Strategy for sustainable human health and environment in petroleum-contaminated areas

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ABSTRACT

Anthropogenic and other activities associated with the petroleum industry have contaminated several sites. Amongst these sites are old pits, onshore release sites of hydrocarbons, and areas where oil slicks from offshore releases are blown onshore. In several instances, remediation is necessary for the restoration of the affected areas, even though, the complexity and intricacy of the pore structure and fluid transport pathways of soil are not easily susceptible to remediation. As a result of the complex distribution of contaminants in soil, it is pertinent to perform a comprehensive site assessment by taking into consideration the potential impact to the environment and human health before the selection and proper implementation of an optimum remediation process. Varied remediation processes are effective and efficient to clean up contaminated shorelines and other petroleum contaminated sites. There are significant variations of these processes and techniques for the effective and efficient removal of contaminants with respect to time and involved costs because most of the various remediation processes entail more or less expansive environmental hazards. This study makes provision to develop strategic approaches in operations in the petroleum industry for the management of biological diversity, plant, animal and human health, as well as food-chain linkage, air, soil and water. Also, it provides the public, researchers, policy makers, environmental scientists, engineers and consultants, health workers and legal practitioners the opportunity to harness and sustain the capacity to mitigate untoward impacts and generate avenues for an enabling ambit in inter alia health, environment and development in the petroleum industry.

KEYWORDS:

Environmental Impact Assessment, Remediation, Petroleum-Contaminated Sites, Environment, Health, Capacity Building

Introduction

Petroleum and its products as evidenced by the global petrochemical industry constitute an integral part of modern developed society. Petroleum is located in several sedimentary rocks. It is the by-product of organic matter decomposition at high temperatures spanning millions of years culminating in a complex mixture of solid, liquid and gaseous hydrocarbons. A vast majority of the world's energy, transportation, electrical utility, heating requirements, lubricants, solvents, highway surfacing, waterproofing, manufacturing of feed stocks, etc are derived from petroleum (Russell D et al 2009).

Petroleum consists of aliphatic and aromatic hydrocarbons, paraffins (aliphatic alkanes) and naphthalenes (cycloalkanes). The physicochemical properties of the chemical compounds are hydrophilic and amphipathic which make them readi;y dissolvable in water, whereas the lipophilic components bind to soil, aquatic sediments and edible crops. Petroleum contaminates soil and water with deleterious effects on vegetables (Zhang et al 2014). Thus, petroleum hydrocarbons releases are likely to permeate and contaminate environmental compartments. Due to the complex nature of petroleum releases and the potential impact of severe public health derangement by inhalation, ingestion and dermal contact grave risks are presented to society (Russell D et al 2009). Also, Heavy metals are major ubiquitous pollutants in the worldwide soil environment. In oilfields, the crude oil extraction process result in the concomitant contamination of the soil with petroleum and heavy metals. Researchers investigated the effects of oil extraction on the migration, speciation, and temporal distribution of heavy metals (Cu, Zn, Pb, Cd, Cr, Mn, Ni, V, and Mn) in soils of an oil region of Shengli Oilfield, China. It was detected that the most vital component of Cd is ion exchangeable and acid soluble; thus indicating that Cd is the most labile, available, and harmful heavy metal in comparison to other elements which damage the soil environment in oil-polluted soil (Fu et al 2014).

