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ENVIRONMENTAL STUDY OF A MAJOR ALUMINUM SULPHATE AND SULPHURIC ACID MANUFACTURER IN LAGOS STATE, NIGERIA, SUB-SAHARAN AFRICA

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Abstract. Environmental pollution poses significant challenges in West African countries and globally, necessitating urgent mitigation efforts. The article presents the results of environmental quality assessment in the territory of the aluminum sulfate and sulfuric acid production plant. The aim was to assess the ecological condition of the studied area and the impact of the company's activities on people and environmental resources. Environmental parameters assessed during the audit include groundwater and soil. Notably, Drury Industries Limited underwent environmental research following its establishment as a leading manufacturer of Aluminum sulphate and Sulphuric acid in West Africa. The company's production lines include Sulphuric acid plant I with a capacity of 80,000MT/Annum and Aluminum sulphate with a capacity of 72,000MT/Annum, crucial for various industrial processes. Situated on a 177,145m^2 land area in Ogun State, Nigeria, the company adhered to environmental regulations such as S.I. 36 of 2009 and S.I. 8 of 1991 to monitor effluent discharge and waste management. The environmental study, conducted in compliance with ISO 14001:2015 standards and national regulations, highlighted key findings and recommendations for Drury Industries Limited. Recommendations included developing an HSE plan, enhancing materials utilization efficiency, and implementing measures for waste management and pollution abatement. The study emphasized the importance of occupational health safety facilities, personal protective equipment, and efficient waste management practices to ensure sustainable operations. Furthermore, the research underscored the company's contribution to government revenue through tax payments at the local, state, and federal levels. By implementing the recommended measures and enhancing existing practices, Drury Industries Limited can not only improve its operational efficiency but also contribute to environmental protection and sustainable development in the region.

Keywords: Aluminum sulphate, Environmental Research, Pollution, Sulphuric acid, West Africa

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ЭКОЛОГИЧЕСКОЕ ИССЛЕДОВАНИЕ КРУПНОГО ПРОИЗВОДИТЕЛЯ СУЛЬФАТА АЛЮМИНИЯ И СЕРНОЙ КИСЛОТЫ В ШТАТЕ ЛАГОС, НИГЕРИЯ, АФРИКА К ЮГУ ОТ САХАРЫ

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Аннотация. Загрязнение окружающей среды представляет собой существенную проблему в странах Западной Африки и во всем мире, требуя принятия срочных мер по смягчению последствий. В статье приведены результаты оценки

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качества окружающей среды на территории завода по производству сульфата алюминия и серной кислоты. Цель исследований - оценка экологического состояния исследуемой территории и воздействия деятельности компании на людей и ресурсы окружающей среды. Экологические параметры, оцениваемые в ходе аудита, включают грунтовые воды и почву. Компания Drury Industries Limited прошла экологический аудит в качестве ведущего производителя сульфата алюминия и серной кислоты в Западной Африке. Производственные линии компании включают завод по производству серной кислоты I мощностью 80 000 тонн в год и сульфата алюминия мощностью 72 000 тонн в год, что имеет решающее значение для различных промышленных процессов. Расположенная на земельном участке площадью 177 145 м^2 в штате Огун, Нигерия, компания придерживается экологических норм, таких как S.I. 36 от 2009 года и S.I. 8 от 1991 года, для контроля сброса сточных вод и управления отходами. Экологический аудит, проведенный в соответствии со стандартами ISO 14001:2015 и национальными нормами, выделил основные результаты исследования и рекомендации для Drury Industries Limited. Рекомендации включали разработку плана HSE, повышение эффективности использования материалов и реализацию мер по управлению отходами и снижению загрязнения. Аудит подчеркнул важность объектов охраны труда, средств индивидуальной защиты и эффективных методов управления отходами для обеспечения устойчивой деятельности. Кроме того, аудит подчеркнул вклад компании в государственный доход за счет налоговых платежей на местном, государственном и федеральном уровнях. Внедряя рекомендуемые меры и совершенствуя существующие методы, Drury Industries Limited может не только повысить свою эффективность, но и внести вклад в защиту окружающей среды и устойчивое развитие в регионе.

Ключевые слова: сульфат алюминия, экологический аудит, загрязнение, серная кислота, западная Африка

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Introduction

Environmental research helps provide a detailed description of a property or establishment to enhance our understanding of material flows and identify areas where waste reduction can lead to cost savings [1]. To ensure its effectiveness, the research must be conducted systematically and thoroughly with full management support [2]. In line with the Stockholm Declaration on Environmental Law, Guidelines and Principles of June 1972 and the Koko episode of 1986, the Federal Government of Nigeria established the Federal Environmental Protection Agency (FEPA) in 1988, which is now integrated into the Federal Ministry of Environment (FMEnv) [3]. «The Federal Environmental Protection Agency Act, CAP 131, LFN, 1990 (as amended) by Decree No. 59 of 1992, established the Federal Environmental Protection agency now the FMEnv. By section 4 of the Decree, the Ministry has responsibility for the protection and development of the environment and biodiversity conservation and sustainable development of Nigeria's natural resources in general and environmental technology including initiation of policy in relation to environmental research and technology. The protection of the Nigerian environment from degradation in its entirety is the responsibility of the FMEnv.

