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Review

## Remediation of contaminated lands in the Niger Delta, Nigeria: Prospects and challenges



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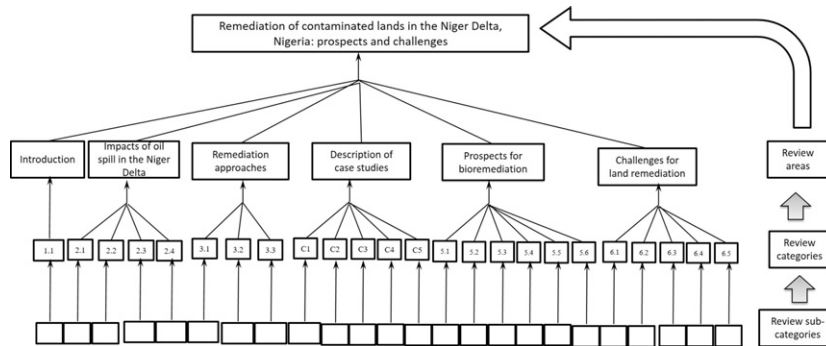
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HIGHLIGHTS

- Land contamination remediation in the Niger Delta region of Nigeria is ad hoc and utilises the do-nothing approach to clean-up.
- Impacts of oil toxicity on the environment and exposed populations is variable and deleterious.
- Different factors including overlapping governance structure, stakeholder conflict, funding and lack of expertise is a challenge to land contamination remediation.
- Bioremediation is a potential approach to effective and efficient clean-up given its low greenhouse emissions and environmental footprints.

GRAPHICAL ABSTRACT



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ABSTRACT

Contamination of the total environment (air, soil, water and biota) by crude oil has become a paramount interest in the Niger Delta region of Nigeria. Studies have revealed variable impacts of oil toxicity on the environment and exposed populations. The revelation gained much international attention in 2011 with the release of Environmental Assessment of Ogoniland report by the United Nations Environment Programme (UNEP). This has up scaled local and international pressures for urgent clean-up and restoration of degraded bio-resource rich environments of the Niger Delta, starting from Ogoniland. Previous remediation attempts in the area had failed due to erroneous operational conclusions (such as conclusions by oil industry operators that the Niger Delta soil is covered by a layer of clay and as such oil percolation remains within the top soil and makes remediation by enhanced natural attenuation (RENA) suitable for the region) and the adoption of incompatible and ineffective approaches (i.e. RENA) for the complex and dynamic environments. Perennial conflicts, poor regulatory oversights and incoherent standards are also challenges. Following UNEP recommendations, the Federal Government of Nigeria recently commissioned the clean-up and remediation of Ogoniland project; it would be novel and trend setting. While UNEP outlined some measures of contaminated land remediation, no specific approach was identified to be most effective for the Niger Delta region. Resolving the technical dilemma and identified social impediments is the key success driver of the above project. In this paper, we reviewed the socio-economic and ecological impacts of contaminated land in the Niger Delta region and the global state-of-the-art remediation approaches. We use coastal environment clean-up case studies to demonstrate the effectiveness of bioremediation (sometimes in combination with other technologies) for remediating most of the polluted sites in the Niger

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Delta. Bioremediation should primarily be the preferred option considering its low greenhouse gas and environmental footprints, and low-cost burden on the weak and overstretched economy of Nigeria.

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## 1. Introduction

Land is a scarce commodity, an important factor in economic systems and a critical component of the earth's life support system (Hou and Al-Tabbaa, 2014; Yao et al., 2012). However, historic and ongoing human activities have resulted in large-scale contamination of lands, and in worst case scenario hitherto useful lands are transformed to wastelands (Tinsley and Farewell, 2015). Nigeria is the eleventh largest oil producer in the world. And the Niger Delta is the oil and gas region of Nigeria, and doubles as the country's hub of mangroves and extraordinary biodiversity. In Nigeria, oil extraction and processing activities has resulted in massive land contamination (Sam et al., 2016; UNEP, 2011). Land affected by oil spill has been identified as a major challenge to livelihood, human and environmental health in the Niger Delta region of Nigeria (Sam et al., 2016).

Over the last five decades, environmental degradation and specifically soil contamination caused by petroleum hydrocarbon spill was perceived in terms of relatively rare events, with poorly understood but highly devastating impacts on human health and ecological systems (Döberl et al., 2013). However, several incidences including the New York Love canal in the US (Ikehata and Liu, 2011) and the Minamata disaster in Japan (Murata and Sakamoto, 2013) drew media attention to the issue of soil contamination. Currently, the perception has changed

to issues of large-scale infrastructural damage, ecological devastation and adverse human health impacts, resulting from legacy sites and current waste disposal methods. Presently, the issue of soil contamination is gaining global recognition as it poses significant challenge to the present and future generations. To this end, different countries (e.g. the UK and USA) (Luo et al., 2009) have developed approaches and policies for dealing with contaminated sites. Many developed countries have gone further to implement such policies, for example, the UK, Netherlands and the USA.

Developing countries on the other hand are yet to reflect this global response to land contamination. Nigeria, for example, is yet to develop policies that meet international standards in dealing with land contamination despite widespread environmental contamination in the Niger Delta region of the country (UNEP, 2011). As such, the level of land contamination continues to surge with associated socio-economic and environmental impacts. While soil quality, surface and ground water has been adversely affected thus impacting drinking water quality (Nduka and Orisakwe, 2011; UNEP, 2011; Ahirakwem et al., 2012; Lindén and Pålsson, 2013; Nganje et al., 2015; Davies and Abolude, 2016), many aquatic fauna and flora have reportedly gone into extinction (Luiselli et al., 2015). For example, the mangrove ecosystem in the Niger Delta region is fast degrading (UNEP, 2011). This has led to decades of public protest and outrage demanding urgent remediation in

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