The relation between the environment and successful economic development is gaining global recognition. The realization of the significance of predicting environmental impacts of development gave birth to environmental impact assessment (EIA) which is basically concerned with the identification and assessment of the environmental effects of development projects, plans, programmes and policies in order that an appropriate choice selection from presenting alternatives be made (Chukwuma, 2011). EIAs have been mostly concerned with development projects, while a significant few have undergone implementation for land use and sectoral plans; and in particular, the domestic policies from which these development activities generated. Identification and assessment of environmental development impacts are intricate because of the variants of impacts which may be caused by anthropogenic activities as in the petroleum exploitation industry on environmental and social systems. To identify and assess these impacts necessitates collation of extensive data, and most significantly, presenting, communicating or articulating the findings to decision makers and the public, most of whom lack the knowledge of the technicalities entailed. In order to surmount certain problems related to EIAs, attention is given to the development of structured aids or approaches to assessment, oftentimes referred to as EIA methodologies or methods (Chukwuma, 1996a). Moreover, following the cessation of the petroleum industry or with an ongoing process after a short- or long-term, it is pertinent to undertake an environmental risk assessment (ERA) of the probable consequences on health and the environment. The combination of both EIA and ERA constitute generally what is termed environmental assessment (EA). These are necessary to ascertain the extent of contamination in sites resulting from the petroleum industry for correct remediation strategy.

An important challenge in the future regarding environment and development is learning how long-term, large-scale interactions can be appropriately managed for increased improvements in ecological sustainability in extant anthropogenic activities of the petroleum industry. The issue is to determine the long-term trends of environmental change which are capable of limiting the development of society, to configure usable knowledge and expertise regarding these limits and alternatives for obviating or abating them, to determine the scientific research, institution or technology needed in the immediate future to augment freedom of action for sustainable development (Chukwuma, 1996b; Chukwuma, 2011: Clark & Munn, 1986).

The importance of the strategy

Governments in non-industrialised countries are becoming increasingly informed of the adverse effects of environmental and natural resource degradation on long-term and short-term development potentials. On that score, they are more inclined to implement vital measures in which the environment and natural resources are taken into consideration in the petroleum exploitative industry. Available land is the main source of livelihood for a vast majority of the people in non-industrialised countries. They are directly dependent on land for the natural resources which generate their food, employment and shelter. Their well-being and welfare, in both the short- and long-term, are inextricably linked to the productivity of natural systems. Therefore, the socio-economic repercussions of environmental degradation are worse on the poor. It is clear that fruitful economic development is dependent on the prudent use of environmental resources and on abating the unfavourable impact of the exploitative petroleum industry. This can be accomplished by improvement in project selection, planning, design and implementation. The indirect and direct benefits and costs of proposed actions must therefore be assessed by economic analyses of alternative development projects. A broader perspective that takes into account a wide spectrum of benefits and costs (Chukwuma, 1996a) included in the proposed project activity as petroleum extraction will be called for in these analyses.

It is now being globally recognised that an ecological and environmental crisis of potentially catastrophic dimensions is extant. By pursuing economic growth as in the petroleum industry, the naturally available vital resources – air, forests, fuels, land, minerals and water – are undergoing rapid depletion, pollution and destruction. This is a critical situation that has left many concerned interests in doubt about the survival capability of humanity at the on-going production, exploitation and consumption of petroleum resources. The resultant effects of the petroleum industry are the presence of various types of pollution and environmental deterioration culminating in a decline in the quality of life of several habitats; and acutely excruciating deficits and increasing costs of numerous essential goods such as fish, forests, fuels and their products (Chukwuma, 1996a).

Nigeria exemplifies a country in the throes of environmental crisis, and may encounter problems associated with resource depletion, industrial, mining and petroleum pollution. In the near future, there will be complete depletion of our timber, petroleum and other mineral resources. With overfishing and marine pollution, fish stocks approach severe depletion, affecting present and future fishing incomes of fishermen and the nutritional intake and buying cost of the population. The impact of crude oil pollution in Nigeria's Niger Delta are inter alia depletion of crop and fish yields as well as soil sterilization (Ite et al 2013). In Nigeria, an excess of one million barrels of oil in eighteen significant oil spillages between 1970 and 1980 led to increased production and compensation costs. Attempts at cleanup and estimation of the toxicity of waste drilling fluids have sometimes been exasperating and frustrating (Ikporukpo, 1983). Microorganisms on drill mud currings obtained from the Agbara oil fields were isolated on mineral salts agar plates, but 27 of the 32 isolates did not grow on any of the drilling fluids (Nnubia & Okpokwasili, 1993). Also, the forest habitat that from an aerial view seems to obliterate much of southern Nigeria has actually undergone extensive alteration by anthropogenic activities such as the petroleum and mining industries both in relation to its fauna and flora (Chukwuma, 1996c).

