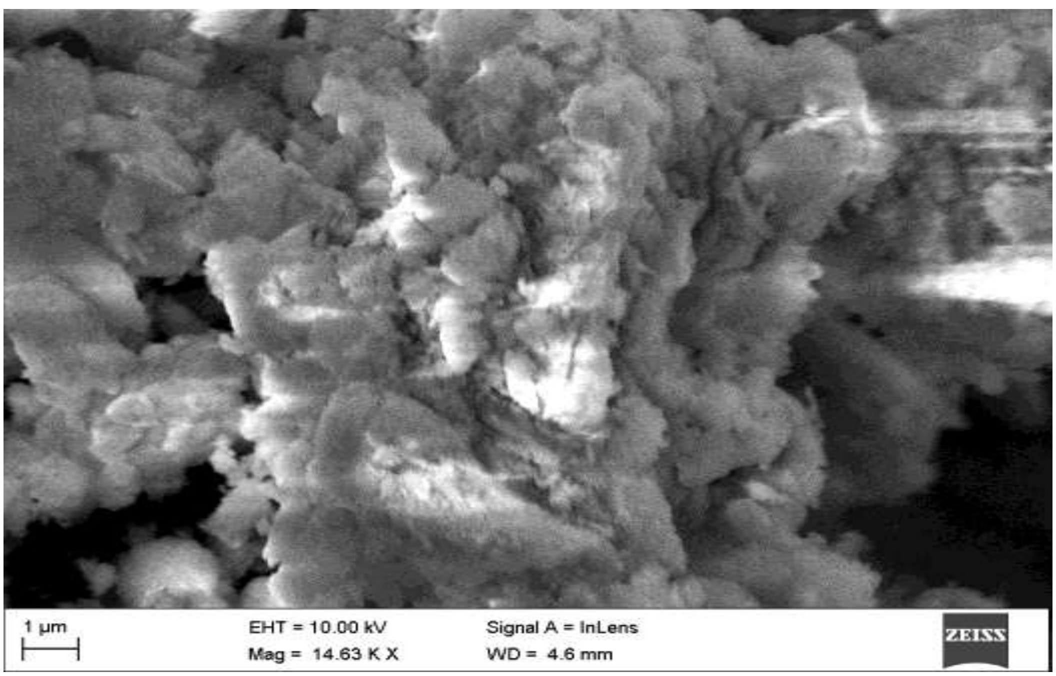

Figure 13. SEM micrograph B.

hence rendering the raw materials useful for commercial production of ceramic products and eventually maximizing its potential utilization.

Conflict of interests

The authors have not declared any conflict of interests.

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Air pollution emission inventory along a major traffic route within Ibadan Metropolis, southwestern Nigeria

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Increasing road congestion and high traffic volume is often times an indicator of atmospheric air pollution. Ibadan, being the largest metropolitan city in southwestern Nigeria, experiences steady influx of vehicular movement on daily bases. The situation is made worse as a greater number of these vehicles are old and poorly maintained. This study therefore investigated the likely impact of high traffic volume along a major roadway (the Ojoo-Mokola road) within the Ibadan metropolis on atmospheric air quality. Eight sampling points along a stretch of the roadway were identified for traffic density and air quality monitoring. Data was collected monthly over a period of four months in the morning peak, off peak and evening peak hours. Air quality parameters, carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S) and ammonia (NH_3) were measured using handheld Crowcon Triple Plus+ and Crowcon Tetra-Portable Multi-Gas Detectors. The average concentration of CO range between 3.25 and 50.8 ppm with highest concentration observed during the morning and evening peak hours. There was a strong correlation (*p=0.05*) between ambient CO levels and traffic density. Relatively low levels of H_2S, and NH_3 were detected while NO_2 levels were relatively constant (<0.1 ppm). Sulphur dioxide was generally not detected within the study locations. Though this study did not cover the whole city of Ibadan, findings from the eight sampling points suggest that this major stretch of road may altogether not be safe from traffic related problems. There is need for constant monitoring of vehicular emissions to forestall possible air pollution.

Key words: Air quality, vehicular emissions, traffic density, carbon dioxide.

INTRODUCTION

The rising number of cars on major roads is an emerging problem in most developing and developed cities (Baldasano et al., 2003; Schrank and Lomax, 2007; Shiva et al., 2007; Kai and Stuart, 2013; Chao et al., 2014). In most developing cities, rapid urbanization has resulted in uncontrolled growth characterized by poor physical planning, deteriorating environment and increasing vehicular traffic. In such urban environments, traffic emissions are the dominant source of gaseous pollutants, such as NO_X, CO and volatile organic

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compounds (Hellen et al., 2006; Kumar et al., 2011; Pirjola et al., 2012). This has created high levels of traffic-related air pollutants, which have been shown to constitute up to 80-90% of CO emissions. Atmospheric air pollution problems are here and are still rising on many fronts despite consented efforts by government regulatory agencies. The number of motor vehicles globally - excluding motorbikes and three wheelers has significantly increased by a factor of 10 since the 1950's and is now above 600 million (WHO/UNEP, 1992). In addition to this, there is now an estimated 80 million motorcycles (OECD, 1995). Traffic congestion increases vehicular emissions and degrades ambient air quality, and recent studies have shown excess morbidity and mortality for drivers, commuters and individual's a-like living or working near major roadways (Kai and Stuart, 2013). Furthermore, epidemiological studies have demonstrated adverse health effects of short-term and long-term exposure to traffic-related air polution (Kettunen et al., 2007; Su et al., 2008; Jacobs et al., 2010).

Information on air pollution in developing countries and some countries with economies in transition is limited and longer time-series are very rare. In some cases, general trend in air quality can only be estimated on the basis of emission inventories. Data presented in the open literature are seldom up to date and normally concern with specific cities, which may or may not be fully representative. In recent years, many governmental and private institutions from the industrialized countries have acted as consultants to developing countries on air quality investigations, but not all the efforts are reported in open literatures (Fenger et al., 2002). Unconfirmed statistics from the Ibadan city transport authority has shown that there is an average of 150 vehicles and 180 motor cycles to every kilometer of road within the metropolis.

Increasing road congestion and high traffic volume is a fundamental issue in some major roads within Ibadan metropolis. Being the largest metropolitan city in southwestern Nigeria, Ibadan experiences steady influx of vehicular movement on daily bases. The situation is made worse as a great number of these vehicles are old and poorly maintained, and worse still in an environment with ineffective or no transport regulating laws. One such important major road with high flux of traffic is the Mokola-Ojoo route which transverses about 10 km and currently undergoing major road reconstruction works. This research work was therefore, aimed to assess the levels and magnitude of ambient air pollutants on this stretch of major road (hot spot) which was undergoing major reconstruction work in relation to traffic density. Monitoring of traffic density distribution and concentrations of ambient carbon dioxide, nitrogen dioxide, sulphur dioxide, hydrogen sulphide and ammonia was carried out along designated traffic areas on the route. Concentrations of CO_2, SO_2, NO_2, H_2S and NH_4 along the route were also compared with ambient air quality standards. It is hope that this study will help unfold if any, the relationship between traffic density, road reconstruction and ambient air quality. The outcome will therefore be useful for addressing interventions to reduce exposure rates to air pollutants by city dwellers.

