ASEAN Journal for Science and Engineering in Materials 2(1) (2023) 1-8

ASEAN Journal for Science and Engineering in Materials

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajsem

Metabolic Disequilibrium: A Review in the Indication of Soil Ecosystem Insulted with Xenobiotics

M. M. Ebulue

Pollution Control Unit; Department of Biotechnology, Federal University of Technology, Owerri, Imo State, Nigeria

Correspondence: E-mail: ebuluemm801f@yahoo.com

ABSTRACTS

The establishment of metabolic equilibrium in the soil ecosystem the following insolation is a prerogative of soil communities. These communities comprise microorganisms of diverse species and populations. The hydrocarbon-degrading communities (i.e., hydocarbonclastics) are found in petroleum or crude oil, polluting soil ecosystems. Others, the non-petroleum degrading microbial communities are diverse in nature and occur in soil, water, and air ecosystems. In the event of oil pollution with inherent disequilibrium in the ecosystem, the prejudicial nature of the petroleum will reduce the biomass of the non-hydrocarbon degrading organisms. Consequently, there will be an insurgence of the hydrocarbon degraders to metabolize the xenobiotics and bring the affected ecosystem to a balance and equilibrium. This is the hallmark of the entire ecosystem function. For other non-petroleum degraders in an ecosystem insolted with xenobiotics except petroleum, they will consolidate in their degradative activity to bring the affected ecosystem to a balance and equilibrium. Overall, the insolation of an ecosystem with any xenobiotics results in a disequilibrium, in which the indigenous microbial communities through their metabolic activities will bring the affected ecosystem to a balance and equilibrium.

ARTICLE INFO

Article History:
Submitted/Received 21 Feb 2022
First revised 20 Mar 2022
Accepted 03 Apr 2022
First available online 05 Apr 2022
Publication date 01 Mar 2023

Keyword:
Metabolic,
Soil ecosystem,
Xenobiotics.

1. INTRODUCTION

Assessment of the level of contaminations from the possible impact of xenobiotics on the soil ecosystem is imperative for the determination of environmental acceptability (Ebulue, 2021). Attainment of metabolic equilibrium is a necessity of nature. Maintenance of ecological equilibrium is a necessity of every natural ecosystem. Any biological disequilibrium as a result of the impact of hydrocarbon from crude oil or any xenobiotics will provoke the insurgence of indigenous microbial communities to biodegrade the foreign compounds and bring the ecosystem to a balance and equilibrium. This is the hallmark of the entire ecosystem function (Ebulue, 2022).

The science of ecotoxicology has revealed that the effects of pollutants in natural ecosystems are diverse, complex, and often unpredictable. Dissatisfaction is gradually increasing due to the lack of enough standard ecotoxicological tests and the realization that extrapolation from laboratory findings to real-world situations is often not feasible. This situation has spurred efforts into finding more ecologically relevant methods to assess the effects of pollutants in marine and terrestrial environments. For an assessment to be useful in ecotoxicological decision-making, the fate of the pollutant must be related to the effects to which they give rise.

A key problem in ecotoxicology is that many of the terms used are ambiguous. Therefore, the terminology used here will be defined. A group of experts in ecotoxicological studies known as ''Group of Experts on the Scientific Aspects of Marine Pollution'' (GESAMP) 1990 defined pollution as any increase in the concentration of matter or energy introduced by man directly or indirectly, into the marine or terrestrial environment (including estuaries) that causes harm or deleterious effects to living communities, or its abiotic environment. A contaminant is a substance that can be detected in an ecosystem above its background concentration, but which has not been demonstrated to cause harm or deleterious effects.

Some ecologists, when discussing the adverse effects of pollutants usually consider the accumulation of pollutant residues in the tissues of organisms as adverse. Others consider physiological processes that could lead to injury only if changes occur in organisms, such as alterations in cellular morphology, metabolic activity, biomass, or physiological rates (Sanders *et al.,* 1991). Ecologists might restrict this definition still further to only those pollutant-induced effects that give rise to ecologically significant changes, i.e., those at the population level. The other effects mentioned are also important since they represent stages in the progression of ecological adaptation.