How the issue of petroleum contaminated sites has affected health and environment

The diverse concepts which have been developed on an international scale, clearly depict how environmental issues are increasingly central to our health, well-being and welfare. The international community is concerned about several issues including the purity of our drinking water, clean air to breathe, and proper disposal of all kinds of wastes. There is a great realisation that the same purposeful petroleum, mining and chemical products are inimical to our health. There is an upsurge in awareness in the interrelatedness of environment and health. Environmental health issues and concepts have evolved rapidly in recent times, with impact of new technologies and advanced data acquisition as well as conceptual framework of public health risk assessment (Chukwuma, 2001).

It is pertinent that government, public and other stakeholders take anticipatory measures for environmental protection before the emergence of problems or their impacts are felt; also, environmental problems must not be viewed exclusively of the social, political, and economic patterns with which they are associated. Environmental and developmental problems from mining and petroleum industries must not be treated in isolation. The policy must require concurrent attention to the sources, channels, and multiple effects of pollutants. The sources are probably social conditions giving rise to specific polluting habits, such as demographic and sociocultural forces. The unanticipated untoward impacts of several large-scale development projects in the rural areas have given cause for concern (Chukwuma, 1996c). Economic planners and policy makers have to adopt new patterns of reasoning for the effective handling of the complex interplay of petroleum issues.

A study (Chukwuma, 1994) revealed that (a) human health was ranked as the highest in importance in Nigeria, followed by natural resources and living settlements, with environmental pollution shadowing them; (b) health and safety was found to be urgent as regards environment and development problems; (c) overpopulation, price supports/farm income for farmers in adverse agricultural conditions, structural adjustment programme (SAP) and sanitation all ranked in first place for possible improvement at the turn of the century, whereas solid waste disposal and rural Nigeria/poverty were presented with worse outcome; (d) a vast majority of respondents indicated that government actions in dealing with environmental problems before the creation of the Federal Environmental Protection Agency (FEPA) had not been adequate; (e) an urgency for governmental action, the economy (inflation/unemployment) ranked highest followed closely by social welfare (health, social security, education), law and order, environmental and energy problems; (f) 93% of the respondents perceived the need to periodically determine the probable health effects on fauna and flora before the inception of any industrial or mining activity; and (g) 93% of the respondents would oppose any industrial or mining activity in their area of residence that may be harmful to the environment even if it presents more jobs or is economically viable.

Another similar study (Dunlap, Dunlap & Gallup, 1993) with much greater financial endowments on an international comparative basis showed similar results as in Nigeria that (a) environmental issues are now salient; (b) environmental problems are of grave concern and rated poorly; and (c) the proportion of those selecting environmental protection over economic growth was higher in every nation except Nigeria.

Relevance of appropriate remediation technologies

The technology specific requirements for soil and groundwater treatment methods are gathering great momentum which encourage new and innovative remediation methods combined with adequate monitoring to validate the progress of remediation; and are inter alia (i) bioremediation that takes into cognisance addition of oxygen and nutrients in a controlled setting; (ii) soil vapour extraction (soil venting) that entails installing vertical or horizontal piping in petroleum-contaminated sites; (iii) air sparging involves installing a system that injects clean air below the groundwater table causing air to flow upward via the groundwater conveying volatile contaminants into unsaturated zone above the water table; (iv) aeration evaporates volatile components of petroleum from the soil into the air; (v) thermal desorption heats soil to elevated temperatures resulting in evaporation of certain hydrocarbons; (vi) landfilling is least preferred for wastes and may be used in the absence of other solutions; and (vii) groundwater pump and treat is feasible when groundwater is beneath a petroleum contaminated site. Hydrocarbons are, however, located in diverse petroleum-contaminated sites. Within these sites are onshore releases of hydrocarbons, wherein enormous amounts are trapped by capillary pressure as a discrete liquid phase within the pores of the soil. With the release of adequate amount or volume of hydrocarbons, it may be incorporated in a disparate, mobile phase that floats on the groundwater. Hydrocarbons also exist as a vapour in air-saturated pores.

