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RESEARCH PAPER

Effects of hazardous waste discharge from the activities of oil and gas companies in Nigeria

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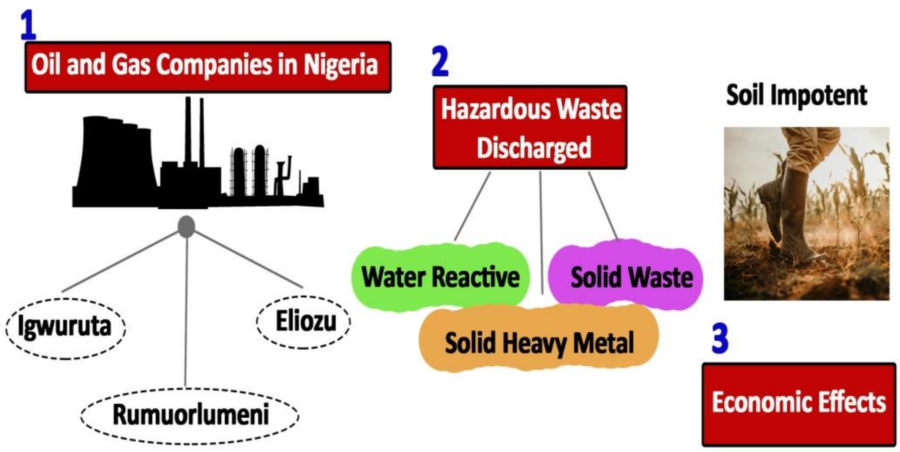
Highlights

- Hazardous waste could be a source of job creation and revenue generation, if properly managed.
- Dumping sites are barren due to the presence of heavy metal.
- Significant difference seen among dumpsite dot parameters for three locations.
- Administrative and Engineering controls is used to manage hazardous chemical discharge.

Graphical Abstract



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Abstract

The paper focused on the economic effects of hazardous waste due to oil and gas companies in Rivers State. It includes direct, indirect, and induced impacts on jobs, labour income and value addition. Hazardous waste could be a source of job creation and revenue generation, if properly managed. However, poor management of hazardous waste can cause great danger to environment, plants animals and human life. There are five major waste disposal dumpsites in Port Harcourt metropolis. The present study was restricted to three functioning dump sites at Rumuorlumeni, Igwuruta, and Eliozu. Data were collected from a wide range of subjects to elicit acceptable generalization, and then analysed and tested in the laboratory. The results showed the p values of the dumpsite dot and parameters measured are significant at 5%, while the p-value of the locations considered is significant at 10%. Hence, there is a significant difference among dumpsite dot parameters measured and the three locations considered. The least squared difference comparison tests were done to identify the significant factors. It showed that the regions where hazardous wastes are dumped are barren due to the presence of heavy metal as they render the soil unfertile to permit crops and plants to germinate and effect on agriculture.

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1. Introduction

The economic effects of hazardous waste discharge on urban cities can be classified into direct, indirect, and induced impact. Direct impacts include revenues and added-value. Indirect impacts are mainly caused by crude oil and natural gas production activities. Induced effects include income and added-value addition caused by the income of waste management. If properly managed, hazardous waste could become a source of huge economic benefit to both the generator and the host community. Waste is a result of businesses, government, and household activities or by material or energy recovery (Gu et al., 2014). Hence, the environment and government are affected by waste management. For instance, hazardous waste management can generate employment through job Creation. Countries like India and the United States of America generate between 15-18% of employment through full-time or part-time employment. The sector applies individuals throughout the world for high wages to be spent and tax the government.

However, Hazardous waste management can pose a great danger to human life if not properly managed. Far be it from exaggeration that between 15-20% of death recorded in a petrochemical related occupation results from the miss-management of hazardous chemicals (Wang et al., 2015). The corrosiveness of hazardous waste varies in terms of effectiveness, tonnage, combustion, ignitibility, etc. Tonnage is essential in impact assessment, so the more the tonnage increases, and the risk probability for human and animal increases. This implies a relative difference in the level of danger by a particular element in a discharge. In terms of tonnage, some low tonnage waste may be more dangerous than others with higher tonnage. For instance, Cadmium, Lead, Nitrogen, Zinc compounds, and wastes fall into the higher risk element category. Alkali's acute results could refer to skin, mouth, throat, or eyes burns (Roy and Mcdonald, 2015).