Pollutants' effects can be detected at several different levels of biological organization, ranging from the level of the whole ecosystem to that of the sub-cellular and molecular. Before selecting methods to detect specific changes, the level of organization (individuals, a population, a community, or an ecosystem) for study must be clearly defined. For instance, detecting changes at the molecular level in one tissue may have little significance for the health and survival of the entire individual. Similarly, alteration at the level of individuals is unlikely to be evident at population or community levels (Moriarty, 1983). Assessments maybe conducted at any location and at any moment in time and maybe repeated periodically to detect insidious changes apparent only as trends over time. Such an approach could be a veritable tool for estimating future changes from proposed introductions of new chemicals into the environment.

The most difficult issue to address is when an effect can be characterized as truly adverse. This matter will be addressed wholesomely as the focus is on the detection and quantification

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

of biological changes induced by pollutant exposure and whether the effects caused by pollutants are of sufficient impact to warrant remedial action.

The most ecologically relevant measurements in the assessment of ecotoxicity are those that describe changes in ecosystem structure and function. However, such measurements are often difficult and time-consuming to make and are sometimes predictive. Tool (1988) postulated that pollutants that do not exert a selection pressure cannot cause any significant biological effects on an ecosystem, since these substances are unable either to restructure communities or to change the genotypic distribution in the populations. A lot of pathological changes and biochemical markers have been identified that signal exposure to pollutants at the cellular and molecular levels. Therefore, of great significance is this study in creating awareness of the toxic effect of insolation of discharged on the soil ecosystem.

2. METHODS

This study was a systematic literature review for explaining metabolic disequilibrium and indication of soil ecosystem insolted with xenobiotics.

3. RESULTS AND DISCUSSION

3.1. General Strategies of Assessment of Pollution

The effects of pollutants (oily waste) can be detected at several different levels of biological organization, ranging from the level of the whole ecosystem to that of the sub-cellular and molecular. Before selecting methods to detect specific changes in individuals, a population, a community, or an ecosystem for study, must be clearly defined (Moriarty, 1983). Assessments may be conducted at any location and at any moment in time and maybe repeated periodically to detect insidious changes apparent only as trends over time. Such an approach may help to evaluate the future changes from proposed introductions of new chemicals such as hydrocarbons from oil into the environment. The most difficult issue to address is when can an effect be characterized as truly adverse, rather than detection and quantification of biological changes induced by pollutant exposure.

The most ecologically relevant measurements to assess ecotoxicity are those that describe changes in ecosystem structure and function. However, such measurements are often difficult and time-consuming to make and are seldom predictive. Thus, by the time a significant change can be measured, for example, in nutrient cycling, the ecosystem may have been severely damaged already. Tool (1988) postulated that pollutants that do not exert a selection pressure cannot cause any significant biological effects on an ecosystem, since these substances are unable either to restructure communities or to change the genotypic distribution in the populations. At the cellular and molecular levels, numerous pathological changes and biochemical markers have been identified that signal exposure to pollutants. Relationships between particular pollutants at known concentrations and pathological or biochemical responses to which they give rise have been established.

3.2. The Fate of Contaminants in Soils

Once contaminants are in soils, they are never static, their dynamics within the ecosystem, (i.e., where they go and how quickly) they travel are a function of several factors. Some organic (carbon-based) contaminants can undergo chemical transformations and degrade into products that may be more or less toxic than the original compound. Note that chemical elements (such as metals) cannot break down, but their characteristics may change so that they can be more or less easily taken up by plants or animals. Different contaminants vary in

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

their tendency to leach to groundwater, volatilize into the air, or bind tightly to the soil particles. The characteristics of the soil also affect the fate of contaminants and whether they can be readily taken up by plants or animals. Site management and land use (such as gardening practices) can affect some soil characteristics. Important soil characteristics that may affect the behavior of contaminants include soil mineralogy and clay content (soil texture), pH (acidity/ alkalinity) of the soil, amount of organic matter in the soil, moisture levels, temperature, and presence of other chemicals.

3.3. Are contaminants Biologically Available?

Bioavailability is the amount of substance that is physio-chemically accessible to microorganisms. The bioavailable portion is the amount of a substance that can cause direct effects on living communities, which could be plants, animals, or humans because it can be taken up by their bodies. Usually, not all contaminants found in soil are biologically available. Soil characteristics are a major dependent on the bioavailability of a contaminant. Site conditions affect how tightly the contaminant is held by soil particles and its solubility (how much of it will dissolve in water). Greater solubility usually implies that more of the contaminants are bioavailable, but this also means that the contaminant tends to leachability. Certain chemicals show an "aging effect" and can become less bioavailable the longer they remain in soils. The bioavailable portion may be only a small fraction of the total amount. Changes in site conditions, such as soil acidity or organic matter content, can change the bioavailability of a contaminant.