It has also been determined that groundwater and soil contamination from light nonaqueous phase liquids (LNAPLs) spills and leakage in the petroleum industry currently constitutes a significant environmental concern in North America (Chen, Huang, Chan et al, 2003). In more than two decades several site remediation technologies, frequently classified as *ex situ* and *in situ* remediation techniques, have been developed and implemented for the cleanup of petroleum-contaminated sites. In recent years, the associated cost of operation using *ex situ* remediation has been expensive. *In situ* remediation techniques are currently in vogue due to operational costs. The selection process of the efficient and effective technique necessitates expansive knowledge and expertise, though. The resultant impact of inadequate expertise in the process is untoward augmentation of expenses. Petroleum waste management experts and Artificial Intelligence (AI) researchers co-operatively developed an expert system (ES) to manage petroleum contaminated sites by employing diverse AI techniques to construct an important tool for contaminated site remediation to assist in decision-making.

Other researchers (Huang, Huang, Chakma et al, 2007) have demonstrated that the remediation process is complicated with dual-phase vacuum extraction (DPVE), residual phase cleanup, and groundwater treatment. Individual system components are not able to effectively reflect interactions within diverse processes of contaminated fate and transport. Therefore, an integrated procedure that utilises transport, DPVE-aided remediation and contaminant transport is suggested to forecast both remediation process and contaminant amelioration at a petroleum-hydrocarbon contaminated site. A model incorporating a three-dimensional multiphase and multi-component subsurface is coupled with a DPVE numerical simulation remediation process. In western Canada, the developed simulation system is applied to a petroleum-contaminated site in an extant DPVE remediation. The developed system possesses an effective simulation effect of free-product recovery and groundwater cleanup via processes of DPVE and groundwater remediation.

Recommended assessment and remediation methodology

In the United States of America, The Petroleum Remediation, Superfund, and Brownfield Programs is geared towards an expansive electronic document management system (PRP 2014). The Petroleum Remediation Program (PRP) convened a Consultant's Day training event at the Continuing Education and Conference Center at the University of Minnesota in St. Paul. The PRP safeguards the environment and human health by investigating, evaluating, mitigating, or ameliorating the impacts of petroleum contamination on soil and ground water due to leakage or release from storage tank systems. The main concerns are those incidents which have resulted or may culminate to inimical situations resulting from petroleum vapours, impacted or may impact surface water quality. Thus, the main goal is to make steady provision of clean drinking water and air supplies, as well as prevention of hazards of explosive vapours.

Pathways linking sources of contamination to receptors are eliminated. Prompt response is mandatory where there are extant verifiable detectable affects of petroleum contaminants in drinking water, petroleum vapours in habitat spaces, or petroleum vapours leading to explosive potential in confined spaces. The requirement is free product recovery to a practicable magnitude. On the whole, the PRP undertakes a risk-based trajectory to corrective approach at petroleum release sites (PRP 2014). Where there are extant pathways connecting contaminant sources to receptors, risk removal actions may include replacement of the water supply wells or provide potable water from the municipality; long-run point-of-use treatment of contaminated groundwater; or active remediation of soil and groundwater contaminated by petroleum. However, water supply replacement is usually done as it provides the obvious manner of demarcating the pathway linkage between contaminant sources to receptors. In the event of low risks to receptors and contamination plumes are stable, contamination is encouraged to occur by time-dependent natural degradation.