MATERIALS AND METHODS

The study area and design

The designated study area is the Ojoo and Mokola road, along Oyo road on the north eastern side of Ibadan city metropolis in Oyo State, southwestern Nigeria (Figure 1). Eight monitoring locations identified along the roadway were selected because they are representative of typical urban commuting routes traversing residential and commercial districts in Ibadan. These locations includes: Ojoo (L-1); Ololoro (L-2); Orogun (L-3); University of Ibadan (L-4); Samonda (L-5); Sango (L-6); Premier Hotel road (L-7) and Mokola (L-8). Locations L-1, L-4, L-6 and L-8 were majorly characterized by high human and vehicular traffic, and commercial activities. Major reconstruction work was ongoing on the study route with the construction of a flyover bridge on location L-8 as at the time of this study. Traffic volume monitoring [comprising of articulated vehicles, cars and motorcycles] and data collection on air quality parameters [carbon monoxide (CO), nitrogen dioxides (NO_2), sulphur dioxides (SO_2), hydrogen sulphide (H_2S) and ammonia (NH_3)] were carried out at these active locations. To assess the magnitude of air pollution within the stretch of the road, air quality data was also monitored at night when traffic volume approached zero. Control results showed zero levels of CO, NO_2, SO_2, H_2S and NH_3 at all sample locations. Data collection was carried out on monthly bases between March and June 2013. Each of the months' data was collected twice in the morning (7:00-10:00am), afternoon (12:00-3:00 pm), evening (4:00-7:00pm) and night (12pm-1am).

Data collection

From the eight locations identified, traffic volume of trucks (articulated vehicles), cars (including minibuses) and motorcycles (tricycles and motorbike) were estimated by personal observation (traffic flow per hour). Air quality parameters: carbon monoxide, nitrogen dioxides, sulphur dioxides, hydrogen sulphide and ammonia within these designated locations were instantly measured at 2.4 m above ground level and 2.0 m from the road. Monitoring of these ambient air pollutants were done using a handheld Crowcon Triple Plus+ (Model M07701) and Crowcon Tetra-Portable (Model M07237) multi-gas microprocessors controlled portable gas detectors. The M07701 model was used to measure NO_2 (0-10ppm) and H_2S (0-100ppm) at -10 to 50°C while M07237 was for CO (0-500 ppm), SO_2 (0-10 ppm) and NH_3 (0-100 ppm) at -20 to +55°C. The instruments were synchronized and zero calibrated (by covering the sensor) before the start of each measurements.

Data were subjected to descriptive and explanatory (inferential) statistical analysis. The descriptive statistics included measures variations (dispersion). The inferential statistical tool used to test the hypotheses was the Analysis of Variance (ANOVA) and Pearson's correlation coefficient. Furthermore, a graphical plot was used to express data set relationships.

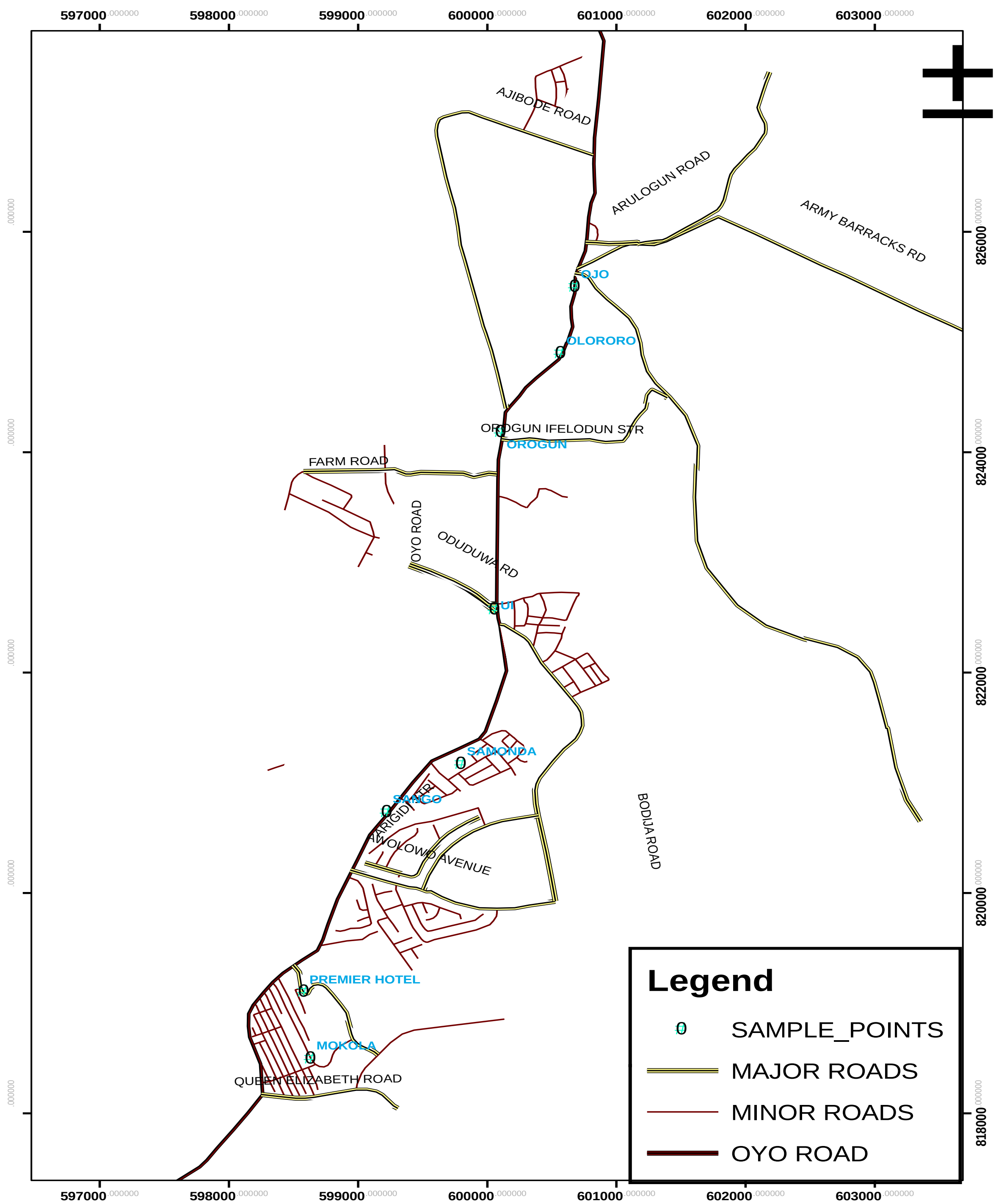

Figure 1. Map showing the study locations.

RESULTS AND DISCUSSION

Carbon monoxide levels

The average traffic volume distribution (Table 1) shows that cars rather than bikes and trucks were more prevalent across the duration of study (cars>bikes>trucks) along the Mokola-Ojo roadway. The total volume of vehicular traffic from all locations which included cars, trucks and bikes was much higher during

Table 1. Average number of vehicles/hour on Ojo-Mokola road.