3.4. Possible Xenobiotics on Soil

There are several sources for the possible xenobiotics on soil:

(i) Lead paint. Lead is a chemical used in making paints for houses and cars. When used on houses and cars, as it ages it peels off and the soil is the primary recipient. However, over time, it leached to groundwater.

(ii) Pesticides. Pesticides are chemicals used on farms. These include chemicals used as insecticides, herbicides, fungicides, rodent poisons, and some other kinds of poisons that thereafter find their way into the soil.

(iii) Industrial / commercial site use. Industrial effluents, wastes, and other discharges find their way into drainages, which finally sink into streams and rivers. Other discharges could be on soil or in the air and pollute the ecosystems.

(iv) High traffic areas. Traffic effluents from busy roadways such as polyaromatic hydrocarbons (PAHs) are chemicals associated with the incomplete combustion of fossil fuel. The levels of PAHs and some other chemicals may also be higher concerning the traffic density of the areas compared to other areas. These make their entry partly into the soil and into the leaves and roots of plants where they hyper-accumulate.

(v) Petroleum spills. Petroleum leaks or spills from gas stations, fuel tanks, or other activities can lead to elevated levels of contaminants such as benzene, toluene, ethylbenzene, and xylene (BTEX) in the soil. Some of these chemicals (especially volatiles) are unlikely to remain in the surface soil where they would be taken up by plants or be in direct contact with humans.

(vi) Furniture refinishing. Effluents from furniture refinishing chemical constituents such as methylene chloride and other solvents, including toluene and methanol used in furniture spraying could contaminate the soil and over time finds their way into groundwater.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

(vii) Fertilizers. The use of some fertilizers can be a source of introduction of heavy metals such as (copper, zinc, cadmium, and lead) into the soils. Products made from cement kiln dust may also contain heavy metals and dioxins. It has been established that the use of animal manure or chemical fertilizers are likely sources of augmenting some soil contaminants. For instance, phosphate fertilizers are known to contain some cadmium (from rock phosphate), and manures are sometimes relatively high in copper or zinc.

3.5. Effect of Petroleum Hydrocarbon Contaminants on the Environment

The consequences of hydrocarbon from an oil spill into the environment and detail of the potential biological damage is a function of the ecosystem where the spillage occurred. The aquatic ecosystem, particularly the marines are the most vulnerable, and this spillage into the marine environment may affect organisms therein by direct toxicity or by physical smothering. Oil spill generally, is likely to cause various damages to the marsh vegetations, and it was found to retard growth, photosynthetic rate, stem height, density, and above-ground biomass of *Spartina alterniflora* and *S. Patens* and may cause their death. In the marine ecosystem, crude oil spill forms a surface slick whose components can follow many pathways. Evidence has shown that some of the spills may pass into the mass of seawater and accounts for persistence for a long time before their degradation by microorganisms in the water. The slick usually becomes more viscous and forms a water-in-oil emulsion.

Oil in water causes depletion of dissolved oxygen due to transformation of the organic component into inorganic compounds, loss of biodiversity through a decrease in amphipod population which is important in the food chain, and eutrophication. In mammals, it possesses an anticoagulant potency (Onwurah, 2002). It was estimated that many seabirds even in thousands were killed as a result of spilled oil in the sea (Dunnet, 1982). Dying mangrove trees, tarred beaches, and declining fish catches, all seem to be threats to the long-term viability of some ecosystems such as the Niger Delta areas of Nigeria. Apart from the inherent toxicity of spilled oil in seas, enhanced toxicity has been reported due to ultraviolet (UV) radiation. This is referred to as photo-enhanced toxicity (Barron *et al*., 2003).

Generally, oil (crude or spent) is toxic to aquatic organisms, due to the presence of polyaromatic hydrocarbons (PAH) (Heintz *et al*., 1999) which can disrupt the development of immunity, and reproduction, growth, and survival of aquatic organisms. Environmental pollution from oil spillage could lead to an increase in exposure of by-products of PAHs to humans. The consequence is an increased risk of mortality from infectious disease (Hall *et al.*, 2006) and the reproductive capacity of the human population (Tiido *et al.*, 2006).