These measures ensure investigations, cleanups, and prompt closures without compromising the mandate to protect the environment and human health. The PRP makes provision to coordinate with the appropriate or responsible partner and the Department of Commerce for prompt reimbursement of eligible expenses from the investigation and cleanup of petroleum releases (PRP 2014).

The process of site characterization is determinant of the expansiveness of the contamination and makes provision for the basis for a remediation strategy. It is essential to know the features of contaminants released at the site, such as phase partitioning, mobility and degradation to predict their behaviour in the subsurface and to make the optimum choice of corrective action technology; (ii) amount released to assist predict if the contaminant has reached the saturated zone; and (iii) duration since the release to predict the degradation, volatization, and flushing from infiltrating rainfall which may cause compositional alterations of contaminants over time. These changes known as weathering, may determine the strategy of sampling and the optimum choice of remediation technology.

For instance, a long-time release may not be amenable to utilise field observation and screening to fixate sampling locations. Samples need to be obtained and analysed (Correll, 2001) to characterize the contamination, plan and evaluate remedial procedures at a site. Adequate sampling is necessary for the determination of the type and extent of contamination and final cleanup status. All sampling activities must be carefully documented at the petroleum-contaminated site. The rationale of soil sampling is to give information required to decide if soil contamination is extant at unacceptable levels, and if that is the case, to define the expansiveness of the contamination and to make informed planning decisions as well as enhance full site check or site assessment.

These are, to wit: (i) study the features of soils, fauna and flora on the site under different climatic conditions; (ii) analyse and estimate the potentials of the plants for biomonitoring/bioindicating and revegetation/remediation, and phytoremediation (Ribeiro et al 2014); (iii) create a requirement to incorporate the economic and financial burden of remediation/revegetation at the cessation of the petroleum operations for site reclamation and soil detoxification; (iv) undertake baseline data evaluation of soils and plants to a reasonable distance to and including the densest population area of the incipient area of petroleum industry activity; (v) undertake data evaluative assessment of the petroleum-contaminated site (vii) encourage community participation in the assessment and remediation process by inter alia conducting a social evaluation survey of the environmental impact and public health risk assessments relative to other socioeconomic development projects necessary in the area; and (vii) take into consideration the geographical, ethnocultural, religious and landuse variations which cut across the sociocultural spectrum of the pluralistic society, such as Nigeria (Chukwuma, 1995) and the United States of America.

The statistical approach entails area-wide sampling of sites where product release has occurred in an expansive area and sites where product may have disseminated over a long distance, making it difficult to ascertain that all areas of contamination have been detected and accurately mapped. These sites may necessitate the use of either random or systematic method to determine where to take samples. A systematic approach involves utilisation of the map site, define the suspected area of contamination, minutely partitioning the area by placing an imaginary grid over it; and from each section of the grid, do a sample analysis. By means of a random approach (Correll, 2001), the contractor defines the area of interest and collects samples from locations in that area by random selection. The systematic approach is preferred to the random approach because it gives even coverage of the area. However, when the sampling approached is employed, statistical methods such as a statistical software package (MTCAStat) may be convenient to assist with the calculations.

Adequate guidance must be followed with excavated soils concerning the number of representative discrete grab samples to take from stock-piled soils using hand tools or appropriate field instruments or other approved techniques about 18 cm beneath the surface of the pile. The analytical methods are based on the substances released.

Benefits and responsibility in applying this strategy

This strategy makes provision for a basis for the development of approaches to the management of biological diversity, plant, animal and human health, as well as food-chain linkage, air, soil and water. It is intended to provide information required by owners, consultants, operators and government agencies to assess and clean up contaminated sites resulting from the petroleum industry due to spills, overfills or leaks, commonly observed from underground storage tanks (Cole, 1994) and associated piping. It also makes provision for information on reporting, sampling strategies, standards and regulations for cleanups, as well as to assist operators to conduct cleanup activities at petroleum-contaminated sites without direct supervision of the regulatory authorities. Whereby contaminated soil is in contact with groundwater, or the contamination reaches below the lowest sampling depth, it is necessary to obtain groundwater samples to test for extant contamination, with prompt removal of extant free product by the owners or operators. Owners and operators have direct responsibility to prevent petroleum hazardous materials from disseminating, to monitor and ameliorate fire and hazards due to vapours and free product, and to promptly mitigate the threat posed by exposure to contaminated soils.