Sample Code	Morning peak hours				Off peak hours				Evening peak hours			
	Trucks	Cars	Bikes	Total	Trucks	Cars	Bikes	Total	Trucks	Cars	Bikes	Total
L-1	240	2880	1095	4215	95	925	145	1165	180	3150	1185	4515
L-2	135	1725	870	2730	60	530	115	705	165	1965	570	2700
L-3	105	2130	1125	3360	25	636	125	786	135	1475	785	2395
L-4	105	2640	1005	3750	40	1020	135	1195	180	2490	1185	3855
L-5	33	1175	885	2093	22	460	105	587	42	1265	955	2262
L-6	60	3375	945	4380	35	1160	125	1320	75	2790	1200	4065
L-7	15	1785	525	2325	9	675	75	759	30	1075	515	1620
L-8	0	2580	780	3360	0	985	120	1105	0	2595	1455	4050

morning and evening period, hence classified as peak hours. Trucks and bikes were more prevalent during the evening peak hours comparatively to cars in the morning hours. Traffic density was generally high along the Ojoo (L-1), University of Ibadan (L-4), Sango (L-6) and Mokola (L-8) axis of the roadway during the morning, off peak and evening peak hours (Table 1). These current traffic volume are higher than previously reported for in the late 90's (Onianwa, 2001), which could be attributed to the rapid urbanization of the city metropolis over the years. A significant difference (p=0.05) was observed in traffic distribution between the morning, afternoon and evening periods, indicating the cosmopolitan nature of the city.

The average concentration of CO for the selected sampling sites ranged between 3.25 and 50.8 ppm with highest concentration observed during the morning and evening peak hours. As shown in Table 2, the highest average CO concentration was measured at locations, L-1 (27.5-36.3 ppm), L-4 (15.8-50.8 ppm), L-6 (33.8-38.3 ppm) and L-8 (10.5-19.5 ppm). These locations were mostly characterized by high traffic congestion as well as commercial activities with ongoing road reconstruction work. The magnitude of CO emission compared to the control values of zero recorded at night will most likely be attributed to high traffic volume/congestion and ongoing reconstruction work along the stretch of the road. Changes in driving pattern (that is traffic flow and speed) due to traffic congestion result in increased number of speedups, slowdowns, stops and starts, which explains the increase concentration of CO at these locations. Evidence of up to 4-, 3- and 2-fold increases in CO emissions have equally been attributed to high traffic congestion with average speed of 20.9 km/h as compared to uncongested conditions with average speed of 61.2-70.8 km/h (Sjodin et al., 1998; Ntziachristos and Samaras, 2001). The statistical significance of peak and off peak hour measurements were assessed using Levene's *t*-test of homogeneity of variance, and no statistical difference in CO concentration was detected (p>0.238). Similarly, analysis of variance (p>0.05) showed no statistically difference between the morning and evening peak hours and off-peak hour CO concentrations.

The relationship between traffic volume and ambient CO concentration in Figure 2 further indicates a positive trend between CO levels and car density during morning, afternoon and evening hours. Pearson's correlation (Table 3) confirms this with a positive correlation in levels of CO with car density for morning (0.664), afternoon (0.810) and evening (0.905) hours. Prevailing meteorological conditions such as exhaust emissions increase with decreasing ambient temperature and high traffic, quality of vehicles; age, maintenance and fuel type (Faiz et al., 1996; WHO, 2005) could possibly explain the high CO levels during the morning and evening period as observed by the correlation coefficient. There was no significant correlation of CO concentrations with trucks and bikes density during the period of study. Concentrations of CO in locations L-1, L-4, L-6 and L-8 which range between 10.5 and 50.8 ppm mostly exceeded the FMENV allowed daily average limit of 10 ppm (FEPA, 1991). Whereas, only one sixth of the measurement periods (16.7%) had CO levels exceeding the USEPA national ambient air quality standards of 35 ppm for an hourly exposure limit (USEPA, 2011). These observed levels of CO are a result of heavy traffic volume around these locations, since vehicular emissions are major sources of CO levels in the atmosphere. The average daily concentration of CO obtained from high traffic congestion areas (L-1 30.4 ppm; L-4 30.9 ppm; L-6 36.2 ppm and L-8 15.3 ppm) where slightly higher than 11.9 ppm recorded around similar areas in Enugu metropolis (Nwadiogbu et al., 2013) as well as with results obtained for heavy traffic intersections of major roads in Ogbomosho (Ojo and Awokola, 2012).

Nitrogen dioxide and other pollutants

Result shows that SO_2 was not generally detected,

Table 2. Average levels (ppm) of air pollutants.

Sample code	CO			NH_3			H_2S			NO_2		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
L-1	36.3±32.2	27.5±15.5	27.5±15.5	0.2±0.3	0.23±0.5	0	0.50±0.6	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-2	8.0±4.8	7.25±9.2	4.50±5.3	0.05±0.1	0.08±0.2	0.05±0.1	0.50±0.6	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-3	4.0±2.3	7.50±6.6	12.8±8.3	0	0.38±0.8	0	0.75±0.5	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-4	26.0±11.7	15.8±5.8	50.8±5.1	0.26±0.6	0.43±0.5	0.08±0.2	1.00	1.25±0.9	<1.0	<0.1	<0.1	<0.1
L-5	3.75±2.6	3.25±2.5	4.50±4.0	0.23±0.5	0	0	0.75±0.5	1.00	<1.0	<0.1	<0.1	<0.1
L-6	38.3±18.4	36.5±17.1	33.8±14.3	0.23±0.5	0.20±0.3	0.20±0.4	1.00	1.00	<1.0	<0.1	<0.1	<0.1
L-7	12.5±8.1	8.25±5.3	8.75±6.4	0	0.10±0.2	0	0.75±0.5	0.75±0.5	<1.0	<0.1	<0.1	<0.1
L-8	19.5±12.8	10.5±9.7	15.8±7.1	0.05±0.1	0.18±0.4	0.25±0.5	0.75±0.5	1.00	<1.0	<0.1	<0.1	<0.1

SO_2 was not detected.

Table 3. Pearson's correlation coefficient (p=0.05) for CO and traffic volume distributions.

	Morning peak hour	Afternoon off peak hour	Evening peak hour
Trucks	0.428	0.458	0.357
Cars	0.664	0.810	0.905
Bikes	0.583	0.528	0.245

whereas relatively low concentrations of NO_2, H_2S and NH_3 were detected. Ammonia and H_2S range from 0 to 0.38 and 0.50 to 1.0 ppm, respectively. Concentration of NO_2 remained constant throughout the period of study. The result also indicates no significant variation in NH_3 and H_2S concentration during the course of this study for all locations. Concentrations were about the same levels for the morning, afternoon and evening periods. Traffic volume did not reflect so much in the levels of NH_3 and H_2S recorded on the different locations. Since SO_2 was generally not detected on the study area, this confirms that Directive 2003/17/EC on introduce modifications to maximum sulphur content in fuels has proved not only effective but also successful (WHO, 2005). The value of NO_2 less than 0.1 ppm at all locations is within the USEPA national ambient air quality standard of 0.1 ppm for hourly exposure rate (USEPA, 2011). These levels were far less than values of 66.5 to 70.5 ppm NO_2 reported around busy streets in the city center of Helsinki, Finland (Pirjola et al., 2012). The health challenges associated with high concentration of air pollutants are enormous. These results further underscore the immediate need to precisely characterize emissions of primary particles from the fugitive sources such as road and windblown dust. This information is essential in future efforts to reduce the levels of atmospheric pollutants.