The agency has enacted various regulations to fulfill its mandate. Some of these regulations, relevant to industries, include:

(a) Regulation S.I.36, 2009. National Environmental (Chemical, Pharmaceutical, Soap and Detergent Manufacturing Industries)

(b.) Regulations S.I.8. National Environmental Protection (Effluent Limitation, 1991), which stipulate the regulations regarding the installation of anti-pollution equipment, and the treatment of effluent. It also tabulates important wastewater parameters for selected industrial classifications and spells out effluent limitations and gaseous emissions guidelines for all categories of industries.

(c.) Regulation S.I.9. National Environmental Protection (Pollution Abatement in Industries and Facilities Generating waste) Regulation 1991. This details restrictions on the release of toxic substances and regulations on the monitoring of the pollution units especially with regard to emergencies.

(d.) Regulation S.I.15. National Environmental Protection Management of solid and Hazardous wastes 1991. This gives regulations on the management of solid and hazardous waste and gives a comprehensive list of toxic, hazardous or dangerous wastes.

(e.) The National Guidelines and Standards for Industrial Effluents, Gaseous Emissions and Hazardous Waste Management in Nigeria. (Popularly known as the “FMENV Green Book»). These sets of guidelines are designed to ensure that industrial activities and waste management practices are compatible with the Nation's overall goal of bequeathing a clean and safe environment to present and future generations of Nigerians [4].

These regulations contain important mandatory provisions that facilities generating waste must comply with.

It is worth mentioning that environmental issues are governed by concurrent legislation in the Nigerian constitution. Therefore, each state in the Federation has a Ministry of Environment and a State Environmental Protection Agency (SEPA) or Board. In Ogun State, the Ogun State Environmental Protection Agency (OGEPA) and Ogun state Ministry of Environment (OGMEnv) are responsible for coordinating, monitoring, enforcing, and overseeing environmental policies, programs, and regulations in Ogun state.

To ensure that industries operate in an environmentally friendly manner, section 21 of regulation S.I.9 of 1991 requires the Agency to demand environmental research from existing industries and environmental impact assessments from new industries and major development projects. The industries must comply with these demands within 90 days of receipt.

Section 3 (1) of S.I. No.36 of National Environmental (Chemical, Pharmaceutical, Soap and Detergent Manufacturing Industries) regulations, 2009 also requires every facility to submit an Environmental Impact Statement (EIS) for new industries and major developmental projects before commencing operations.

Existing industries must submit an Environmental Audit Report (EAR) every 3 years [5]. Additionally, if a facility is to be decommissioned, transferred, or alienated for any reason, an EAR must be conducted and submitted to the agency for verification and approval.

In an effort to regulate itself and comply with global and national requirements for sustainable environmental management, Drury Industries Limited commissioned Roygbiv Analytical and Environmental Services Limited to conduct an environmental study of its facility and provide recommendations for improving its environmental management systems.

The Purpose of the Study

The assessment of the facility's environmental quality was conducted in all sections of the factory and immediate environment. The aim was to assess the environmental condition of the study area and the impacts of the company's operations on humans and environmental resources. The environmental parameters assessed during the research exercise include groundwater and soil.

Characteristics of Drury Industries Limited

Drury Industries Limited was incorporated by the Corporate Affairs Commission of the Federal Republic of Nigeria on July 27, 1982, with registration number RC 39426. Established in 1986, Drury Industries Ltd is one of the largest and pioneering manufacturers of Aluminium sulphate and Sulphuric acid on the West Coast of Africa. The company exemplifies self-reliance in the heavy chemicals manufacturing industry.

The sulphuric acid produced in the acid plant is a valuable raw material that improves efficiency in numerous industrial processes.

The factory consists of various production lines, including:

- Sulphuric acid plant I (production capacity of 80,000MT/Annum);

- Aluminium sulphate (production capacity of 72,000MT/Annum).

The operations of the facility may have the following impacts on the environment:

(a) Improper management of industrial solid waste within the facility.

(b) Discharge of effluent wastewater with high oil and grease content, leading to pollution of underground and surface water.

(c) Discharge of effluent wastewater with high oil/grease, BOD, and COD, affecting the quality of receiving surface water and aquatic life.

(d) Gaseous and noise emissions from the facility, which can pollute the air and harm human respiratory and auditory health if the emissions are not well mitigated.

(e) Unmitigated and prolonged heatwaves in the environment would lead to human exhaustion, loss of concentration, reduced productivity, and ultimate systemic collapse in the environment.

Drury Industries Limited is located at Plot 9/18, OPIC Ota Industrial Estate, Agbara, Ogun State (Fig. 1.). The factory lies on the below sketched geographical coordinates. The area is in an industrial layout and is surrounded by several industrial activities (Fig. 2.). The roads in the area provide access for heavy-duty trucks, other companies' cars etc, which carry commuters and loads to and from the area. The land occupies a tot al area of about 177,145 m^2.

Fig. 1. **Administrative Map of Ogun state showing Ado-Odo /**
Рис. 1. **Административная карта штата Огун с указанием Адо-Одо**

Fig. 2. **Aerial View of Drury Industries Limited /**
Рис. 2. **Вид с сверху на Drury Industries Limited**

Process Operation Description

Process Description of Sulphuric Acid

The production of sulphuric acid at Drury is a continuous process using the double contact double absorption process (Fig. 3.). The solid sulphur is melted into liquid sulphur using steam supplied from the steam boiler. The liquid sulphur is charged into the furnace through a jacketed steam pipe and is made to react with dried oxygen from the absorption tower. In the absorption tower, the liquid sulphur is converted to sulphur (IV) oxide gas, which is an exothermic reaction. Heat is generated; hence, this gas is made to pass through a waste heat boiler to reduce the temperature from 900 degrees centigrade to 400 degrees before passing through the first bed of the conversion chamber.