The rationale for remediation of petroleum-contaminated soils given the budget size, site and regulatory requirements include (a) excavation and disposal of petroleum-contaminated soil;

and (b) excavation and beneficial-reuse of petroleum-contaminated soil (Cole, 1994). For an integrative assessment and remediation petroleum-contaminated sites as well as planning and management of petroleum activities, it is pertinent to inter alia perform site characterization, construction management, remediation design, and regulatory agency liaison. The process of site characterization is determinant of the expansiveness of the contamination and makes provision for the basis for a remediation strategy.

Consultation and public enlightenment

In the Nigerian petroleum industry, consultation and public enlightenment have often been reactive rather than proactive. Hence, it is pertinent to adopt strategies that are action-oriented and within the encompassing interest of the target groups. Inadequate effective and efficient consultation and public enlightenment have been the impediment of several government programmes that are intended to improve the well-being and welfare the of the citizenry (Report of the Special Committee, 2000). Relevant stakeholders are usually not involved at the conceptual stage of major policies. When efforts are made to inform and prevail on people to appreciate the inherent factors of certain adjustments, they were frequently peremptorily done. The resultant effect is that most Nigerians have, therefore, become indifferent in patronising to the insincere appeals which culminate in more sacrifices from them but fall short in the improvement of their welfare. Consultations with various stake holders to reach a common friendly understanding and consensus on issues pertaining too the oil industry as regards assessment and remediation of petroleum contaminated sites is necessary for a durable policy formulation and implementation.

The relevance of the oil industry to the economy and human well-being and welfare makes consultation, participation and creation of awareness among the people necessary to stimulate understanding and interest. Consultation and public enlightenment are essential in promoting understanding of the problems and challenges of petroleum contaminated sites and Government efforts to improve conditions in that sector.

Discussion

Environmental issues resulting from the petroleum extractive and exploitative industries are complex and diverse and result from different factors and situations. These call for a multidimensional approach to combat environmental perturbation with respect to the extant noxious factors, such as toxic chemicals and wastes from petroleum-contaminated sites. The continued success of certain environmental programmes in assessment and remediation of petroleum-contaminated sites in the developed parts of the world, and the continuing refinement of our environmental objectives in a contextually designed sustainable development, coupled with significant additional knowledge in environmental planning and management have all led to decision for a global concerted effort to maintain and sustain our environment for the health and safety of present and future generations. However, these objectives are not strongly undergirded in non-industrialized parts of the world; and are not entirely supported by the petroleum, mining and chemical industries, government, policy makers, politicians as well as other interests because they lack the will and dedication to realise that economics and environmental management as well as health, safety, welfare and well-being of both fauna and flora are inextricably linked (Chukwuma, 1998)

The quality of our environment and the effect of environmental agents on our health (Paustenbach, 1989) depend largely on the policies developed and adopted by the international community and governments. Global environmental problems pose a threat to human health (Paustenbach, 2002), well-being and welfare; but all the world’s countries which must act co-operatively to find measures to address such issues have their particular conceptual and diverse environmental challenges. Several concepts have been developed worldwide to show how environmental issues are increasingly central to our health (Chukwuma, 2001), well-being and welfare as regards development projects, extractive and exploitative mining and petroleum industries.