Conclusion

This study helps strengthen the fact that road intersections usually account for high traffic density and invariably lead to much higher concentration of air pollutants. At such intersections particularly during peaks hours, cars remain the dominant source of air pollution. The Ojoo, University of Ibadan, Sango and Mokola intersections were mostly associated with high traffic volume and congestions. Concentration of CO was therefore associated with this high vehicular volume during morning and evening peak hours. The increasing severity and duration of traffic congestion have the potential to greatly

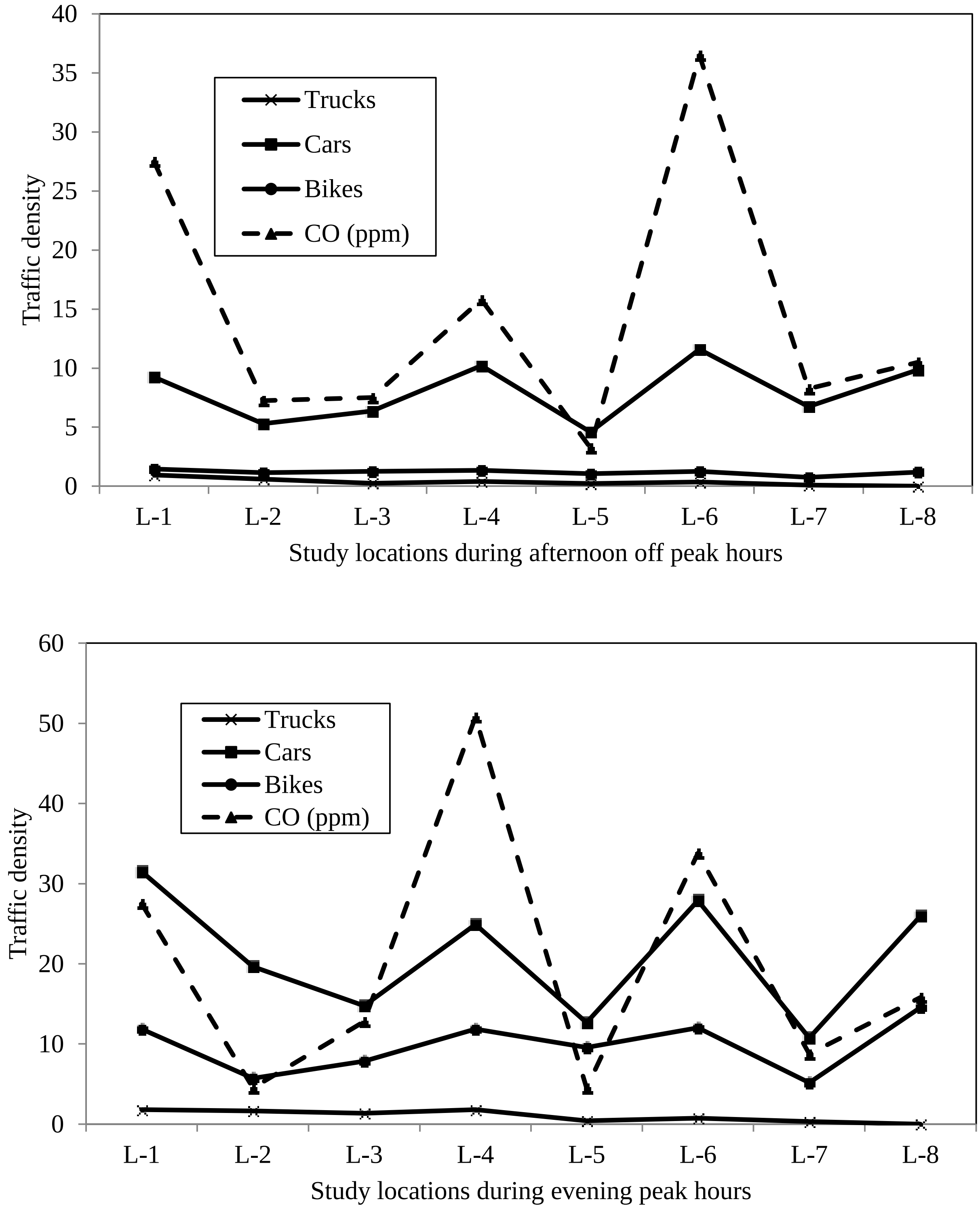

Figure 2. Relationships between traffic volumes ($x10^2$) and atmospheric CO (ppm) levels.

increase pollutant emissions and to degrade air quality, particularly near large roadways. This research, although confined to nodal traffic points on one important roadway suggest that major roads within Ibadan metropolis may not altogether be safe from traffic related pollution threats. Thus, there is the need for concerted efforts to reduce the threat in order to stem possible air pollution episodes in Ibadan. This can be achieved through legislative and economic measures.

Conflict of Interests

The author has not declared any conflict of interests.

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Full Length Research Paper

The determinants of squatter development in Southern Aba Region of Nigeria

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Squatter developments are settlements predominantly composed of makeshift structures, often constructed on cheap or vacant land. Squatter development in Southern Aba Region of Nigeria constitutes nonconventional housing, constructed by the urban poor- predominantly the rural migrants and migrants from the main city of Aba, Port-Harcourt and Uyo. This study examined the determinants of squatter development in Southern Aba region with the view to ascertaining the policy options for the renewal of the region. The study adopted survey design. Both primary and secondary data were collected with the aid of structured questionnaire, measurement and observation; and from the Abia State Ministry of housing and urban planning handbooks respectively. The sample size of 400 respondents was determined from the study population of 125,257 using the Taro Yamane model for sample size determination. Cluster and systematic random sampling techniques were used to proportionately select the settlements and respondents used in the study. The reliability of the questionnaire was determined using Cronbach's alpha which yielded a correlation co-efficient of 0.80. Data analysis was conducted with appropriate descriptive statistics using SPSS for Windows, Version 17. The study revealed the dynamics of certain factors that replicate squatter development in the study area, among which are: collapse of the agricultural economy of Abia state; weak institutional governance and low level of physical planning at the local government level; and ineffective land policies and the attendant difficulty in securing title to land. The study therefore recommends among other things, an urban renewal strategy based on attracting government institutions, agencies, and some projects outlined in the medium term expenditure framework of Abia state to the region; massive investment in agriculture; and the re-establishment of the local government system to ensure responsive governance and effective physical planning at the suburban areas.

Key words: Squatter development, determinants, slum.

INTRODUCTION

Squatter settlements have been defined by the United Nations Economic Commission for Europe [UNECE] (2009) as settlements established by people who have illegally occupied an area of land and built their houses

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on it, usually through self-help processes. Hartshorn (1992) also described squatter development as nonconventional housing, constructed by the urban poor-predominantly, the rural migrants, without government authorization and frequently, on lands they do not own. Bello (2009) observed that squatter developments usually spring up at urban fringes as a result of land speculators buying agricultural lands, and laying them out without provision for adequate roads and other basic infrastructures. He further stated that the common features of squatter developments include: low incomes; absence of occupational skills and qualifications; poor housing which is manifested by dilapidated state of the buildings; and garbage on the streets.

The research into the physical, socio-economic, and political forces that generate and sustain the formation of squatter settlements or slums is abundant. These include the works of UNCHS Habitat (1996), Kombe and Kreibich (1997), Durand-Lasserve (1996), Kombe and Kreibich (2000), Huchzermeyer (2002), Sietchiping (2005), Berner (2007) and Ahmed et al. (2012). These authors observed that because of their inherently “non-legal” status, squatter settlements have services and infrastructures below the minimum levels. According to Kombe and Kreibich (2000), squatters are predominantly migrants, either rural-urban or urban-urban, though many are also second or third generation squatters. Berner (2007) observed that the disparities created by the global economic system have resulted in wealth and livelihood opportunities being concentrated in nodal centres or cities which in turn become attractive to people who are struggling with livelihood. Inequalities in economic conditions between urban centres and rural areas have forced excess rural labour to migrate into the cities, seeking improved standards of living. While in the city, because they are unable to find decent accommodation, they take over vacant land on which slums are created (Berner, 2007).