In the converter, sulphur (IV) gas is converted to sulphur (VI) oxide gas in the presence of vanadium pentoxide catalyst. The gas passes through a hot heat and cold heat exchanger, as well as an economizer, to regulate the heat and prevent it from burning the catalyst [6].

The sulphur (VI) oxide gas passes through an inter-pass absorption tower and a final absorption tower. This gas is used to concentrate the sulphuric acid in the acid production tank, resulting in oleum. The oleum is diluted with demineralized water to produce two molecules of concentrated sulphuric acid.

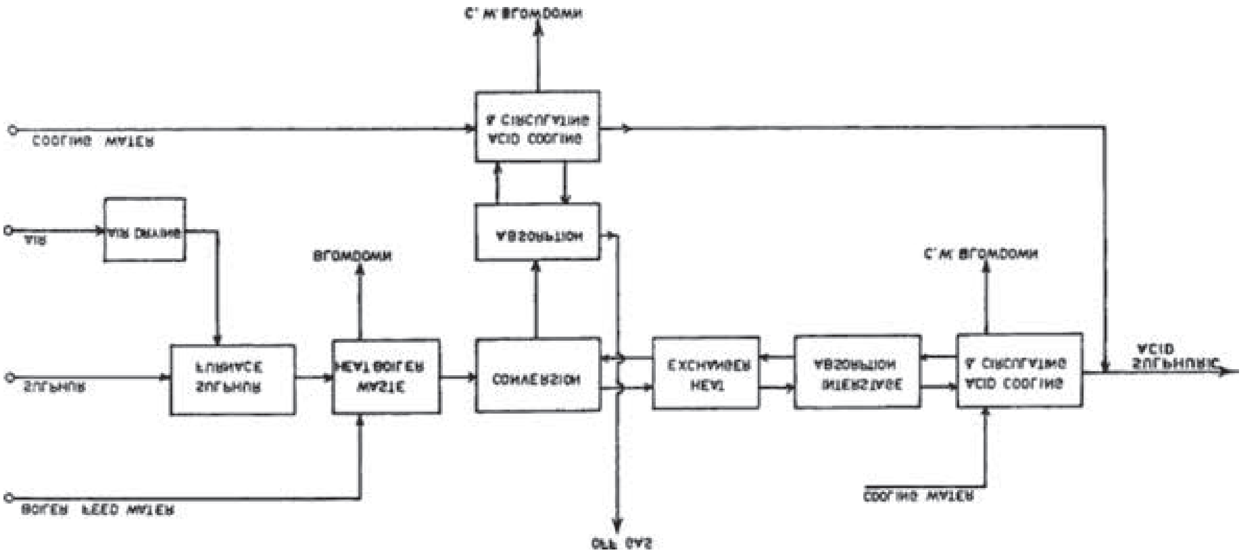

Fig. 3. **Sulphuric Acid production Process Flowchart /** ***Рис. 3.*** **Технологическая схема производства серной кислоты**

Aluminium Sulphate Process Description

Bauxite ore is fed into the feed end of the apron conveyor with the aid of a wheelbarrow. It is then charged into the crusher. The crushed ore is fed to the bucket elevator, which transfers the crushed ore to the mill feed hopper. In the grinding mill, the ore is ground to a fine powder with 80% passing through a 100-mesh sieve. The ground ore is then transferred through a cyclone to the ground bauxite hopper.

The flow from Thickener-2, collected in the leach liquor tank, is pumped to the leach liquor overhead tank for transfer to digester-1 for further enrichment with bauxite. The slurry from the bottom of Thickener-2 is transferred to Thickener-3 after dilution with water, if necessary. The slurry from the bottom of Thickener-3 is taken to one of the vacuum filters for filtration. The filtrate is returned to the leach liquor tank. The product liquor from the product liquor tank is transferred to the evaporator for concentration to about 16-17% Al_2O_3 content.

Steam is supplied to the steam coils provided in the evaporator. Once the desired density (concentration) of the alum is achieved, the mass is transferred to a cooling tray. The cooled product is then broken and further crushed into the desired size of 1-1/2 inches.

The process operation flowchart of Aluminium Sulphate at Drury is as shown in the follow Figure 4.

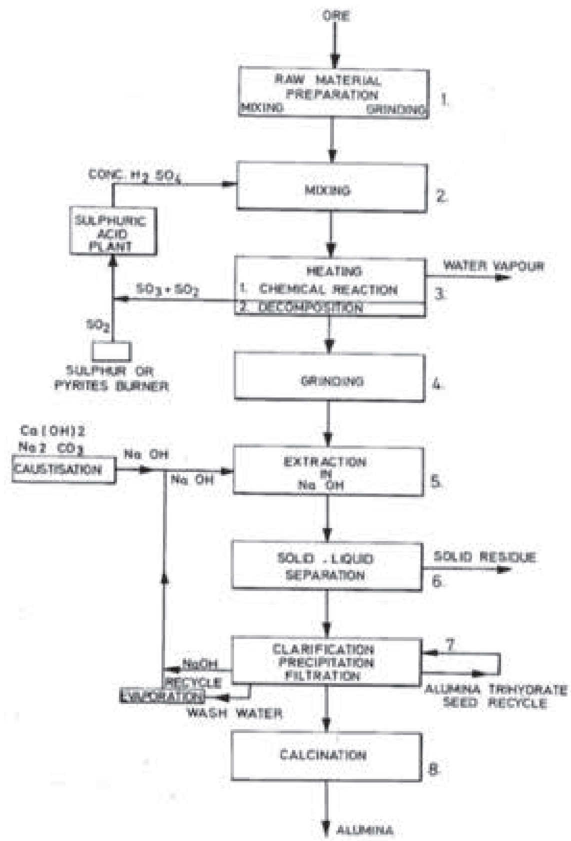

Fig. 4. **The process operation flowchart of Aluminium Sulphate /** ***Рис. 4.*** **Технологическая схема производства сульфата алюминия**