CONCLUSION

Crude oil, refined petroleum products and polycyclic hydrocarbons are commonly present in diverse environmental media. These are capable of bioaccumulation in food chains leading to the derangement of organismal biochemical or physiological activities which are depicted as carcinogenesis, mutagenesis, perturbation of reproductive capacity and haemorrhagic diathesis in at risk populations. The aetiology and of oil are quantifiable by means of biological ens-point parameters or biomarkers. Soil contamination due to spills constitutes a limiting factor to soil fertility. It is, therefore, pertinent to have measures to control petroleum hydrocarbon pollutant in the environment. The main strategy of oil spill bioremediation include bio-stimulation, nutrient application, bio-augmentation, adapted or competent seeding with hydrocarbonoclastic bacteria or combinations thereof, and genetic genetically-engineered microbes (Onwurah et al 2007).

As a result of the complex distribution of contaminants in soil, it is pertinent to perform a comprehensive site assessment by taking into consideration the potential impact to the environment and human health before the selection and proper implementation of an optimum remediation process. Varied remediation processes are effective and efficient to clean up contaminated shorelines and other petroleum contaminated sites. There are significant variations of these processes and techniques for the effective and efficient removal of contaminants with respect to time and involved costs because most of the various remediation processes entail more or less expansive environmental hazards.

For complete remediation/cleanup, on-site treatment is encouraged so that it does not cause a threat to the environment or to health from release of heavy petroleum fumes, contaminated run-off or airborne contaminated soil. The main health and safety modalities for temporary treatment facilities include site safety plans, site monitoring and personnel training. The extent (both vertical and horizontal) of the contamination must be clearly defined. This must be conducted during initial characterization and during treatment. The objective of the sampling is to evaluate treatment progress, perform air monitoring, soil and groundwater sampling as needed, and determine the extent of the cleanup. Following complete maintenance by frequent and regular checks, the treated soil or/and water must be characterized and contaminated soils/water transported to obviate inter alia threat to health and the environment.

What will actually be needed at present and in the foreseeable future include: (a) orientating and promoting financing for renewable energy sources and energy efficiency; (b) rapid and clean petroleum and mining activities (Chukwuma, 1993); (c) environmentally sustainable petroleum industrial activities; and (d) improved management of fisheries, tropical forests and other renewable and non-renewable resources. The main focus of the strategy is poverty alleviation with an improved predictive understanding of the integrated area, including human interactions, making provision of direct benefits by anticipating impacts of the petroleum industry on agriculture, resource utilization, commerce, energy and human safety. It, therefore, implies that environment and development improvements are achievable in societies with extant petroleum and chemical industries, if social, political, economic and technical resources are mobilized in non-industrialised countries (Chukwuma, 1996b). Planners, decision makers and citizens must be sensitized to problems and subsequent solutions of petroleum-contaminated sites. Assessment and remediation of petroleum-contaminated soils is necessary for an adequate planning and management of oil operations. This study considers these aspects as they fit into the local, ecological, sociological and economic environment of oil producing areas and storage sites of the petroleum industry.

References

1. *Chen Z, Huang GH, Chan CW et al (2003). Development of an expert system for the remediation of petroleum-contaminated sites. Environmental Modelling & Assessment 8(4):323-334.*
2. *Chukwuma, Sr C. (1993). The impacts of mining operations in Nigeria, with particular reference to the Enyigba-Abakaliki area. Env. Edu. & Info., 12(4):321-336.*
3. *Chukwuma, Sr C. (1994). Environment and development: a social evaluation survey in Nigeria in 1992. Env. Edu. & Inf. 13(2):183-208.*
4. *Chukwuma, Sr C. (1995). Integrative procedure for environmental impact assessment, planning and management of non-ferrous metal mining operations in Nigeria. Academic Dissertation, Faculty of Agriculture & Forestry, Dept of Limnology & Environmental Protection, University of Helsinki, Helsinki, Finland, University of Helsinki*
5. *Chukwuma, Sr C. (1996a). Environmental impact assessment of development projects and natural resources – a viewpoint. Intern J Environ. Studies, 50, 187-200.*
6. *Chukwuma, Sr C. (1996b). Perspectives for a sustainable society. Environmental Management and Health, 7(5):6-20.*
7. *Chukwuma, Sr C. (1996c). Defining environmental management and planning policy in Nigeria. IAAMRH Journal, 20(1):13-15.*

8. Chukwuma, Sr C. (1998). Environmental issues and our chemical world – the need for a multidimensional approach in environmental safety, health and management. Environmental Management and Health 9(3):136-143.

