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Causes and Contaminants of Soils and Water in the Niger Delta Region of Nigeria: A Systematic Review

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ABSTRACT

Contaminants of various sources and types constitute a great environmental nuisance to many oil producing regions of the world, and the Niger Delta region of Nigeria is no exception from this menace. This has negatively impacted the region, posing a lot of health and environmental risks to the inhabitants. Hence, in the quest to ascertain the causes and common contaminants of soils and water in the region, a systematic review was conducted across three academic databases (PubMed, Scopus and Web of Science) by two independent reviewers within a five-year period (2020-2025). Keywords, synonyms, Boolean search strings as applicable and the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) was used. A total of 533 articles were obtained from the initial search which were later filtered down to 393 articles using specific inclusion criteria, language and journal publication filters. Further screening using additional keywords and abstract preview reduced the set to 131 and subsequently 23 articles included in this systematic review. The reviewed articles revealed that contaminants from the Niger Delta region could be classified into five categories which are heavy/trace metals (Cd, Pb, Cr, Ni, Cu, Zn, Fe, Mn, As and Ba), Petroleum-related hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAHs), BTEX and Total Petroleum Hydrocarbons (TPHs), Persistent Organic Pesticides (POPs) and microbial contamination. Unfortunately, anthropogenic activities which include indiscriminate waste disposal, spills from oil and gas exploration activities, spillage from petroleum tankers and vandalised pipelines, waste and spent oil from mechanic workshops and agricultural runoffs were implicated as the causes of these pollution. Hence, this review recommends extensive enlightenment and mass awareness as a crucial part of addressing contaminations and environmental degradation within the Niger Delta region.

Keywords: Contaminants, Niger Delta; PAHs, BTEX, Total Petroleum Hydrocarbons, Persistent Organic Pesticides.

INTRODUCTION

For several years, the Niger Delta region of Nigeria had experienced continuous and frequent pollution emanating majorly from oil spills from oil mining and processing. This had negatively impacted the region, posing a lot of health and environmental risks to the inhabitants [1]. Moreover, other studies by Ekhator et al. [3] and Numbere et al. [4] had reported persistent vegetation deterioration, surface and ground water contamination, soil degradation and air pollution [3,4]. Globally, massive agricultural activities, urbanisation, and increasing industrialisation and several anthropogenic activities had been implicated in the pollution of both terrestrial and aquatic ecosystems via the emission of harmful pollutants like heavy metals, pesticides, persistent organic pollutants (POPs) and pharmaceutical residues which accumulate in the ecosystem portending a long-term health and ecological risks to humans [5]. Similarly, in the Niger Delta region of Nigeria, crude exploration activities, mining, maritime and shipping operations had all been linked with environmental pollution posing health risk to one of the largest economic hubs of Nigeria [6]. While remediative processes like phytoremediation, chemical remediation and bioremediation had gained prominence with emerging and more sophisticated processes like advanced oxidation processes (AOPs), membrane filtration, activated carbon adsorption and lately nanotechnology [5], the Niger Delta region of Nigeria, suffers from ineffective remediation, monitoring and management, this makes the region a subject of several environmental issues [1].

The consequences of these environmental pollutions are enormous, these range from ecological destruction, abject poverty, depletion and extinction of biodiversity [7], hydrocarbons in soils had been linked to contamination of agricultural produce [10-12] which poses huge challenges to availability and safety of food. Long and short-term health consequences like neuro-behavioural disorder, inflammation of joints, bronchitis, dermatitis, renal dysfunctions, cancer, high blood pressure and gastro-intestinal disorder had been linked with heavy metals contaminants which are common pollutants in the Niger Delta region of Nigeria [13-15]. Although oil spills had been mainly documented as the major source of pollution, it is pertinent to understand that other sources of pollutants in the region are often under looked hence this study stems to present a thorough systematic review of the causes and common contaminants of soils and water in the Niger Delta region of Nigeria. In the quest to provide actionable plans towards reduction and total eradication of environmental pollution in the region.