ENVIRONMENTAL ASSESSMENT

Water Quality

Water is one of the most abundant resources on Earth and has been used by humans in several ways: for drinking, household use, cooking, washing equipment, cooling, lubrication, conveyance of materials, steam boilers for heating, and industrial processes [7].

Water quality is an indication of the purity or health of the water resources based on the quantity of pollutants it contains. Water is considered safe when it contains no harmful chemicals, low numbers of coliforms or none at all, and only low levels of other chemicals that become harmful at higher concentrations to humans, other animals, plants, or their ecosystems [8]. Coliform bacteria are an index of contamination. The type of coliform, including Escherichia coli, will determine if the contamination is from fecal sources or recent.

Water is necessary for life on Earth. All organisms contain it; some live in it and some drink it. Plants and animals require moderately potable water, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. If severe, water pollution can kill large numbers of fish, birds, and other animals and in some cases kill all members of a species in an affected area. Then people who ingest polluted water can become ill, and with prolonged exposure, may develop cancers or bear children with birth defects (congenital diseases).

It is quite amazing that the quality of water now available to humans has been adversely affected by activities such as urbanization and industrialization that have derived benefits from it. The need, therefore, to monitor it in an environmental investigation report has become imperative.

In line with the EAR procedure, the water analysis was carried out in an external laboratory and the results of the analysis are hereby presented and discussed below.

Field Sampling. Type of Sample and Location Description

The samples were grab samples, collected at one time from the following locations. See the Table 1 below for the location description in the facility layout [9].

Table 1 / Таблица 1

Sampling Location Description / Описание места отбора проб

Sample Name / Название образца	GPS Coordinates / Координаты GPS	Location Description / Описание местоположения	Date / Дата
Borehole Water	6⁰32'29.6''N 3⁰04'36.8''E Elev:104ft	Borehole water was taken from the designated sampling point at the borehole section	September 28, 2022
Drinking Water	6⁰32'28.2''N 3⁰04'34.8''E Elev:106ft	Drinking water was taken from the designated sampling point of the water treatment plant	September 28, 2022
Wastewater	6⁰32'31.2''N 3⁰04'34.8''E Elev:113ft	Wastewater from the factory was taken at the final discharge point of the drainage channel	September 28, 2022

Results and Discussion

Samples of water and wastewater were collected as detailed in Table 1 for analysis. The table of results of water and wastewater quality is hereby presented after this discussion.

Generally, the result of the water sample collected during the research was relatively good in terms of physical and chemical quality, while the wastewater required treatment.

- Appearance / Colour: The borehole water, drinking water, and discharge wastewater samples were clear and colorless liquid with particles, while the raw effluent was a brownish liquid with particles. The odor of the borehole water and drinking water were unobjectionable in compliance with reference standards, while the odor of the wastewater was objectionable.
- Conductivity: Electrical conductivity, which is a measure of the ionic richness of the water, is considered satisfactory for the samples when compared with specified limits.
- pH: The pH of the collected samples was lower when compared with the reference standards.
- Total Dissolved Solids (TDS) and Total Suspended Solids (TSS): TDS and TSS values of the borehole and drinking water samples were considered satisfactory when compared with the statutory limits. The TSS of the wastewater sample was above the NESREA limit of effluent discharge into the environment.
- Heavy Metals: The trace elements and heavy metals analyzed in the samples were detected in relatively low levels and were within the statutory limits [10].
- Anions: Monovalent, divalent, and tetravalent anions were determined, and they occurred in varying amounts at all sampling stations. These include NO_3-N, NO_2-N, and NH_4+-N (which are different forms of nitrogen in the aquatic ecosystem), phosphates, sulfate, and chlorides.

Compounds of nitrogen and especially those of phosphorus are major cellular components of organisms. They are highly dynamic in the aquatic ecosystem. Of all forms of nitrogen, the most stable and easily utilized is the nitrate derived from the oxidation of nitrite. Aquatic organisms need nitrates as an essential nutrient for primary productivity.

Nitrate, Carbonate, Bicarbonate, Sulfate, and phosphate levels in the borehole sample were detected in relatively low levels.

- Oil and Grease: The oil and grease values in the wastewater sample were satisfactory when compared with the NESREA limit.
- BOD/COD: The Chemical Oxygen Demand (COD) is an expression of the reducing capacity that measures the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The BOD value of the wastewater sample was within the established limit, while the COD value of the wastewater sample was above NESREA specifications for effluent discharge into the environment.
- Biological: The biological parameters of interest are a group of microorganisms which are bacteria called Coliforms. The total coliform count of the borehole water was slightly higher than the limit.

The total plate count of the raw wastewater was higher than the NESREA limit for effluent discharge into the environment.

The health impacts of these different parameters of water quality, as classified by Nathanson, are summarized in Table 2.