In most African countries, squatter developments are common occurrences at the outskirts of major cities, being developed mostly by immigrants to cities from neighbouring villages, who lack financial capacities to rent decent accommodation (Ahmed et al., 2012). In 2012, the estimated population of 47 sub-Sahara African countries was 910.4million (World Bank, 2013) and of this, 167million were Nigerians (FRN-National Population Commission, 2013). Out of the 167million people in Nigeria, 61.1% (over 102.2 million) were said to reside in slums (Pepple, 2012). In Nigeria, the failure of government to respond to the housing needs of the poor has encouraged them to find their own way of putting up houses, and this has given rise to many squatter developments in cities (Fekade, 2000). Sietchiping (2000) observed that many squatter settlements in developing countries result mainly from socio-economic factors: high rent charges and high cost of land in the cities, high immigration rate, problems of landlessness, poverty and unemployment. Amadi (2004) has observed in Port Harcourt, Nigeria, that squatter settlements are the result of low level of education, poverty, unemployment, high dependency ratio, lack of social infrastructure, and low level of city planning by government. Squatter settlements and squalors have sprang up in and around the city of Abuja due to poor housing scheme, which made proper accommodation within the federal capital territory of Nigeria unaffordable for low income residents of the city who were mostly civil servants (Opeyemi et al., 2015). Magigi and Majani (2006) also identified institutional causes of squatter developments which include excessive bureaucracy in issuing development and building permits, and corruption of officials. Sietchiping’s (2005) framework on informal settlements attributes the growth of squatter settlements in urban areas of developing countries to four main factors which are physical, socio-economic, socio-cultural and institutional (rigidity of urban planning regulations). His study shows that squatter settlements flourish on marginal or less valuable urban lands such as river-banks, steep slopes, dumping grounds, abandoned and unexploited plots, and open spaces along transportation networks or near industrial areas and market places, and in low lying areas or wetlands.

Southern Aba region of Abia State is one of the biggest slums in Nigeria which has constantly experience rapid squatter development (Ogbonna, 2014). The rate at which squatter settlements are growing in the region has become worrisome as it has continued unabated despite several attempts, by the government of Abia State to checkmate the phenomenon. New make-shift apartments are being built on daily basis at the urban fringes of Southern Aba without title to land, and without planning approval. There appears to be a strong resilience by the residents of the squatter communities to government attempts at, stopping the proliferation of squatter developments. Over the years, such resiliencies have been exhibited through civil demonstrations, community uproar, and direct confrontations with, government agencies responsible for development control. Squatter developments have impacted negatively on the physical and socio-economic environment of Southern Aba. The region is presently being perceived to be “safe-heaven” for anti-social elements like kidnappers, armed robbers, drug peddlers, and area boys generally referred to in the area as “Agbero”. There is the general perception that crime rates in the city of Aba and Port-Harcourt have remained increasingly high because the perpetrators of such crimes come from the slums and squatter settlements in the Southern Aba region.

The preponderance of squatter development in Southern Aba region is arguably being attributed mainly to the poor socio-economic conditions of residents of the area. There appears to be a total neglect of the area by government in terms of provision of social infrastructure like schools, hospitals, markets, and low income housing. These coupled with high rate of unemployment, illiteracy, and dilapidated physical infrastructure has reduced the region to a poverty zone with a common name “Azuobodo” in local parlance, meaning the backyard of city.

Azuobodo as it were, has become the first point of call for a prospective immigrant to the city of Aba, and maybe, this encourages squatter developments in the area. The policies of various governments in Nigeria regarding squatter developments have usually been to demolish them, with either a shabby resettlement plan for the affected evictees or total abandonment thereafter (Mallo, Samuel, Esther, Choji, and Aliyu, 2015).

However, these scholars observed that such policies have had adverse ramifications all over the country, hence the need for this study which seeks to understand the dynamics that replicate squatter developments in Sothern Aba, with the view to ascertaining the policy options for the renewal of the region. The specific objectives were to review the physical and socio-economic conditions of Southern Aba region, and examine the dynamics of factors that replicate squatter development in the region.

THE STUDY AREA, SOUTHERN ABA REGION, NIGERIA

The study area is Southern Aba region of Abia State, Nigeria. The area is sandwiched between four local government territories: Aba-South, Ugwunagbor, Osisioma Ngwa and Obingwa Local government areas. Southern Aba is located approximately between latitudes 05° 01’ 30” and 05° 07’ 00”N of the equator and longitudes 07° 22’ 00” and 07° 26’ 00”E of the Greenwich meridian. The area lies within the tropical rain forest zone of West Africa. The districts that form part of Southern Aba Region are: Ngwa road, Omuma, Izuogu, Obohia, Ohanku, Ndiegoro, Urata, Ohabiam, Ihieoji, Umuosi and Owerri-Aba. Figure 1 is map of Abia State showing the study area, and the seventeen local government territories.

MATERIALS AND METHODS

The researchers adopted the survey research design. The population of study comprises of the residents of the eleven districts that make up Southern Aba, of which the number is 125,257. This population figure was gotten from the projection of the 2006 National Population Census (NPC) figures of 88,951 for the area, to 2016 using the Malthus Population Projection Model. The population growth rate for the area by NPC (2006) is 3.5%. The sample size of approximately 400 was estimated from the population using the model:

$$n = \left\{ \frac{N}{1+N(e)^2} \right\}$$

derived by Yamane (1967).

Cluster sampling technique was used to divide the region into four quadrants for purposes of fair representation, and equal numbers of questionnaires were administered in all the quadrants. Systematic random sampling method was then used to select the houses (street by street) where the survey instruments were administered to house hold heads in all the streets in each quadrant. The study was based on both primary and secondary data. The primary data was collected through field survey making use of structured questionnaire, direct measurement using measuring wheels, and observation. The secondary sources include books, journals and government publications from the Abia state ministry of lands and urban planning. Data collected was analyzed with appropriate descriptive statistics using SPSS for Windows, Version 17.

RESULTS AND DISCUSSION

Physical and socio-economic conditions of the residents of Southern Aba region

A total of 400 copies of questionnaires were administered while 364 were retrieved, which implied 91% success rate. Table 1 shows results of surveys on physical and socio-economic conditions of residents of Southern Aba region, and these have been summarized as follows. Majority of the squatters (over 70%) are male-family people whose average age fall between 30 to 50 years. About half of the population either did not go to school or managed to acquired basic education (up to secondary school level) while the rest have some tertiary education certificate, with those that obtained degree or higher certificates comprising about 19% of the total population. The rate of poverty in the area is very high, with about 60% of the residents earning less than N200, 000 ($1000) per annum, which translates to less than $3 per day. Those who may qualify as medium income earners in the area, who earn between N500, 000 to N1million ($2,500 to $5,000) per annum constitute only about 19%. Unemployment is also very high, with over 83% of the residents either unemployed or underemployed - being involved in some daily labour, petty trading or subsistent farming for survival. Findings also show that over 78% of the respondents have migrated into the area either from the inner city of Aba or neighbouring towns like Port-Harcourt, Owerri, Umuahia and Uyo. Four types of housing are predominant in the area: make-shift apartments; rooming (face-to-face) apartments; block of 2 or 3 bedroom flats; and detached/semi-detached bungalows. However, it is significant to note that about 50% of the respondents occupy rooming apartments, while about 23% occupy block of flats. Also significant is the fact that 17% of respondents live in make-shift

Figure 1. Map of Abia state showing southern Aba Region Source: Ministry of Lands and Urban Planning Abia State, Nigeria.