MATERIALS AND METHODS

Search for articles

In this systematic review, extensive literature search was done by two independent reviewers on three reliable databases which include PubMed, Scopus and Web of Science. The reporting standard deployed for this study is the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2020. Keywords and synonyms, including Boolean search strings were used. The search synonyms terms are “Pollution” OR “Contamination” OR “Environmental degradation”, “Soil” OR “Land”, “Impacts” OR “Effects” or “Consequences” or “Outcome” or “Repercussion”, “Niger Delta” or “South-south”, while the used Boolean Strings are: (“Soil pollution” OR “Soil contamination” OR “Water pollution” OR “Water contamination” OR “Environmental degradation”) AND (“Impacts” OR “Effects” OR “Consequences” or “Outcomes”) AND (“Niger Delta” OR “Rivers” OR “Bayelsa” OR “Delta” OR “Akwa Ibom” OR “Cross River” OR “Abia” OR “Edo” OR “Ondo” OR “Imo”).

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Eligibility Criteria

To arrive at more recent research findings, this study was limited to research articles published in the last five years (2020-2025), in addition, only original quantitative studies, published in English and studies that investigated soil and/or water pollution within the Niger Delta region were included. Niger Delta in this review refers to 9 states which encapsulate the political and geographical definition of Niger Delta state. The states include Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers. This describes the area that surrounds the Niger River's Delta, where it meets the Atlantic Ocean, Spanning the River states officially designated by the Niger Delta Development Commission (NDDC). It is located in the southern region of Nigeria bordering the Atlantic Ocean; it spans about 2000km of swampy mangrove, creeks, rivers fresh water swamp, and lowland forest (figure 1). Classified as a tropical rain forest (4°N - 10°N of the equator), the region has an altitude less than 1km with high annual rainfall of about 2400mm [7,8]. It is home to diverse flora and fauna and also 75% of Nigeria petroleum products. Fishing and Agricultural activities are the major source of livelihood indicating the core dependence of the inhabitants on the ecosystem for survival [7,9].

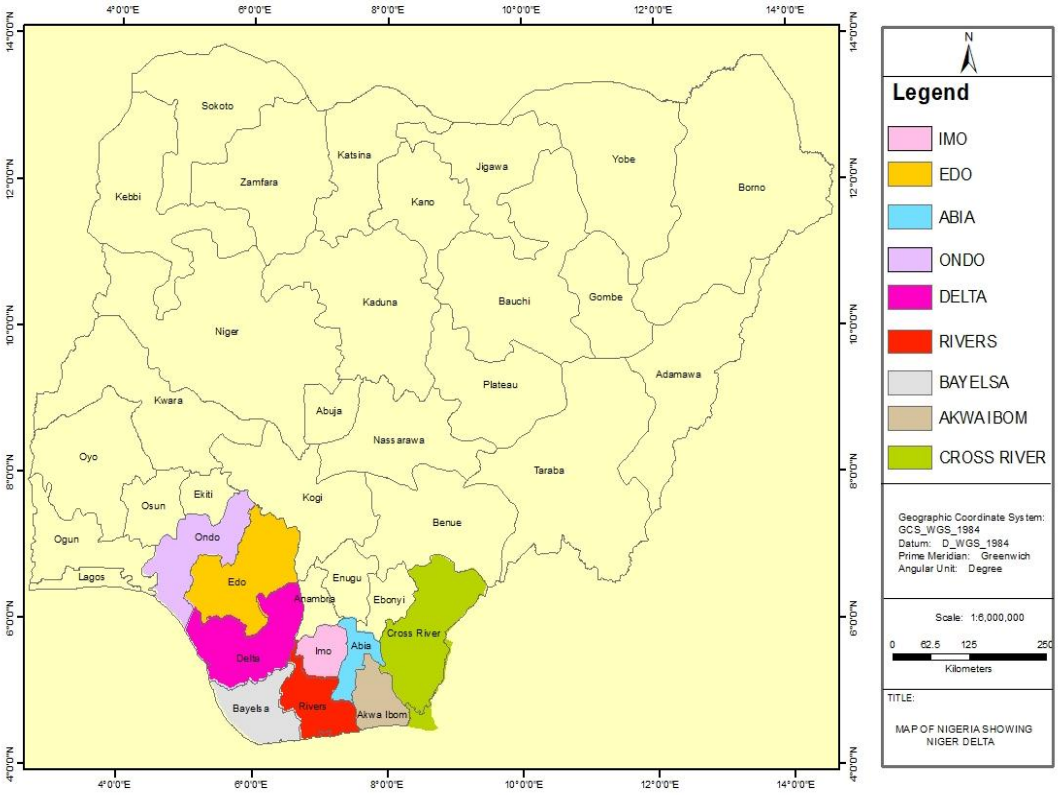

Figure 1: Map of the Niger Delta region of Nigeria

RESULTS

Selection of Studies

The initial search using the keywords and Boolean search strings yielded 533 articles, 140 of these were eliminated when systematic review, conference papers, book chapters, letters, data paper and editorial were excluded. The remaining 393 were reduced to 255 as they were either unrelated to the review's focus or published in other languages. Further screening based on keywords and field of studies excluded 131 articles. The remaining 124 articles were pruned