Table 2 / Таблица 2

Health Impacts of Parameters / Воздействие параметров на здоровье

Parameters / Параметры	Potential Impact on the Environment / Потенциальное воздействие на окружающую среду
Turbidity, colour, taste and odour	Aesthetically offensive and impair light penetration
Temperature	High temperatures harmful to aquatic life
DO	Fish and other aquatic organisms need DO in water to survive and lack of O2 portends problem
BOD	As biodegradable organic matters are metabolized by bacteria and other microorganisms, oxygen is consumed. The microbes consume the DO in water and so reduce it. The extent to which they do this is the BOD. Therefore, BOD should not be too high.
COD	This is like BOD but refers to the metabolization of all organics including non-organic substances.
TDS	May cause taste problems, hardness, corrosion, or aesthetic problems, if the TDS is too high.
TSS	Causes Turbidity
Hardness	Hardness causes scale deposits in hot water pipes and difficulty in producing lather with soap. On the other hand, very soft water tends to increase corrosion problems in metal pipes, and, some health officials believe, the incidence of heart disease.

Continuation of table 2 / Продолжение таблицы 2

Parameters / Параметры	Potential Impact on the Environment / Потенциальное воздействие на окружающую среду
Metals and trace elements	Iron causes brown or black stains on laundry and on plumbing fixtures. Copper (Cu) and Zinc (Zn) are nontoxic in small concentrations, but they cause undesirable tastes in drinking water. At high concentrations, zinc makes water appear milky.
Fluorides	Contributes to good dental health in moderate amounts. Discolours teeth at higher concentrations.
Chlorides	No taste.
Sulphate	Has objectionable taste, may have laxative effects. In wastewater, it can result in offensive odours from the formation of Hydrogen sulphide. Also leads to corrosion in water pipes.
Nitrogen	Excessive nitrate concentrations in surface waters encourage the rapid growth of microscopic plants called algae', excessive growth of algae degrades water quality. This problem is called eutrophication.
Phosphorous	Like Nitrogen, phosphorous also leads to eutrophication in lakes. It has little effect on health in drinking water.
Toxic substances	The heavy metals Cr, Fe, Ag, Be, CN as also As and Se are toxic, that is, they are poisonous inorganic elements.
Coliforms & E. coli	Biological indicators of pollution.

Source: Nathanson, JA. (1197) Basic Environmental Toxicology (Prentice Hall, Upper Saddle River.

The results of the well water analysis are shown in Table 3.

Table 3 / Таблица 3

Result of Borehole Water Analysis / Результаты анализа воды из скважины

S/N	Test / Тест	Unit / Единица измерения	Method / Метод	Result / Результат	Limit / Норма
1	Appearance		Visual Evaluation (APHA)	Colourless liquid with particles	
2	Odour		Sensory Evaluation (APHA)	Unobjectionable	Unobjectionable
3	Colour	Cu	Colorimetry (APHA)	5.00	50 (Max)
4	Temperature	^0C	Thermometer (APHA)	24.5	
5	Specific gravity	g/cm^3	Pyknometry (APHA)	1.0019	
6	Conductivity	µs/cm	Conductivity meter (APHA)	15.59	
7	Turbidity	NTU	Turbidity meter (APHA)	0.1	
8	pH		pH meter (APHA)	**5.76**	6.5 – 9.2
9	Total solids	mg/l	Gravimetry (APHA)	25.00	1500 (Max)
10	Total dissolved solids	mg/l	TDS meter (APHA)	8.51	
11	Total suspended solids	mg/l	Gravimetry (APHA)	16.49	
12	Total settleable solids	mg/l	Gravimetry (APHA)	0.20	
13	Total hardness ($CaCO_3$)	mg/l	EDTA Titrimetry (APHA)	11.11	500 (Max)
14	Alkalinity	mg/l	Titrimetry (APHA)	13.46	
15	Acidity	mg/l	Titrimetry (APHA)	4.85	
16	Calcium	mg/l	EDTA Titrimetry (APHA)	4.4530	200 (Max)
17	Magnesium	mg/l	Spectrophotometry (APHA)	2.0432	150 (Max)
18	Zinc	mg/l	Spectrophotometry (APHA)	0.0081	15 (Max)
19	Lead	mg/l	Spectrophotometry (APHA)	< 0.01	0.01 (Max)
20	Copper	mg/l	Spectrophotometry (APHA)	0.0066	1.5 (Max)
21	Manganase	mg/l	Spectrophotometry (APHA)	0.0401	0.5 (Max)
22	Cadmuim	mg/l	Spectrophotometry (APHA)	< 0.002	0.006 (Max)
23	Nickel	mg/l	Spectrophotometry (APHA)	0.0157	0.02 (Max)
24	Nitrate	mg/l	Spectrophotometry (APHA)	0.00	50 (Max)
25	Nitrite	mg/l	Spectrophotometry (APHA)	0.0056	2 (Max)
26	Chloride	mg/l	Argentometry (APHA)	7.42	600 (Max)
27	Sulphate	mg/l	Spectrophotometry (APHA)	5.64	400 (Max)
28	Chromium	mg/l	Spectrophotometry (APHA)	< 0.006	0.03 (Max)
29	Iron	mg/l	Spectrophotometry (APHA)	0.7468	1.0 (Max)
30	Sodium	mg/l	Spectrophotometry (APHA)	5.36	
31	Faecal streptococcus	cfu/100ml	Pour plate technique (APHA)	0	0
32	Total plate count	cfu/ml	Pour plate technique (APHA)	0	
33	Total coliform count	cfu/ml	Pour plate technique (APHA)	0	10
34	E. coli	cfu/100ml	Pour plate technique (APHA)	Absent	Must be absent

Comments: Majority of the analyzed parameters complied with NESREA specification for Ground water except pH.