The present research examines the economic impact of hazardous waste management. A hazard is the probability of an unacceptable outcome. From the chemist's point of view, Disease or deaths are the most dangerous hazards. Epidemiologists call them as morbidity and mortality, respectively. Medicine and environmental experts refer to them as toxicity. Human toxicology investigates health status and probable risks. On the contrary, ecotoxicology studies ecosystems hazards (Patwary et al., 2011).

The theoretical foundation of the work is derived from the behavioral change model was posited. The more informed the population, they would be more conscious regarding environmental issues and, as a result, behave more responsibly. Knowledge increases developed environmental attitudes (Amadi et al., 2013). Hence, this linear model was not adopted for a long time. The behavioral model thinks so simple. It makes possible relations between environmental knowledge, awareness, and attitude. Sufficient knowledge about environmental variables could not provide evitable sustainable environmental behavior.

Meanwhile, an environmental practice could not essentially reduce due to poor environmental knowledge. Other factors are also important. This linear trend is not the reality, and so a more advanced model is needed.

Generally, wastes are classified into three broad spectra of solid, liquid, and gaseous. The liquid waste flows freely, while solid waste is the direct opposite. Besides, waste can be classified as either Domestic waste or Industrial waste. Irrespective of the means of generation, waste could be harmful, toxic, and or radioactive.

The open dumpsite is exposing to infiltration from precipitation. An organic and inorganic compound available in waste accumulates at the bottom of the dumpsite during water leakage. locations close to dumping sites have greater possibilities of groundwater contamination due to leachates. (Aderemi et al., 2011). The leachate can contaminate the groundwater if not adequately managed. Groundwater contamination leads to water-borne diseases and risks such as typhoid, cholera, and infectious dysentery, to the local groundwater users (Ikem et al., 2002).

Landfilling is applied in significant cases to fix it. The waste stream is treated with low technologies and environmental standards (Patwary et al., 2011). Land replacement and sedimentation of unproductive and contaminated Soil are considered one of the hazardous waste effects on land (Amadi et al., 2013). Dangerous wastes of industrial activities can be in different states, including solid, liquid, and gas. Inadequate storage or disposal of wastes may lead to surface and groundwater pollution. Inhabitants of near-dumping sites are at dramatically dangerous position.

1.1. Conceptual framework

The exact and scientific management in confronting hazardous waste discharge is different, and it depends on the amount of risk that the person or society is willing to take (Nema and Gupta, 1999). The mail Components of the conceptual framework has shown in Fig. 1.

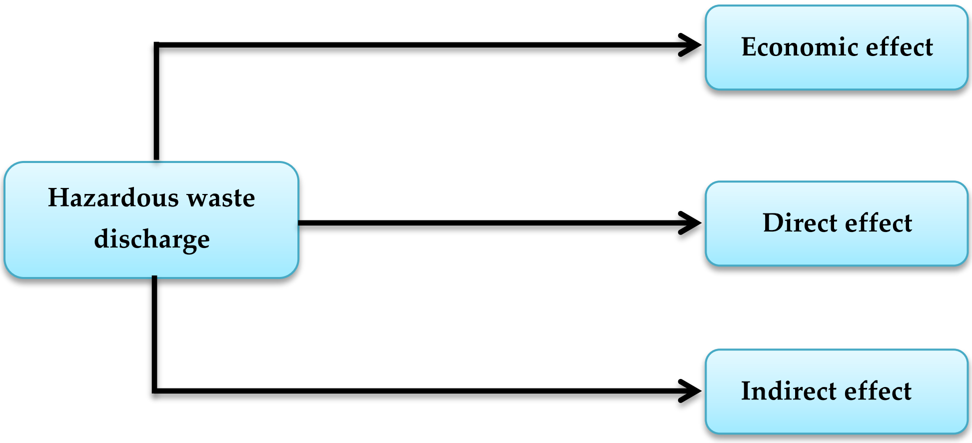

Fig. 1. The schematic representation of the economic effect of hazardous waste discharge.