down to 23 by examining the complete texts, the topics, abstract and locations and how they align with the focus of the study eliminating 101 articles. The PRISMA flow chart is shown in figure 2, and an overview of the reviewed articles is presented in table 1.

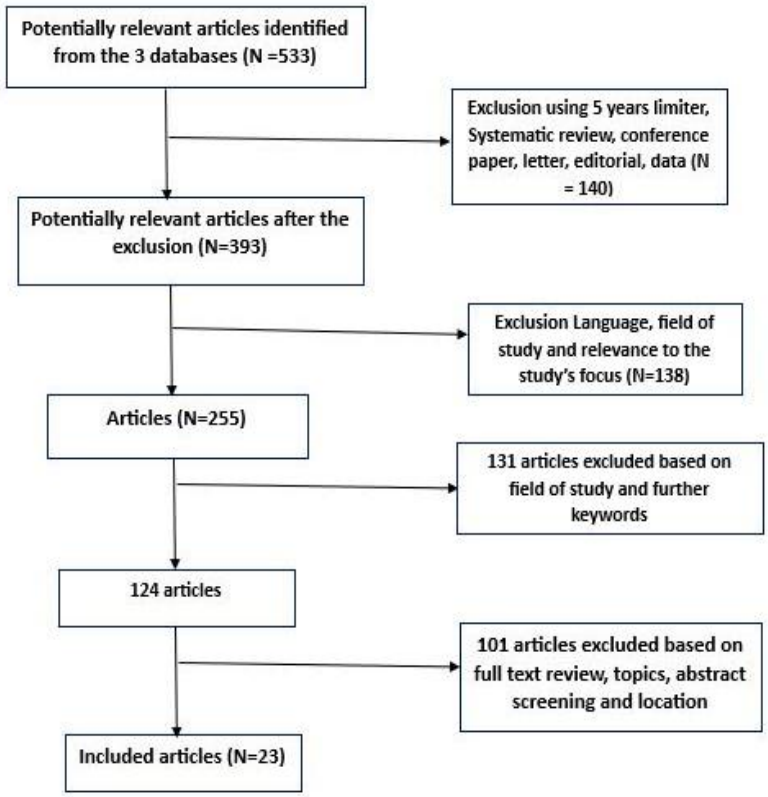

Figure 2: Prisma flow chart of Selected articles

Table 1: Overview of the reviewed articles

Sample	Location	Methods	Contaminants detected	Abnormally high (reported)	Identified causes	References
Soil	Akure, Ondo State	ICP-OES	Cu, Fe, Zn, Mn, Ti, Pb, Cd, Cr, Ni, Co, Al, Sn, Se, Ba, As, V, Sr, Mo, Sb	Cd (strong pollution)	Spent oil from auto-mechanic services, panel beating, repairs	16
Soil	Akure, Ondo State	2D Electrical resistivity	Zn, Cu, Pb, Cr, Cd	Cd, Cu, Pb, Zn exceeded background; Cd high ecological risk	Improper waste disposal, leachate percolation	17
Surface water, groundwater, leachates, rainwater	Cross River State	Chemical assays	TDS, TH, Na^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO^{3-}, $SO4^{2-}$, NO^{3-}, Al, Fe, Mn	Cd, Cr and Ni	Open waste disposal, water-rock interactions	18
Sediments	Bayelsa	AAS	Fe, Cu, Zn, Pb, Cd, Ni, Co	Cd, Pb and Ni exceeded	Agriculture, oil & gas exploration, mining, waste	19
Soil	Rivers State	AAS	Cr, Co, Cu, Ni, Mn, Cd, Pb, Zn	Cd above regulatory limits	Industrial emissions, road runoff	20