(temporary) structures. Results also show that majority of the residents are tenants, with the few that own houses (21.8%) being mostly the natives of the area. Rent regime for housing in Southern Aba is relatively low compared with Aba main city. For instance, a 3bedroom flat in the area costs between N120, 000 to N150, 000 ($600 to $750) per annum, whereas similar apartment in the Aba main city costs between N250, 000 to N350, 000 ($1,250 to $1,750). Over 74% of the residents of the area live in houses where they pay less than N50, 000 ($250) annually, with just less than 3% paying more than N150, 000 ($750) as annual rent.

The dynamics of factors that replicate squatter development in southern Aba

The survey revealed that the primary factors which

Table 1. Socio-economic and physical conditions of respondents.

	Sex	**Frequency***	**Percentage**		**Status**	**Frequency**	**Percentage**
A. Sex Distribution of respondents	Male	316	86.6	**B. Marital status of respondents**	Single	76	20.8
	Female	48	13.2		Married	270	74.0
					Divorce	7	1.9
	Total	**364**	**100**		Widowed	11	3.0
					Total	**364**	**100**
	Age	**Frequency**	**Percentage**		**Qualification**	**Frequency**	**Percentage**
C. Age category of respondents	18 - 30yr	38	10.4	**D. Academic qualification of respondents**	SSCE or below	169	46.3
	31 -40yr	205	56.2		ND	121	33.9
	41 - 50yr	94	25.8		HND or Degree	64	17.8
	51-60yr	27	7.4		Masters or PhD	9	2.5
	Total	**364**	**100**		**Total**	**363**	**100**
	Income Class	**Frequency**	**Percentage**		**Occupation**	**Frequency**	**Percentage**
E. Average yearly income of respondents (N)	Less than 60,000	65	17.8	**F. Occupation of respondents**	Daily labor/Craft/Farmer	205	56.2
	61,000 to 200,000	143	39.2		Trader/Business man	98	26.8
	201,000 to 500,000	69	18.9		Junior civil servant	21	5.8
	501,000 to 1000,000	70	19.2		Senior civil servant	34	9.3
	Above 1,000,000	17	4.7		Major entrepreneur	6	1.6
	Total	**364**	**100**		**Total**	**364**	**100**
	Type of House	**Frequency**	**Percentage**		**Rent category**	**Frequency**	**Percentage**
G. Type of house occupied by respondents	Make-shift	61	16.7	**H. Amount of annual rent paid by respondents**	Owner occupier	79	21.6
	Rooming	183	50.1		N20,000 or less	40	11.0
	Block of 2 or 3 b/d	82	22.5		N21,000 - N50,000	154	42.2
	Bungalow	35	9.6		N51,000 - N100,000	42	11.5

Table 1. Contd.

	Duplex	3	0.8		N101,000 - N150,000	39	10.7
	Total	**364**	**100**		Above N150,000	10	2.7
					Total	**363**	**100**
	Migratory Status	**Frequency**	**Percentage**		**Road condition**	**Frequency**	**Percentage**
	Native	77	21.1				
I. Migratory status of respondents	Immigrant	274	75.1		Tarred	2	3.7
				K. Road condition in Southern Aba	Un-tarred/gullied	34	63
	Total	**351**	**100**		Available Storm drain	0	0
					Always Flooded	18	33.3
					Total	**54**	**100**

Source: Researchers' survey, (2016) * Frequency.

initiate the growth of squatter development in the study area are socio-economic in nature, as presented in Table 2. Certain socio-economic deficiencies propel both developers and home seekers to go for squatter development in the Southern Aba region. Such factors include: prevalence of cheap land (mostly not serviced with access roads and other infrastructures) in the region, as against high cost of land and housing in Aba main city; influx of immigrant population with high demand for squatter apartments; high rate of unemployment among residents which translates to low income and poverty; less municipal taxes and levies such as business permit, sanitation levy, and infrastructure fees enforced in the area; and the fact that the area offer cheaper locations for starters of micro enterprises. Land is cheap and property value is very low in southern Aba because of very low level of infrastructure and social services development. The area offer a comfort zone for new immigrants to Aba due to the prevalence of low priced make-shift apartments, and majority of these immigrants are job seekers who commute daily to the Aba main city and Port-Harcourt in search of jobs.

Endemic poverty and choice of housing

Table 3 is a cross tabulation of average yearly income, and type of housing occupied by respondents. The results demonstrate that residents with lesser annual income occupy the worst types of housing. For instance out of 65 respondents who earn less than N60,000 annually, 42 live in make-shift apartments, 22 live in rooming apartments, and one person lives in block of flats. No respondent within this income group lives in either bungalow or duplex. All three respondents who indicated living in duplexes earn above N1million annually. The implication of this is that poverty is endemic in the region such that even if there is abundance of standard accommodation, more than 90% of the residents would also live in make-shift apartments because they cannot afford such quality of accommodation.

Gross deficiency in qualitative housing, and government housing policies

The surveyed revealed gross deficiency in qualitative housing in the region as illustrated in Figure 2. The class of housing that may be regarded as qualitative housing in the area are the bungalows and duplexes which constitute about 11% of the existing housing stock. The lack of

Table 2. Factors that initiate squatter development in Southern Aba region.

	Factors	Freq.*	%		Factors	Freq.	%
A. F**actors that encourage Landlords to build new squatter apartments**	Much housing demand (1)	15	4.1	**B. Factors that encourage renters to go for squatter apartments**	High cost of Land/House in City (1)	8	2.2
	Cheaper Housing/Land in Sothern Aba (2)	6	1.6		Unemployment (2)	6	1.6
	Inability of tenants to pay for good quality Housing (3)	3	0.8		Cheaper area to locate micro business (3)	9	2.5
	Cheaper building materials for temporary housing (4)	1	0.3		Less tax and Bills (4)	3	.8
	All of the above (5)	276	75.6		Social affinity to family (5)	6	1.6
	1 & 2	22	6.0		all of the above	93	25.5
	1,2 &3	37	10.1		1,2,3 &4	237	64.9
	1, 2, 3 &4	2	.5		**Total**	**362**	**100**
	Total	**362**	**100**				

qualitative housing in the region is as a result of marginalisation by the government in previous housing policies in Abia State. There has never been any direct government housing programme or intervention in the region in the past decades. On the contrary, the region has been a recipient of negative fallouts of housing policies implemented in Aba metropolis and Port-Harcourt city by way of urban sprawl and outward migration occasioned by such policies.

Unemployment and housing challenges

Table 4 displays cross tabulation of employment status and the type of housing occupied by respondents. The results indicate that the unemployed and underemployed persons patronize make-shift and rooming apartments, while respondents with good regular employment occupy more decent accommodation. Respondents who are involved in daily labour or petty trading are essentially unemployed migrants to the region, and they have migrated from the main cities where they could not sustain their accommodations. The result implies that squatter developments increase in direct proportion with rate of unemployment in the region.