The result of Drinking Water Analysis is shown in Table 4.

Table 4 / Таблица 4

Result of Drinking Water Analysis / Результат анализа питьевой воды

S/N	Test / Тест	Unit / Единица измерения	Method / Метод	Result / Результат	Limit* / Норма
1	Appearance		Visual Evaluation (APHA)	Colourless liquid	
2	Taste		Sensory Evaluation (APHA)	Unobjectionable	Unobjectionable
3	Odour		Sensory Evaluation (APHA)	Unobjectionable	Unobjectionable
4	Colour	Cu	Colorimetry (APHA)	1.00	
5	Temperature	^{0}C	Thermometer (APHA)	24.80	
6	Turbidity	NTU	Turbidity meter (APHA)	0.05	
7	Conductivity	μs/cm	Conductivity meter (APHA)	35.6	1000 (Max)
8	pH		pH meter (APHA)	6.78	6.5 - 8.5
9	Total solids	mg/l	Gravimetry (APHA)	40.00	
10	Total dissolved solids	mg/l	TDS meter (APHA)	19.54	500 (Max)
11	Total suspended solids	mg/l	Gravimetry (APHA)	0.00	
12	Total hardness ($CaCO_3$)	mg/l	EDTA Titrimetry (APHA)	15.15	150 (Max)
13	Calcium	mg/l	EDTA Titrimetry (APHA)	6.0721	
14	Magnesium	mg/l	Spectophotometry (APHA)	2.2635	20 (Max)
15	Chloride	mg/l	Argentometry (APHA)	4.99	250 (Max)
16	Residual chloride	mg/l	Iodometric (APHA)	0.00	0.25 (Max)
17	Alkalinity	mg/l	Titrimetry (APHA)	48.96	
18	Sulphate	mg/l	Spectrophotometry (APHA)	1.71	100 (Max)
19	Bicarbonate	mg/l	Titrimetry (APHA)	59.78	
20	Carbonate	mg/l	Titrimetry (APHA)	0.00	
21	Nitrite	mg/l	Spectrophotometry (APHA)	0.0056	0.2 (Max)
22	Iron	mg/l	Spectrophotometry (APHA)	0.0459	0.3 (Max)
23	Manganese	mg/l	Spectrophotometry (APHA)	0.0775	0.2 (Max)
24	Copper	mg/l	Spectrophotometry (APHA)	0.0055	1 (Max)
25	Chromium	mg/l	Spectrophotometry (APHA)	< 0.006	0.05 (Max)
26	Cadmium	mg/l	Spectrophotometry (APHA)	< 0.002	0.003 (Max)
27	Nitrate	mg/l	Spectrophotometry (APHA)	0	50 (Max)
28	Zinc	mg/l	Spectrophotometry (APHA)	< 0.001	3 (Max)
29	Lead	mg/l	Spectrophotometry (APHA)	< 0.010	0.01 (Max)
30	Sodium	mg/l	Spectrophotometry (APHA)	13.80	100 (Max)
31	Nickel	mg/l	Spectrophotometry (APHA)	0.0169	0.02 (Max)
32	Aerobic mesophilic count	cfu/ml	Pour plate technique (APHA)	66	
33	Total coliform count	cfu/ml	Pour plate technique (APHA)	**42**	10

*LIMIT: NIS 554:2015 - Nigerian Industrial Standard for Drinking Water.

Comments: Majority of the analyzed parameters complied with NIS specification for Drinking water except Total coliform count.

The result of Drainage of Wastewater is shown in Table 5.

Table 5 / Таблица 5

Result of Drainage Wastewater / Результаты анализа дренажных сточных вод

S/N	Test / Тест	Unit / Единица измерения	Method / Метод	Result / Результат	Limit* / Норма
1	Appearance		Visual Evaluation (APHA)	Colourless liquid with particles	
2	Odour		Sensory Evaluation (APHA)	Objectionable	
3	Colour	Cu	Colorimetry	5.00	
4	Temperature	^{o}C	Thermometer (APHA)	23.0	
5	Specific gravity	g/cm^3	Pyknometry (APHA)	1.0019	
6	Conductivity	μs/cm	Conductivity meter (APHA)	560	