On land, assessment of oil spills whether crude or spent oil has shown to be of great negative effect on food production. For instance, a good percentage of oil spills in Nigeria on dry land between 1978 and 1979 affected farmlands in which crops such as rice, maize, yams, cassava, and plantain were grown (Onyefulu and Awobajo, 1979). Oil affects the germination and growth of some plants (Onwurah, 1999). It also affects soil fertility but the scale of impact depends on the quantity and type of oil spilled. A severe crude oil spill in Cross-River State, Nigeria, has forced some farmers to migrate out of their traditional homes, especially those that depend solely on agriculture. This is because petroleum hydrocarbon 'sterilizes the soil and its prejudicial nature prevents crop growth and yield for a long period. Spent oil contamination of land affects certain soil parameters such as the mineral and organic matter content, the cation exchange capacity (CEC), redox properties, and pH value. As oil creates an anaerobic condition in the soil, coupled with waterlogging and acidic metabolites, the result is a high accumulation of aluminum and manganese ions. These phytotoxic elements are often taken up by root crops and other plants with a consequent reduction in agricultural productivity and the death of the affected plants. That is why the oil-spilled forest looks like a burnt bush.

3.6. Assessing Pollutant's Effects at the Ecosystem Level

The effects of chemical stressors such as hydrocarbons from oily waste are manifested initially as a loss of sensitive species and changes in the relative abundance of rapidly reproducing ones that will degrade the xenobiotic. Numerous authors have attempted to find indices of overall ecosystem health, such as the rate of photosynthesis, the photosynthesis-respiration ratio, the activity of electron transport systems, enzyme induction, physicochemical parameters, total microbial counts, and total petroleum hydrocarbon. Critical reviews of the concept of ecosystem health have recently been issued by Calow (1992) and Rapport (1992). A key problem with this approach is that little attention has been paid to relating changes in ecosystem health to particular degrees or types of pollution. Babich *et al.* (1983) attempted to overcome this limitation by suggesting the establishment of dose-response relationships for ecosystems in which a pollutant that causes a 50 percent or a 10 percent reduction in an ecosystem process is determined (EcD_{50} or EcD_{10}) respectively.

3.7. Response of Crude Oil Insolt by Soil Communities

The environmental impact of petroleum exploration in Nigeria and other oil-producing countries has been on the increase. Oil spills are destructive to both vegetations and lives in the soil, not only because of their contact toxicity but also because the hydrocarbons in the soil create oxygen tension and increase anaerobiosis which is prejudicial to plant roots.

In a disturbed soil equilibrium following an insult from petroleum hydrocarbons, microbial communities are initially affected adversely; the non-hydrocarbon degraders would be exterminated due to the prejudicial nature of the insult. Thus, there is a limitation in microbial diversity. Thereafter, there is an insurgence of hydrocarbon-degrading microorganisms, the hydrocarbonclastics. This is because petroleum contains a wide range of organic compounds that are nutrients for microorganisms. The degradation of petroleum hydrocarbons is primarily an oxidation process, although there is evidence of anaerobic degradation (Gutnick & Rosenberg, 1979).

Microbial petroleum hydrocarbon degraders share two distinct characteristics:

(i) they possess unique compounds that assist in the emulsification and transport of hydrocarbons into their cells, and

(ii) they possess inducer specificity features.

Exposure of microbes to petroleum hydrocarbons (PHCs) activates the two systems mentioned. On exposure, these microbes, *Pseudomonas aeruginosa, Bacillus subtillis,* and *Micrococcus varians* devise metabolic diversity with increased catabolic properties primarily aimed at biodegrading the xenobiotic; thus, making them hydrocarbonclastic organisms (Ekpo & Udofia, 2008).

The following hydrocarbonclastic microorganisms in the descending order of their biodegradation potentials based on the frequency of isolation from the oil impacted soil are *Pseudomonas aeruginosa, Arthrobacter*, *Alealigena*, *Corynebacter*, *Flavobacterium*, *Archromobacter*, *Micrococcus*, *Norcardia, and Mycobacterium*. The disequilibrium occasion from the insult is normalized by the consolidation of hydrocarbon degraders, the hydrocarbonclastics.