1.2. Direct economic effect of hazardous waste discharge

The direct Economic effect of hazardous waste discharge is the view from the perspective of agriculture regarding Soil's impact. That a plant survived is a function of the quality of the Soil. It is a soil nutrient that determines all agricultural activities. Soil nutrient is either made or marred depending on deposited on the land or the chemical composition. Soil may be contaminated based on the presence of heavy metals. The heavy metals contamination has increased remarkably because smelting, production, agricultural fertilizers, and pesticides apply municipal waste, traffic emissions, and industrial effluents (Chibuike and Obiora, 2014). Soil Contamination is now widely. Heavy metals affected adversely on land degradation, which influenced as a result of Ecosystems and the Environment (Li et al., 2015; Chen et al., 2016). Heavy metals dispersed in irrigated soils and plants lead to pollution of food and, consequently, hazardous for humans and animals (Jolly et al., 2013). Heavy metals have low solubility then usually prefer to be accumulated in soils and as results in plants. Also, heavy metals remain in the Soil and afterward permeate inside the groundwater, which leads to antioxidant enzymatic activities in plants or become adsorbed with solid soil particles (Iannelli et al., 2002).

Carrots cultivated in Cd contaminated soils may cause toxicological problems in humans. Carrot roots could adsorb Cadmium about 5, 8, and 12 times more than the permitted level for men, women, and children, respectively. High amounts of Cd in Soil lead to Itai-Itai disease in Toyama Prefecture, Japan (Roy and McDonald, 2015). However, the high level of Cd dissolved in Soil was determined to not lead to health problems for inhabitants of Shipham, England. About tomato cultivated in Cu-contaminated soils (*Solanum Lycopersicum* L.), based on soil properties, this amount is 32.9-1696.5 mg/kg (Sacristán et al., 2015). Disorders in cellular activities as well as prevention from plant growth, are caused by heavy metals accumulation (Farooqi et al., 2009). Heavy metals are transferred into plants and threaten the food chain in this way frequently. To heavy metals risk assessment, phytoremediation is applied (Roy and McDonald, 2015; Ye et al., 2014). Heavy metal pollution could not be inhibited (Wang et al., 2009) and threat food crops, atmosphere, and water, and more dramatically, humans and animals livings (Dong et al., 2011). Excessive intake of Lead in the human body can lead to irreversible damage to the nervous system, skeletal, endocrine, enzymatic, circulatory, and immune systems (Zhang et al., 2000).

Lung and prostatic cancer, pulmonary, kidney disorders, hypertension as well as bone fractures are of the adverse effects of Cadmium. Soil as the crucial sector of the Earth planet manages all biological, hydrological, erosional, and geochemical cycles and supplies all essential needs and services for human beings (Berendse et al., 2015; Decock et al., 2015; Smith et al., 2015). Therefore, a study about the effect of the issue on the Soil is important. Pollution is a dramatic effect induced by human activities (Mahmoud and El-Kader, 2015; Roy and Mcdonald, 2015; Wang et al., 2015). Soils were investigated to determine the deposition, accumulation, and distribution of heavy metals in different locations, but little results exist about agricultural soil contamination in Port Harcourt.

1.3. Indirect economic effect

The indirect effect of hazardous waste discharge refers to the various benefits of handling and managing waste discharge (Li et al., 2015). Such benefits as the generation of employment, the capacity to export the waste to generate income for the individual, and the government are some of the benefits of waste management. We must note that these benefits cannot be tested empirically.

2. Materials and Methods

This study will use an experimental design method. The approach is justified because the research involves carrying out laboratory tests of collected specimens. The laboratory experiment's essence is to empirically validate the assertion that hazardous waste discharge has some economic effect. Data will be generated through the specimen sample collection. The controlled laboratory experiment offers the researcher complete control of the experimental outcome; hence, reduce biases of all kinds as much as possible. The researcher is assumed to have great control over the study variables and does not influence the test's outcome .

Cross-sectional data is permissible in this study, generated through a series of systematic pilot surveys. The data will be collected from a wide range of subjects to elicit acceptable generalization. This will involve a preliminary study of the study areas, the testing of the stored containers, light-gauge open head drum, large-capacity tanks, etc. used in carrying hazardous wastes to the dumpsites' location.

These will help us determine the effects of oil and gas industry activities in Port Harcourt, Rivers State, on soil quality. The design will help us elucidate knowledge on types and volume of hazardous wastes generated, how they are generated, the method of disposal methods used, and its impact on agricultural Soil (Brevik et al., 2015). It is important to note the specific waste generation considered in this study, namely: Solid waste, solid heavy metal, and water-reactive, they are as hazardous to the waste disposer. There are five major waste disposal dumpsites in Rivers state. The study will be limited to three functioning dump sites located at Rumuorlumeni, Igwuruta, and Eliozu dumpsites (Fig. 2 and 3).