Migration and socio-economic inequalities between the region and surrounding cities

The survey revealed high rate of migration to the Southern Aba region, mostly from Aba metropolis and Port-Harcourt. Figure 3 shows that migrants constitute about 78% while natives make up just about 21% of residents in the region. This trend is also a fallout of marginalisation and social inequality created by the rapid socio-economic development of Aba and Port-Harcourt at the total neglect of the Southern Aba region. The lopsided developments create protected zones for the middle and upper classes in those cities, whereas the poor are forced out of the cities by rising land and property values.

Title to land and land value in southern Aba region

Figure 4 shows that less than 18% of households in the region own land. Furthermore, less than half of those who own land actually have title to their lands, the rest own land by inheritance without having regularized ownership from government. This result suggests that squatter settlements are built by few landlords to make quick money which has been made possible by demand pressure from home seekers. Though land value is

Table 3. Cross tabulation of average yearly income and type of housing occupied by respondents

Variable		What type of house do you Occupy?					Total
		Make-shift	Rooming face-to-face	Block of 2 or 3 bedroom flat	Bungalow	Duplex	
Av. Yearly Income	less than 60,000	42	22	1	0	0	65
	61,000 to 200,000	15	120	8	0	0	143
	201,000 to 500,000	1	38	30	0	0	69
	501,000 to 1000,000	2	3	41	24	0	70
	Above N1,000,000	1	0	2	11	3	17
Total		61	183	82	35	3	364

Source: Researchers' survey, (2016).

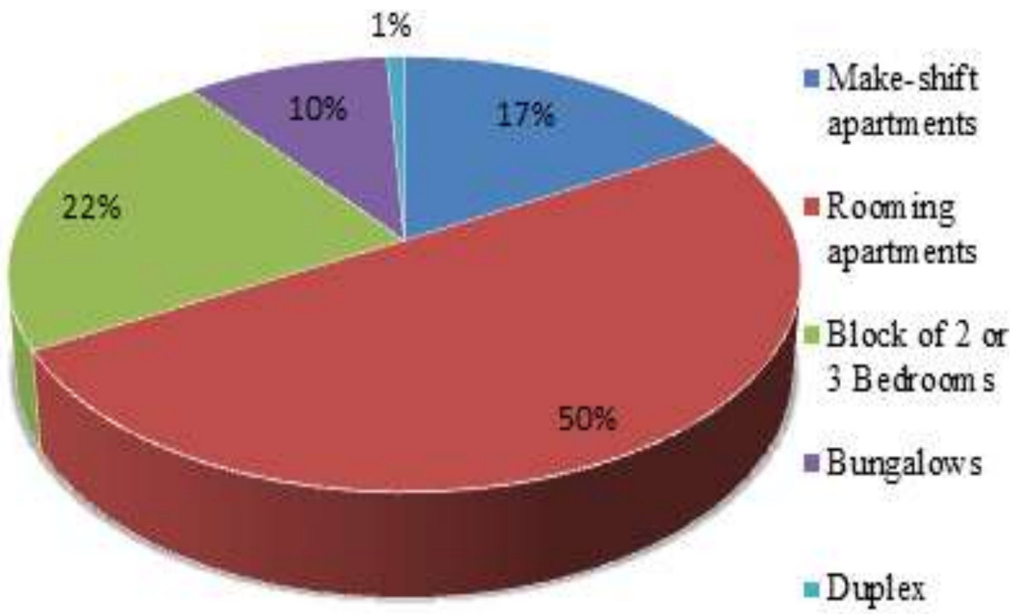

Figure 2. Existing housing stock in southern Aba.

comparatively very low, the land owners are reluctant to sell to prospective developers. Government land policies have been largely inconsistent, and entirely not implemented in Southern Aba. Nigeria, and Abia state in particular, still operates the long outdated Land Use Act of 1978, which has been a subject of much controversy, and also been seen to frustrate access to land by the poor. If it were possible and relatively cheaper for migrants to Southern Aba region to own land, most of them would build standard houses and maintain good environment even if it takes long to achieve.

Quality of infrastructure and direction of squatter development

The survey further revealed that parts of the region with better road and electricity have more standard housing and environment than those areas where the roads are bad and where there is no supply of electricity from the national grid. Table 5 shows that only Urrata and Ngwa road neighbourhoods which have comparatively fair quality of roads and electricity have above 10% of the housing stock being of standard quality, the rest have

Table 4. Cross tabulation of Employment Status and Type of housing occupied by respondents.

Variables		What type of house do you Occupy?					Total
		Make-shift	Rooming face-to-face	Block of 2 or 3 bedroom flat	Bungalow	Duplex	
What is your occupation/ employment status?	Daily labor/Craft/Farmer	53	125	22	5	0	205
	Trader/Business man	7	42	35	14	0	98
	Junior civil servant	0	13	6	1	1	21
	Senior civil servant	1	3	16	13	1	34
	Major entrepreneur	0	0	3	2	1	6
Total		**61**	**183**	**82**	**35**	**3**	**364**

Source: Researchers' survey, (2016).

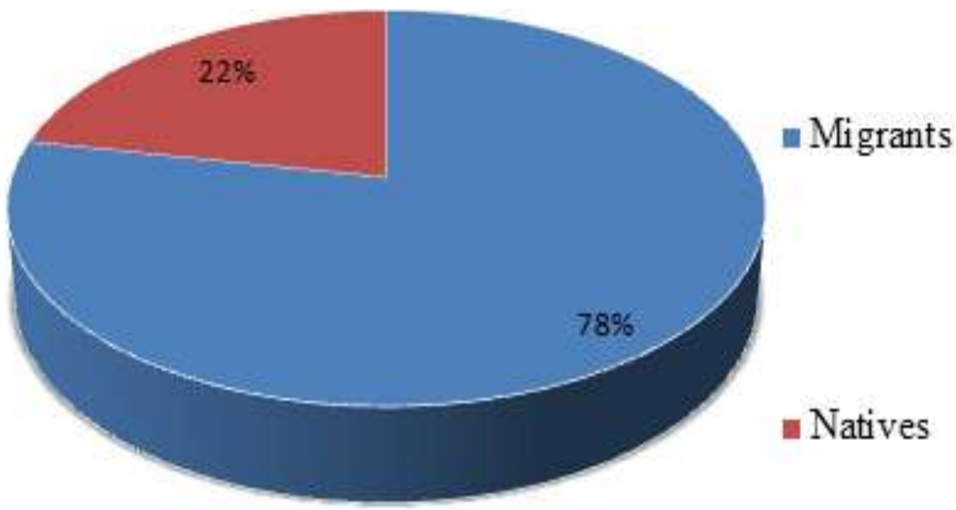

Figure 3. Rate of Migration to Southern Aba.