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Soil	Port Harcourt	AAS	Fe, Cr, Cd, Cu, Zn, Ni, Pb	Cd significant contributor	Gas flaring, oil operations	21
Water	Cross River State	AAS	Cd, Pb, Fe, Mn, Zn, Ba	Mn high	Surface runoff, mining, geogenic sources	22
Soil	Ondo State	AAS	Fe, Zn, Pb	Elevated metals	Improper waste disposal, industrial activity	23
Soil	Rivers State	XRF	PAHs, Fe, Cr, Cu, Co, Zn, Mn, V, Pb, U	Cr, Ni high	Oil spills, operational failure, sabotage	24
Soil	Rivers State	ICP-MS, GC-MS	Cu, Cd, Ni, Pb, Cr, Fe, Mn, Zn, Co; 13 PAHs	Cu, Cd, Ni, Pb, B[a]P, Cr high	Oil spills, coal combustion, gas flaring	25
Water	Delta State	AAS	Fe, Zn, Pb, Ni, Cd, Cu, Cr	Fe, Zn high	Oil & gas exploration, dumping, agrochemicals	26
Soil & Plants	Cross River State	AAS	Fe, Zn, Mn, Ba, Pb, Cd	Cd exceeded	Barite mining, refuse disposal	27
Groundwater & Leachate	Rivers State	AAS	As, Cd, Zn, Ba, Mn, Cu, Co, Cr, Ni, Pb	Ni, Pb high	Landfill leachate	28
Soil	Delta State	GC-MS	16 PAHs	B[a]P high	Oil spillage, solvents, crankcase oil	29
Soil	Delta State	HS-GC-MS	BTEX, VOCs	BTEX high	Diesel generator emissions, fuel stations	30
Water	Niger Delta	GC-MS	OCPs (HCH, DDT, etc.)	gamma-HCH high	Pesticide use, runoff	31
Groundwater & Subsoil	Ondo State	AAS	Fe, Mn, Ni, Cd, Co, Zn, Pb, Cu	Cd, Cu, Zn high; Fe, Mn high	Anthropogenic activities	32
Water & Sediment	Niger Delta (Forcados River)	AAS	Pb, Zn, Cu, Cr, Ni, As, Ba, V; PAHs, BTEX, TPH	Cd, Pb, Ba high	Oil brine discharge, production waste	33
Soil & Water	Rivers State	PAH assays	16 PAHs	B[a]P high	Oil spillage, industrial activity	34
Water & Human blood	Bayelsa State	AAS, ELISA	Pb, Cd, As	Above WHO in water; serum markers elevated	Pipeline spillage, petroleum	35
Soil, Water & Crops	Edo State	AAS, XRF	Fe, Ni, Cd, Pb, Cr, Cu	Fe, Ni, Pb high	Dumpsites	36
Soil	Abia & Rivers states	AAS, chromatogram	Pb, Cr, Cd; PAHs; TPH	PAHs high; Pb, Cd exceeded	Indiscriminate waste disposal	37
Soil	Delta State	Spectrophotometry, bacteriology	Suspended solids, metals, coliforms	Faecal contamination	Open defaecation, wastewater	38