4. CONCLUSION

In a disturbed ecological soil equilibrium, following an insult from petroleum hydrocarbons, microbial communities are initially affected adversely. The non-hydrocarbon degraders are exterminated due to the prejudicial nature of the insult. Thus, there is a limitation in microbial diversity. Thereafter, to attain ecological equilibrium, there is an insurgence of hydrocarbon-degrading microorganisms, the hydrocarbonclastics. Their degradation would counter the biological disequilibrium arising from the insult. This is the hallmark of the entire ecosystem function.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

6. REFERENCES

Babich, H. R., Bewley, R. J. F. and Stotzky, G. (1983). Application of the ecological dose concept to the impact of heavy metals on some microbe-mediated ecological processes in soil. *Archives of Environmental Contamination and Toxicology*, *12*, 421-426.

Barron, M. G., Short, J. W. and Rice, S. D. (2003). Photo-enhanced toxicity of aqueous phase and chemically dispersed weathered Alaska North Slope crude oil to pacific herring eggs and lavae. *Environmental Toxicology and Chemistry*, *22*(3), 650-660.

Calow, P. (1992). Can ecosystems be healthy? Critical consideration of concepts. *Journal of Aquatic Ecosystems Health*, *1*, 1-6.

Dunnet, G. M. (1982). Oil pollution and seabird populations. *Philosophical Transactions of the Royal Society of London*, *297*, 413- 427.

Ebulue, M. M. (2021). Impact assessment of the activities of soil lipase and dehydrogenases in spent engine oil-polluted ecosystem undergoing remediation. *Journal of Bio Innovation*, *10*(1), 265-274.

Ebulue, M. M. (2022). Soil enzymatic activity – an indication of ecosystem stressed with hydrocarbon. *Journal of Bio Innovation, 11*(1), 113-125.

Ekpo, M. A. and Udofia, U. S. (2008). Rate of biodegradation of crude oil by microorganisms isolated from oil sludge environment. *Africa Journal of Biotechnology*, 7(24), 4495 - 4499.

Gutnick, D. L. and Rosenberg, E. (1979). Oil tankers and pollution: A microbial approach. *Annual Revolution Microbiology*, *31*, 379-396.

Hall, A. J., Hugunin, K., Deaville, R., Law, R. J., Allchin, C. R. and Jepson, P. D. (2006). The risk of infection from polychlorinated biphenyl exposure in the Harbor Porpoise. *Environmental Health Perspectives*, *114*, 704-711.

Heintz, R. A., Short, J. W. and Rice, S. D. (1999). Sensitivity of fish embryos to weathered crude oil Part 11. *Environmental Toxicology and Chemistry*, *18*, 494-503.

Moriarty, F. (1983). The study of pollutants in ecosystems. *Ecotoxicolgy Academic Pres*, *289*, 233-340.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

Onwurah, I. N. E. (1999). Restoring the crop sustaining potential of crude oil polluted soil by means of *Azotobacter* inoculation. *Plant Production Research Journal*, *4*, 6-16.

Onwurah, I. N. E. (2002). Anticoagulant potency of water-soluble fractions of Bonny light Oil and enzyme induction in rats. *Biomedical Research*, *13*(1), 33-37.

Onyefulu, K. O., and Awobajo, O. A. (1979). Environmental aspects of the petroleum industry in the Niger Delta, problems and solutions in the Petroleum Industry and Niger Delta. *Proceedings of the NNPC Seminar on Environment*, *2*, 242-248.

Rapport, D. J. (1992). Evaluating ecosystem health. *Journal of Aquatic Ecosystems Health*, *1*, 15-24.

Sanders, B. M., Martin, L. S., Nelson, W. G., and Welch, W. (1991). Relationships between accumulation of a 60 kD a stress protein and scope of growth in *Mytilus edulis* exposed to copper contaminations. *Marine Environmental Research*, *31*, 81-97.

Tiido, T., Rignell-Hydbom, A., Jönsson, B. A., Giwercman, Y. L., Pedersen, H. S., Wojtyniak, B., Ludwicki, J.K., Lesovoy, V., Zvyezday, V., Spano, M. and Manicardi, G.C. (2006). Impact of PCB and p, p'-DDE contaminants on human sperm Y: X chromosome ratio: studies in three European populations and the Inuit population in Greenland. *Environmental Health Perspectives*, *114*(5), 718-724.

Tool, T. A. N. E. (1988). Pollution-induced community tolerance—a new ecotoxicological tool. *Functional Testing of Aquatic Biota for Estimating Hazards of Chemicals*, *988*, 219.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951