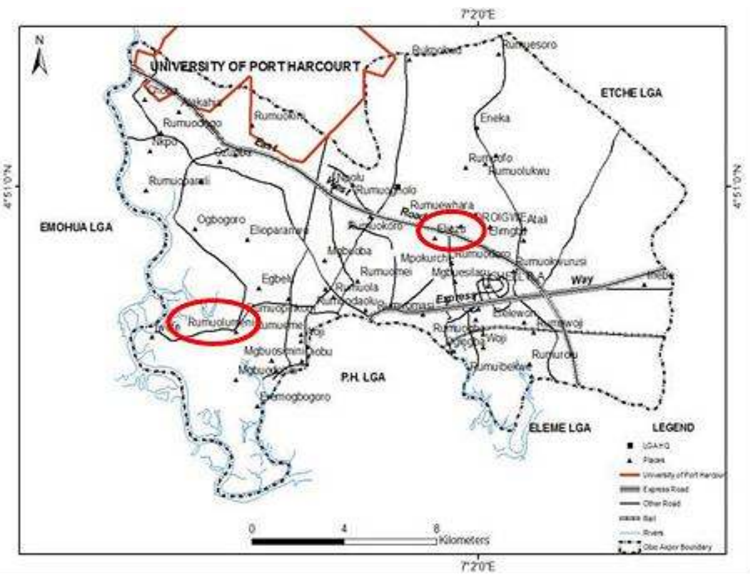

Fig. 2. Showing Rumuorlumeni and Eliozu Dumpsite.

Two different soil samples were collected. The first is at the topsoil ranging from (0-15 cm); this covers the area close to the dumpsite, which was regarded as the experimental site. The second Soil samples were collected from about 900 meters away from the dumpsite. The area was considered free from the dumping of refuse; the area is considered to have relatively less disturbed vegetation.

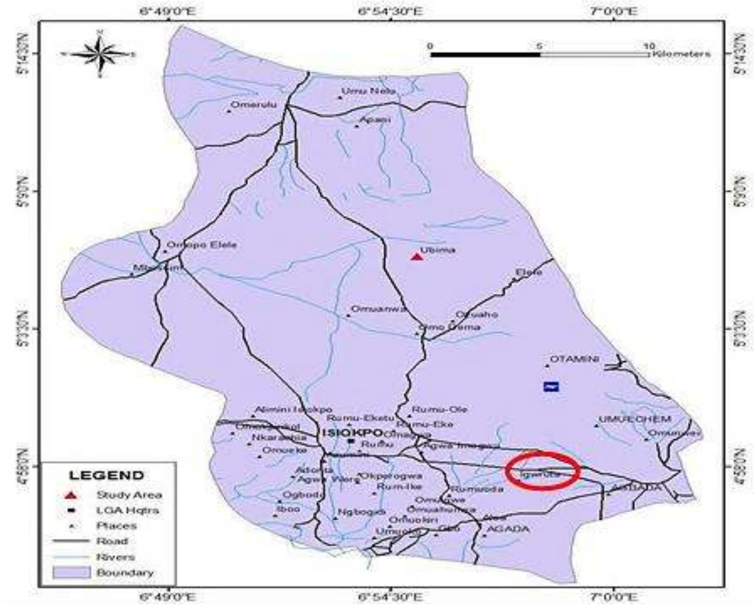

Fig. 3. Showing Igwuruta Dumpsite.

The samples collected were air-dried and sieved with a 2 mm mesh to conduct a standard laboratory test to investigate soil properties physically and chemically by the hydrometer method (Amadi et al., 2012). Additionally, the core method's bulk density and porosity were assayed (Li et al., 2015). Exchangeable bases comprising of Ca, k, and Na were identified through flame photometry and exchangeable magnesium by atomic absorption spectrophotometer. Cation exchange capacity (CEC) was calculated using the ammonium acetate method, and total Nitrogen (N) was determined by Kjeldahl steam distillation. Available Phosphorous (P) was extracted with a Bray P solution. Soil pH was measured in 0.01 M CaCl, while OC was defined by 51 Walkey-Black methods (Skjemstad and Taylor, 1999). The study of trace metals (Pb, Zu, Mn, Co, Cd, Cr, and Fe) was also analyzed. Extracts used for determining heavy metals were obtained by leaching soil samples using 0.1 EDTA. The concentrations of these elements' extracts were determined using an atomic absorption spectrophotometer (Wang et al., 2015).