9. Chukwuma, Sr C. (2001). Environmental health concepts and issues – A viewpoint. Intern. J. Environ. Studies 58:631-644.

10. Chukwuma Sr C (2011). Environmental impact assessment, land degradation and remediation in Nigeria: current problems and implications for future global change in agricultural and mining areas. The International Journal of Sustainable Development and World Ecology, 18:36-41

11. Clark WC & Munn RE (1986). Sustainable Development of the Biosphere. Cambridge University Press, 491pp.

12. Cole GM (1994). Assessment and Remediation of Petroleum Contaminated Sites. CRC Press Inc., 384pp

13. Correll RL (2001). The use of composite sampling in contaminated sites – a case study. Environmental & Ecological Statistics 8(3):185-200.

14. Dunlap RE, Gallup Jr, GH & Gallup AM (1993). Of global concern – results of the health of the planet survey. Environment 35(9):7-15, 33-39.

15. Fu X, Cui Z, Zang G (2014). Migration, speciation and distribution of heavy metals in an oil-polluted soil affected by crude oil extraction processes. Environ Sci Process Impacts. 16(7):1737-44

16. Huang YF, Huang GH, Chakma A, et al (2007). Remediation of petroleum-contaminated sites through simulation of a DPVE-aided cleanup process: Part 1. Model Development. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 29(4):347-365.

17. Ikporukpo, CO (1983). Environmental deterioration and public policy in Nigeria. Applied Geography, 3:303-316.

18. Ite AE, Ibok UJ, Ite MU, Petters SW (2013). Petroleum Exploration and Production: Past and Present Environmental Issues in the Nigeria's Niger Delta. American Journal of Environmental Protection, 2013 1 (4), pp 78-90.

19. Nnubia, C & Okpokwasili, GC (1993). The microbiology of drill mud currings from a new offshore oilfield in Nigeria. Environ. Pollut. 83:153.

20. Omwurah INE, Ogugua VN, Onyike NB et al (2007). Crude oil spills in the environment, effects and some innovative clean-up technologies. Int J Env Res 1(4):307-320.

21. Paustenbach, DJ (ed) (1989). The Risk Assessment of Environmental and Human Health Hazards: A Textbook of Case Studies. Wiley-Interscience, 1184pp.

22. Paustenbach, DJ (2002. human and Ecological Risk Assessment: Theory and Practice. Wiley-Interscience, 1592pp.

23. PRP (2014). Petroleum Remediation Program – Minnesota Pollution Control Agency (2014). http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/cleanup/petroleum-remediation-program/index.htm

24. Report of the Special Committee on the Review of Petroleum Products Supply and Distribution (October 2000); Federal Republic of Nigeria Press, Abuja, pp112.

25. Ribeiro H, Mucha AP, Almeida CM, Bordalo AA (2014). Potential of phytoremediation for the removal of petroleum hydrocarbons in contaminated salt marsh sediments. J Environ Manage. 1, 137:10-15.

26. Russell D, Jones AP, Davies PG et al (2009).Petroleum hydrocarbons, JP-8 spillage, environmental contamination, community exposure and multi-agency response. JEHR 9(1). http://www.cieh.org/jehr/fuel_spillage_contamination.html

27. Zhang J, Fan SK, Yang JC et al (2014) Petroleum contamination of soil and water, and their effects on vegetables by statistically analyzing entire data set.. Sci Total Environ;476-477:258-65.