FINDINGS AND DISCUSSION

Contaminants across the Niger Delta

Environmental contamination still remains a vital issue of concern across Niger Delta States of Nigeria as indicated by the articles reviewed. The articles documented five categories of contaminants. This includes the heavy metals like Cd, Pb, Cr, Ni, Cu, Zn, Fe, Mn, As and Ba [16,17,19, 20-23,32-33,36-38], petroleum related hydrocarbons and PAHs [24-25,29-30,32-33,36-37], BTEX and TPH [24-25,29-30,33-34,37], Persistent organic pesticides [31] and microbial contamination [38]. Cadmium (Cd), Pb, Ni and Benzo(a)pyrene (B[a]P) whose values repeatedly exceeded regulatory thresholds in several of the articles [16-17,19-21,25,29,33-34,37]. This aligns with other findings from the Niger Delta which implicated oil explorations, spills, gas flaring and other anthropogenic activities as major causes of environmental contaminations [39-41]. Cadmium (Cd) appears as a major contaminant with repeated elevated risks across several of the review articles [16-17,19-22,27,32-33,37], while several of the papers deployed health risk indices like Potential Ecological Risk Index (PERI), Ecological Risk Index (ERI), Hazard Quotient (HQ) and Incremental Lifetime Cancer Risk (ILCR), Cd was constantly identified as dominant contributor to environmental risks [16-17,19,21]. This consistent implication of Cd aligns with other study which linked oil production waste, spent lubricants, residues from mechanic workshops and industrial effluents with abnormally high levels of Cd in soils and water sediments [42]. Lead (Pb) and Ni were also repeatedly detected at alarming levels from several of the reviewed articles [16-17,21,24-26,28,36-37]. Findings from [36] which reported Fe, Ni and Pb clearly exceeding the Standard Organisation of Nigeria (SON), Food and Agriculture Organisation (FAO), World Health Organisation (WHO) and National Agency for Food and Drug Administration and Control (NAFDAC) in food crops reflects the exposure pathways from soil, crops to humans. Similarly, [25,29,34] identified B[a]P and other high molecular weight PAHs as clearly above the threshold levels, this is vital in carcinogenic risk and consistent with PAH burdens reported by other study [41]. BTEX and TPH were also recognised as major contaminants [25,30,33-34,37], [33] which investigated sediments at oil discharge points which revealed high TPH and hydrocarbon loads, buttressing other research showing high levels of TPH near discharge spills and sites [40]. Organochlorine pesticides (OCPs) and Hexachlorocyclohexane (HCH) were documented by [31] in soils and sediments, this reflects historical and ongoing pesticides usage as reported by earlier study [43].

Exposure Pathways

Several of the reviewed articles revealed exposure to contaminants and the associated risks [18-19,22,25,29-30,35], notably is [20] which linked water and heavy metal contaminations with abnormally elevated serum biomarkers and enzymatic activities in the liver, this reflects the negative implications of ingestion or dermal exposures. In addition, [25,29-30] calculated ILC, Hazard Index (HI) and Carcinogenic Risks (RI) linked to ingestion and dermal exposures to PAHs, B[a]P and heavy metals (Cr, Cd, Ni). These risk assessments indicate how contaminations not only pose environmental issues but also constitute health risks when irrigation, ingestion or dermal pathways exists, which aligns with other studies [39, 40].

Anthropogenic Activities as Major Sources of Environmental Contaminants in the Niger Delta

All reviewed articles attributed the contaminations to localized anthropogenic activities although there unique and overlapping emphases across the articles. Oil and gas exploration,

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spills and discharges from operational activities were repeatedly implicated [19-20,24-26,33-35], specifically with high TPH, PAHs and metals at discharge and spill points. This aligns with studies which previously documented that crude oil contamination remains a dominant driver of metals and hydrocarbon pollution in the Niger-Delta [39-40], while [21,25,29] pinpointed gas flaring and combustion emissions as sources of pyrogenic PAHs and other acidic depositions which support easy mobilisation of metals as buttressed by [45]. Mechanic workshops, spent oil and urban dumpsites were clearly reported as other anthropogenic sources of contaminants [16-17,23,27,36-37], these activities increase environmental pollutants from lubricants and metal wear products which increase the levels of Cd, Pb and Cu in soils. Studies from other mechanic workshop had also indicated similar potential toxic elements around mechanic workshops [46-47]. Agricultural pesticides usage and runoff reported by [31] accounts for OCPs and HCH isomers also attributed to anthropogenic and indiscriminate use of agricultural chemicals, these chemicals are vital for increased agricultural activities vis-a-vis food sustainability, their abilities to travel via run-off and atmospheric redistribution makes them contaminants of concerns across the world [43].

CONCLUSION

With historical and continuous exploration of crude products across the Niger Delta region of Nigeria, contamination of both soil and water remain a crucial issue worthy of consideration by all stakeholders, this necessitated this systematic review. The 23 studies which met the inclusion criteria in the review jointly showed that soils, sediments and water across the Niger Delta region of Nigeria are contaminated with heavy metals, hydrocarbons and in some places OCPs and microbial pathogens. Anthropogenic activities which include oil and gas operations, mechanic and industrial emissions, waste disposal and agricultural practices are repeated primary causes of these pollutions. The evidences support targeted remediation, harmonised monitoring and integrative health studies to characterise exposure and also to reduce risk. In this vein, this review recommends extensive enlightenment and mass awareness as a crucial part of addressing contaminations and environmental degradation within the Niger Delta region.

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