The study is scientific research and adopts an experimental survey, involving descriptive and inferential statistics methods. Descriptive statistics include using such measures as mean and standard deviation, while inferential statistics apply ANOVA, regression, post HOC, multiple regressions, and test the various research hypotheses. The justification for adopting experimental and descriptive survey methods of research was because these methods offer a systematic analysis of a phenomenon or situation of interest factually and accurately. The physic-chemical properties of soil and water samples were explained using the mean values. Simultaneously, testing the hypotheses raised was tested using t-test statistics, ANOVA, and Post HOC Multiple regression.

3. Results and Discussion

Table 1 shows the various wastes discharge samples in two-state (solid-state and liquid state) collected from Rumuorlumeni. Two reasons account for this; first, the site accommodates the largest waste dump in the state, and secondly, and the rates paid were relatively lower compared to the other two areas. These reasons accounted for more samples being taken from the dumpsite in Rumuorlumeni. The dumpsite in Igwuruta recorded the lost sample collection relative to Eliozu.

It is important to note that the hypotheses are categorically divided into two subcategories. This is justified by the need to fully capture the various themes (aspect) of the study.

Table 1. The samples of three dumpsites in Port Harcourt city.

Type of waste collected	Distance or range of collection	Dumpsites		
Soil samples		Number collected from Rumuorlumeni	Number collected from Igwuruta	Number collected from Eliozu
	Range (0-1 m)	12	8	10
	100 cm	18	10	14
Liquid waste	Shaw (1-25 M)	15	10	12
	45-100 M	12	7	8

Source: O'Brien, 2019.

Table 2. Comparison of the means of the hazardous waste with the standard parameters (Rumuorlumeni).

Waste Disposal Types	Parameters	Experimental site	Control site	Remarks
Solid Waste	H_2O	6.70	6.10	Slightly Higher
	Organic Carbon (g/kg)	294.00	155.00	very High
	Nitrogen (g/kg)	3.05	2.32	Slightly Higher
	Phosphorous (g/kg)	15.80	11.84	Slightly Higher
	Potassium (Cmol/kg)	0.95	0.36	Slightly Higher
	Sodium (Cmol/kg)	0.66	0.87	slightly lower
	Calcium (Cmol/kg)	22.02	12.51	very High
	Chlorine (Cmol/kg)	242.67	223.20	very High
	Magnesium (Cmol/kg)	2.24	2.31	slightly lower
Solid Heavy Metal	Lead (mg/kg)	0.48	0.48	Normal
	Cadmium (mg/kg)	0.41	0.41	Normal
	Chromium (mg/kg)	0.00	0.01	Normal
	Zinc (mg/kg)	362.63	220.64	very High
	Copper (mg/kg)	21.68	12.30	very High
	Manganese (mg/kg)	56.17	38.20	very High
	Cobalt (mg/kg)	0.99	1.03	Normal
	Iron (mg/kg)	185.00	179.90	very High
Water Reactive	Chloride (mg/I)	10.80	6.27	Slightly Higher
	Nitrate (mg/I)	3.73	4.00	slightly lower
	Phosphate (mg/I)	0.52	0.77	slightly lower
	Sulphate (mg/I)	3.73	4.85	slightly lower
	Copper (mg/I)	0.02	0.02	Normal
	Iron (mg/I)	0.06	0.06	Normal

Source: O'Brien, 2019.

H_{03}**:** There is no significant relationship between the hazardous solid waste discharge of oil and gas companies and economic life in Rivers State in the three locations dumpsite and standard parameters measurement. See SPSS 21 result output in Table 4 to 5 for the analysis of the hypothesis.

Results show a significant difference between dumpsite dots, parameters measured and the three locations considered. Since the p values of the dumpsite dot and parameters measured are significant at 5%, the p-value of the locations considered is significant at 10%. Thus, difference significance was among factors (dumpsite dot, parameters measured, and the three locations considered). The least squared difference (LSD) comparison tests were then made to identify significant factors in Tables 4 and 5.

The result of the experiment showed that regions were hazardous discharge are dumped are rendered barren because of the heavy presence of metal, such as Organic Carbon (g/kg); Calcium (Cmol/kg); Chlorine (Cmol/kg); Zn (mg/kg); Cu (mg/kg); Mn (mg/kg); Iron (mg/kg). These metals render the Soil impotent and unfertile to permit crops and plants to germinate. This implies that hazardous waste discharge harms agriculture by rending the Soil impotent.