Continuation of table 5 / Продолжение таблицы 5

S/N	Test / Тест	Unit / Единица измерения	Method / Метод	Result / Результат	Limit* / Норма
7	Turbidity	NTU	Turbidity meter (APHA)	1.00	
8	pH		pH meter (APHA)	3.30	6 – 9
9	Total solids	mg/l	Gravimetry (APHA)	535.00	
10	Total dissolved solids	mg/l	TDS meter (APHA)	402.5	
11	Total suspended solids	mg/l	Gravimetry (APHA)	132.50	10 (Max)
12	Total settleable solids	mg/l	Gravimetry (APHA)	1.00	
13	Total hardness ($CaCO_3$)	mg/l	EDTA Titrimetry (APHA)	126.25	
14	Alkalinity	mg/l	Titrimetry (APHA)	0.00	150 (Max)
15	Acidity	mg/l	Titrimetry (APHA)	48.50	
16	Calcium	mg/l	EDTA Titrimetry (APHA)	50.60	
17	Magnesium	mg/l	Spectrophotometry (APHA)	1.61	
18	Zinc	mg/l	Spectrophotometry (APHA)	0.1156	5.0 (Max)
19	Lead	mg/l	Spectrophotometry (APHA)	< 0.01	0.1 (Max)
20	Copper	mg/l	Spectrophotometry (APHA)	0.0493	1.0 (Max)
21	Manganese	mg/l	Spectrophotometry (APHA)	0.2118	1.0 (Max)
22	Cadmium	mg/l	Spectrophotometry (APHA)	0.0029	0.1 (Max)
23	Nitrate	mg/l	Spectrophotometry (APHA)	1.945	
23	Chloride	mg/l	Argentometry (APHA)	13.61	
24	Sulphate	mg/l	Spectrophotometry (APHA)	246.87	100 (Max)
25	Iron	mg/l	Spectrophotometry (APHA)	1.8185	
26	Chromium (hexavalent)	mg/l	Spectrophotometry (APHA)	0.0405	0.5 (Max)
27	BOD_5	mg/l	DO meter (APHA)	13.00	20 (Max)
28	COD	mg/l	Closed reflux, colorimetry (APHA)	81.90	40 (Max)
29	Nickel	mg/l	Spectrophotometry (APHA)	0.0323	0.1 (Max)
30	Sodium	mg/l	Spectrophotometry (APHA)	5.43	200 (Max)
31	Dissolved oxygen (DO)	mg/l	DO meter (APHA)	6.70	
32	Oil and grease	mg/l	Gravimetry (APHA)	1.40	10 (Max)

*Limit - National Environmental Standards and Regulations Enforcement Agency (NESREA)National Environmental (Chemical, Pharmaceutical, Soap and Detergent Manufacturing Industries) Regulation, 2009 Schedule.

Comments: Majority of the parameters analyzed complied with NESREA specification for Effluent water except; pH, Total suspended, solid, Sulphate, COD and Total plate count.

Soil Quality Studies

Soil is not only a support for vegetation, but it is also the zone beneath our feet (the pedosphere) of numerous interactions between climate (water, air, temperature), soil life (micro-organisms, plants, animals), and its residues, the mineral material of the original and added rock, and its position in the landscape. During its formation and genesis, the soil profile slowly deepens and develops characteristic layers, called 'horizons', while a steady-state balance is approached. Soil contaminant or soil pollution is caused by the presence of xenobiotic (human-made) chemicals or other alterations in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals, or improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, polynuclear aromatic hydrocarbons (such as naphthalene and benzo(a)pyrene), solvents, pesticides, lead, and other heavy metals. Contamination is correlated with the degree of industrialization and intensity of chemical usage.

The concern over soil contamination stems primarily from health risks, from direct contact with the contaminated soil, vapor from the contaminants, and secondary contamination of water supplies within and underlying the soil. Mapping of contaminated soil sites and the resulting cleanups are time-consuming and expensive tasks, requiring extensive amounts of geology, hydrology, chemistry, computer modeling skills, and GIS in Environmental Contamination, as well as an appreciation of the history of industrial chemistry. The need, therefore, to monitor it in any environmental report has become imperative as established in the statutory regulatory guidelines and standards of FMEnv and NESREA [11].

As part of the statutory exercise, Roygbiv Analytical and Environmental Services Limited took soil samples from the predetermined location for monitoring and carried out the analysis in accordance with the reference guidelines/standards. The results of the analysis are hereby presented and discussed as follows.

Sampling

Soil samples were collected at a location adjacent to the Production Section in the factory (Table 6). Topsoil (0-15 cm) samples were taken with the aid of a 90 cm diameter Dutch soil auger, mixed to form a composite sample, and put into labeled (coded) aluminum foil and polythene bags.

Table 6 / Таблица 6

Sampling Location / *Место отбора проб*

Sample Location Description / Описание места отбора проб	GPS Coordinates / Координаты GPS	Type Of Sample Collected / Тип образца	Date / Дата
Sample of soil was collected adjacent to the production section in the factory	6032'28.8"N 3004'38.6"E Elev: 133ft	Composite of top-soil and sub-soil	28-09-2022

Methodology

The soil sample was analyzed for physico-chemical and microbiology parameters (Table 7).

Table 7 / Таблица 7

Summary of Methodology for Soil Analysis / Краткое изложение методологии анализа почвы

S/N	Parameter / Параметры	Method Description / Описание способа
1	pH	Electrode (Meter)
2.	Exchangeable Cation - Na+, K+, Mg2+, Ca2+	Atomic Absorption Spectrophotometer
3.	Chloride	Titration (Silver Nitrate)
4.	Sulphate	Turbidimetric
5.	Nitrate	Colorimetric
6.	Phosphate	Colorimetric
7.	Total Hydrocarbon content	Gas Chromatography
8.	Conductivity	Digital Meter
9.	Particle Size Distribution	Gravimetric
10.	Heavy metals	Atomic Absorption Spectrophotometer

Soil Texture

Soil texture is a property used to describe the relative proportion of different grain sizes of mineral particles in soil. These particles are grouped into soil separates, which include clay, silt, and sand (Table 8 - USDA Classification). The soil texture class, such as sand, clay, loam, etc., corresponds to a specific range of separate fractions. Coarse-textured soils have a high proportion of sand, medium-textured soils are primarily composed of silt, and fine-textured soils consist mainly of clay [12].