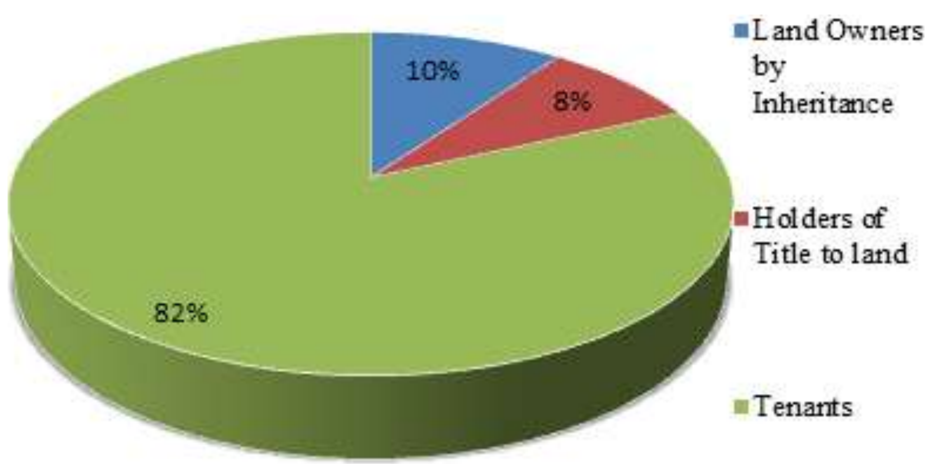

Figure 4. Title to Land in Southern Aba.

Table 5. Road /electricity quality and percentage of standard houses.

Neighbourhood	Road quality	Electricity	Percentage (%) of Standard Houses
Ngwa road	Tarred but gullied	Fair	14.3
Omuma	Tarred, gullied and flooded	Bad	8.5
Izuogu	Un-tarred, flooded	Fair	6.0
Obohia	Tarred, badly eroded, flooded	Very bad	3.4
Ohanku	Tarred, badly eroded, flooded	Very bad	2.5
Ndiegoro	Un-tarred, flooded	Very bad	0.6
Urrata	tarred	Good	18.1
Ohabiam	Un-tarred, flooded	Bad	5.0
Iheoji	Un-tarred	Very bad	4.5
Owerri-Aba	Un-tarred, flooded	Very bad	2.8

Source: Researchers' survey, (2016).

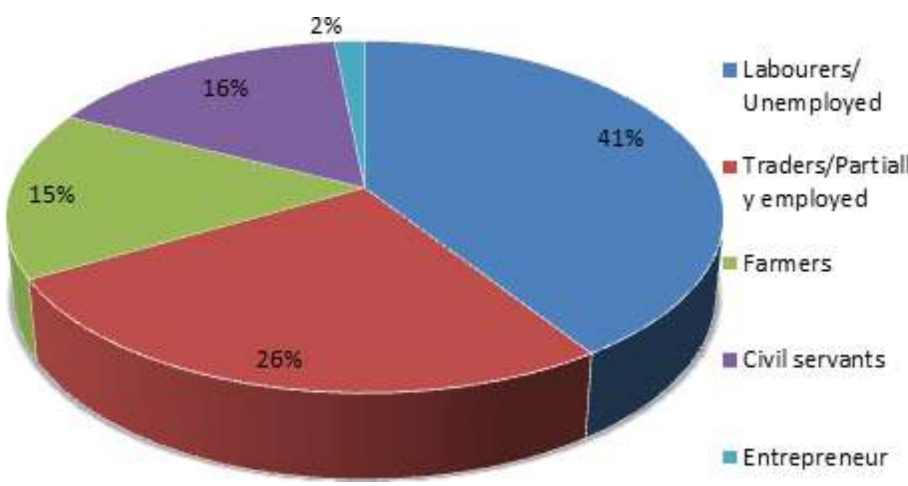

Figure 5. Employment Statistics in Southern Aba.

insignificant percentages of standard housing. This shows that the quality of municipal infrastructure plays out to determine the direction where squatter developments spread in the region.

Collapse of the agricultural economy and availability of cheap suburban land

National statistics shows that Southern Aba region had a population of about 18,655 by 1991 census, of which 85.6% were farmers, and 69.6% of the entire land use was agriculture. The 2006 census also showed that the region had a population of about 88, 951 with 48.5% being farmers. However, this study reveals (as illustrated in Figure 5) that with present projected population of about 125,257 for the region, only about 18.5% are involved in farming, with area of land devoted to agriculture being less than 40%. This however is a local reflection of the collapsed agricultural economy of Nigeria which was as a result of oil exploration and the attendant neglect of the sector. The implication of this result is that, as the residents abandoned agriculture, their lands became available, cheap, and vulnerable to urban encroachment, hence the rapid growth of squatter settlements in the region.

Destabilization of the local government system and weak development control

Results from the study (Table 6) show that: no government planned layout exists in the study area; 92.4% of the existing buildings do not have planning approval; more than 90% of the residents claim not having been served with enforcement order for planning

Table 6. Application of local government tools for land administration.

Local government tools for land administration	Yes responses	Percentage of total sample
Houses which have been built in approved government layouts	0	0
Houses with planning approval	27	7.4
Houses which have been served with town Planning enforcement notices	34	9.3
Houses which have been served with Environmental health demand notices	29	8.0
Houses which have been paying local government property/ sanitation fees	83	22.8

approval or demand notice for environmental health approval by either, town planning authorities or public health departments of the local governments. This is a reflection of inefficient public administration, lack of planning, and inadequate tools for land administration by the local government authorities. The failures of the local government system is however a constitutional issue since the beginning of the fourth republic in Nigeria in 1999, whereby state governments usurped the autonomy of the local government system – fallout of the application of “true federalism” as contained in the 1999 Nigerian constitution. This situation has given rise to conflicting actions regarding the informal settlement. Whereas the local government authorities which are responsible for planning and monitoring development in the area have been less concerned, the state government has continually demolished squatter houses in the region without alternative development for the demolished areas. These mechanics have played out to replicate squatter settlements in Southern Aba region.

Conclusion

This study examined the determinants of squatter development in Southern Aba Region of Abia State, Nigeria. The investigation revealed the interplay of certain factors which create the mechanics that replicate squatter development in the study area as follows:

i). Collapse of the agricultural economy of Abia State, which gave rise to abject poverty and availability of cheap suburban land for squatter development in Southern Aba.
ii) Weak institutional governance and low level of physical planning at the local government level occasioned by the destabilization of local government system by the state government.
iii). Marginalisation of Southern Aba resulting in socio-economic inequalities between the region and surrounding cities, which gave impetus to urban sprawl and influx of the urban poor to the region.
iv). Failure of state government housing policies, which gave give rise to deficiency of qualitative housing in the region.
v). Ineffective land policies and the attendant difficulty in securing title to land.
vi). Unemployment resulting in dismal poverty and inability to secure decent housing.
vii). Poor state of the physical and social infrastructures which influences the direction of spread of squatter development.

The study therefore recommends an urban renewal strategy for Southern Aba region, which should be based on attracting government institutions, agencies, and some projects outlined in the medium term expenditure framework of Abia state to the region, to achieve social integration and address the twin problems of unemployment and poverty. Some existing government institutions like the Abia Line Transportation Network limited; the Aba Ultra-modern Shopping Village; the College of Health Technology Aba; the Modern Ceramics Company Plc, and the proposed Abia Agro-Industrial Zone should be relocated to the region. The state government should utilize the advantage of abundant low-priced suburban land to invest massively in agriculture in the region, and use agriculture to create buffer zones that will serve to limit urban encroachment. In addition, Abia state government should locate the 2016/2017 Direct Federal Housing Project (DFHP) allocated to it in Southern Aba. This will attract massive federal presence in the region and revive the housing sector. Abia state should conduct local government elections and re-establish the local government system to ensure responsive governance and effective physical planning at the suburban areas. Finally, the government should adopt public-private partnership approach to collaborate with the squatters and slum residents, NGOs, and financial institutions to effect social integration, formulate and fund urban renewal plan for Southern Aba region.

Conflict of Interests

The authors have not declared any conflict of interests.

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