Table 3. Comparison of the Means of the Hazardous Waste with the Standard Parameters (Eliozu Dumpsite).

Waste Disposal Types	Parameters	Experimental site	Control site	Remarks
Solid Waste	PH (H_2O)	6.70	6.30	Slightly Higher
	Organic Carbon (g/kg)	293.33	140.00	very High
	Nitrogen (g/kg)	3.32	2.32	Slightly Higher
	Phosphorous (g/kg)	15.83	11.84	Slightly Higher
	Potassium (Cmol/kg)	0.99	0.36	Slightly Higher
	Sodium (Cmol/kg)	0.66	0.87	slightly lower
	Calcium (Cmol/kg)	22.02	12.51	very High
	Chlorine (Cmol/kg)	237.01	223.20	very High
	Magnesium (Cmol/kg)	3.24	2.31	Slightly Higher
Solid Heavy Metal	Lead (mg/kg)	0.51	0.48	Normal
	Cadmium (mg/kg)	0.41	0.41	Normal
	Chromium (mg/kg)	0.01	0.01	Normal
	Zink (mg/kg)	334.20	220.64	very High
	Copper (mg/kg)	24.38	18.30	very High
	Manganese (mg/kg)	56.17	38.20	very High
	Cobalt (mg/kg)	1.03	1.03	Normal
	Iron (mg/kg)	182.67	179.90	very High
Water Reactive	Chloride (mg/I)	10.80	6.27	Slightly Higher
	Nitrate (mg/I)	3.77	4.00	slightly lower
	Phosphate (mg/I)	0.49	0.77	slightly lower
	Sulphate (mg/I)	3.07	4.85	slightly lower
	Copper (mg/I)	0.02	0.02	Normal
	Iron (mg/I)	0.06	0.06	Normal

Source: O'Brien, 2019.

Table 4. The three locations dumpsite measurements with the measurement of the standard parameters.

Dumpsites	Parameters	Rumuorlumeni Dumpsite	Igwuruta Dumpsite	Eliozu Dumpsite	Control
Dumpsite Point of Discharge	Organic Carbon (g/kg)	100.0	111.0	100.0	100.00
	Calcium (Cmol/kg)	16.06	17.06	16.06	0.12
	Chlorine (Cmol/kg)	160.50	163.50	160.50	163.93
	Zinc ((mg/kg)	110.6	110.9	110.6	5.27
	Copper (mg/kg)	2.83	3.75	2.83	0.69
	Manganese (mg/kg)	29.6	30.6	29.6	2.30
	Iron (mg/kg)	131.0	125.0	131.0	47.80
Upstream Dumpsite	Organic Carbon (g/kg)	560.0	580.0	560.0	153.33
	Calcium (Cmol/kg)	27.90	27.90	27.90	12.51
	Chlorine (Cmol/kg)	290.00	286.00	290.00	223.40
	Zinc (mg/kg)	456.0	505.0	456.0	220.64
	Copper (mg/kg)	35.8	35.8	35.8	14.30
	Manganese (mg/kg)	84.2	74.2	84.2	38.20
	Iron (mg/kg)	187.0	178.0	187.0	179.90
Downstream Dumpsite	Organic Carbon (g/kg)	220.0	212.0	220.0	153.33
	Calcium (Cmol/kg)	22.10	20.10	22.10	12.51
	Chlorine (Cmol/kg)	260.52	254.52	260.52	223.40
	Zinc (mg/kg)	436.0	496.0	436.0	220.64
	Copper (mg/kg)	34.5	34.5	34.5	14.30
	Manganese (mg/kg)	54.7	64.7	54.7	38.20
	Iron (mg/kg)	230.0	150.6	230.0	179.90

Source: Duru et al., 2019.

Table 5. Response to Hazardous Waste versus Parameters, Dumpsites, Locations (ANOVA).

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1.2796	28	45676.421	4.393	0.000*
Intercept	35405.155	1	35405.155	3.405	0.070**
Dumpsite	273099.140	2	136549.570	34.371	0.001*
Parameters measured	998891.610	6	166481.935	16.013	0.000*
Locations	75665.817	3	25221.939	2.426	0.075**
Error	571806.146	55	10396.475		
Total	3676625.218	84			
Corrected Total	1850745.947	83			
Footnote: R Squared = 0.691 (Adjusted R Squared = 0.534)					

* P< 0.05 and ** P< 0.10.

Leaching soil sample 0.1 EDTA obtained the extract used for determining heavy metals. The concentration of the extracts of elements was determined using an atomic absorption spectrometer. Deductions were made by comparing experimental site mean results with the control site mean result. An element's corrosiveness depends on the relative difference between the experimental site result and the control site. If the experimental site result exceeds the control site result, the outcome is very high (highly corrosive). This implies that the discharge, whether in a solid or liquid state, is highly dangerous to human health, and aquatic life, by inference, dangerous to plant. The outcome will be mild if the experimental site result is slightly higher than the control site value. If they are equal, it implies no harmful effect on both human and aquatic life and by inference to plants. Descriptive tools such as mean and standard deviation were used to compare the results from a different location. Hypotheses were tested within the range of 1-5% confidence levels.

Elements tested at a 5% degree of confidence with a correlation level range of 0.5 and above are highly correlated. Similarly, a correlation level range between 0.4 and below is considered a low correlation value. Elements such as Cadmium (mg/kg), Magnesium (Cmol/kg), Lead (mg/kg), Cadmium (mg/kg), Chromium (mg/kg), Zinc (mg/kg), Manganese (mg/kg), and Copper (mg/kg), were tested at confidence level of 5% the result obtained showed high correlation(r) value of over 0.765 or R^2 = .5852 implying that the mishandling of these elements will result in severe negative human and aquatic health problems. We observed that it is impossible to wipe out the negative effect of these elements completely; rather, we can minimize the environmental effect to a manageable proportion through the public's proper sensitization. Water quality represented by pH (H_20) can be enhanced through proper handling of these dangerous elements.

We also observed the heavy presence of Hazardous Solid Heavy Metal at Rumuorlumeni Dumpsite. To this end, we compared experimental site results and Control Site Parameters. The mean ± standard deviation value of the experimental site value is higher for such elements, such as Lead, zinc cadmium, cobalt, manganese, and iron than the control site value.

4. Conclusions

A hazardous chemical handling planner has the unique ability to choose safer and healthier chemicals and processes and to ensure that the appropriate information on these chemicals is passed to the implementers and ultimately to the workers and handlers of such hazardous chemicals. This diligence will create a safer, healthier workforce where chemical hazards are controlled.

The chemical risk depends on several factors: the hazards of the substance, how it is used, the degree and extent of exposure, and how exposure is controlled. Controlling chemical hazards involves hazard assessment, including anticipating, identifying, assessing, evaluating, and handling hazardous chemical exposure. Monitoring exposure and health surveillance (where applicable), preventing or controlling the risks, developing control measures, informing the general public, and training workers about hazards and controls. The following guideline will help out to be more a bare of the probable dangers in upstream oil and gas industry industries that are highly at risk for high chemical production levels.

A chemical hazard assessment begins with identifying and assessing the chemicals that pose a health or safety risk, the nature of the type and level of exposure that creates a risk, and the operations in which those exposures may take place. Identifying and assessing chemical hazards requires knowledge and technical information. Material safety data sheets are labels with Workplace Hazardous Materials Information System (WHMIS) hazard symbols and other published materials such as Guidance Sheets. Once identified, assessed, and evaluated, the most effective chemical controls can be implemented**.**

The following recommendations on control measures can be used to manage hazardous chemical discharge as it concerns individuals in workplaces and dumpsites.

- Material safety data sheet (MSDS) is a sheet on a given chemical product that includes instructions for the safe use and potential hazards associated with that chemical. The MSDS for a given chemical must be available to all workers on the worksite where the chemical is being used and discharged**.**
- Elimination or substitution controls the chemical hazard by removing the chemical outright from the worksite. Processes are avoided or adjusted to eliminate the need for the chemical, or a safer alternative is used in place of a more hazardous chemical. If elimination or substitution is not possible, engineering controls are the next possible choice.
- Engineering controls eliminate the hazards or support the workers. Engineering controls should always be considered first and includes control, isolation of emission source, and ventilation. Basic engineering controls include basic ventilation or isolation processes that can be done on the spot without assistance, such as opening a window or door or trapping. Advanced engineering controls to design a plant, equipment, or process to minimize the hazard. They include procedures, equipment's, and processes that decrease the source of exposure**.**
- Administrative controls: involve the work process and worker, and include such measures as company policies, safe work procedures, training, work rotation, and signage are often used together with engineering controls.

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