Table 8 / Таблица 8

USDA Classification of Soil by Diameter Limits / Классификация почв USDA по предельным диаметрам

Name of soil separate / Название вида почвы	Diameter limits (mm) (USDA classification) / Предельные диаметры (мм) (классификация USDA)
Clay	less than 0.002
Silt	0.002 - 0.05
Very fine sand	0.05 - 0.10
Fine sand	0.10 - 0.25
Medium sand	0.25 - 0.50
Coarse sand	0.50 - 1.00
Very coarse sand	1.00 - 2.00

Results of Analysis

The results of physico-chemical analysis of the soil sample from the study area are presented in Table 9 below.

Table 9 / Таблица 9

Physico-Chemical and Microbial Characteristics of Soil Sample / Физико-химические и микробные характеристики образца почвы

S/N	Test Parameters / Параметры исследования	Unit / Единица измерения	Method / Метод	Result / Результат	Limit / Норма
1	Appearance		Visual Evaluation	Dark brown coarse loamy soil	
2	Permeability	cm/sec	Falling head method ASTM D2434	0.0383	
3	Porosity	%	Pore volume method ASTM D152h	16.67	
4	Bulk density	g/cm^3	AOAC	1.088	
5	Sand	%	Jar/hydrometer ASTM D152h	63.33	
6	Silt	%	Jar/hydrometer ASTM D152h	20.00	
7	Clay	%	Jar/hydrometer ASTM D152h	16.67	
8	pH @ 25^{0}C		pH Meter (APHA)	7.80	6 – 9
9	Moisture content	%	AOAC	16.3126	
10	Electrical conductivity	mS	Conductivity Meter (APHA)	0.04	1000 (Max)
11	Total organic carbon	%	APHA	1.74	
12	Total organic matter	%	Loss on ignition ASTM D2874	3.00	
13	Total nitrogen	%	Kjeldahl	16.10	
14	Nitrate	mg/kg	Spectrophotometry (APHA)	96.60	20 (Max)
15	Sulphate	mg/kg	Spectrophotometry (APHA)	116.20	500 (Max)
16	Phosphate	mg/kg	Spectrophotometry (APHA)	154.17	5 (Max)
17	Calcium	mg/kg	Spectrophotometry (APHA)	428.203	
18	Magnesium	mg/kg	Spectrophotometry (APHA)	36.002	2500 (Max)
19	Sodium	mg/kg	Spectrophotometry (APHA)	110.03	
20	Potassium	mg/kg	Spectrophotometry (APHA)	9.45	
21	Iron	mg/kg	AAS	288.201	
22	Copper	mg/kg	AAS	0.629	100 (Max)
23	Zinc	mg/kg	AAS	6.974	421 (Max)
24	Nickel	mg/kg	AAS	0.237	70 (Max)

Continuation of table 9 / Продолжение таблицы 9

S/N	Test Parameters / Параметры исследования	Unit / Единица измерения	Method / Метод	Result / Результат	Limit / Норма
26	Lead	mg/kg	AAS	3.360	164 (Max)
27	Cadmium	mg/kg	AAS	0.056	3 (Max)
28	Chromium	mg/kg	AAS	0.658	100 (Max)
29	Total heterotrophic bacteria	cfu/g	Pour plate technique (APHA)	810	
30	Total heterotrophic fungi	cfu/g	Pour plate technique (APHA)	525	
31	Hydrocarbon utilizing bacteria	cfu/g	Pour plate technique (APHA)	200	
32	Hydrocarbon utilizing fungi	cfu/g	Pour plate technique (APHA)	175	
33	Faecal coliform	cfu/g	Pour plate technique (APHA)	290	

Discussion

(i) Particle Size Distribution: The result of the analysis of the soil texture (particle size distribution) of the soil sample collected during the study shows that the soil is basically sandy, as presented in Table 3.12 [3].

(ii) pH: The pH of the composite soil sample was 7.8. The value was within the FMEnv limit.

(iii) Conductivity: The conductivity of the composite soil sample was 0.04 mS, which was satisfactory when compared to the FMEnv limit. Hence, there is no indication that the conductivity of the soil in the study area has significantly been affected by their operations.

(iv) Exchangeable Cation and Anion: The exchangeable cations analyzed in the composite soil sample from the factory had the following values: Sodium (Na) 110.03 mg/kg, Potassium (K) 9.45 mg/kg, Calcium (Ca) 428.203 mg/kg, and Magnesium (Mg) 36.002 mg/kg.

Phosphate and Nitrate were present in the soil sample at levels higher than the specified limit of FMEnv, while Sulphate was within the specified limits. It could be attributed to the nature of the soil in the area.

(v) Soil Heavy Metals: The trace metals in the composite soil sample were generally at low concentrations, as are normally found in the composite soil sample of the ambient soil environment and when compared with the statutory limit of the FMEnv Regulations.

Iron (Fe) (a corrosion indicator metal) concentration was 288.201 mg/kg. The following toxic metals: Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu), Zinc (Zn) had concentrations of 8.84 mg/kg, 0.056 mg/kg, 0.658 mg/kg, 0.00 mg/kg, 12.80 mg/kg, and 0.02 mg/kg for sample location, respectively.

Conclusion on Soil Study

The pH, conductivity, exchangeable cations and anions, and heavy metals of the soil sample collected within the premises of the factory were generally at low concentrations, as are normally found in the area. Hence, the soil result does not elicit any cause for concern.

Impact and Compliance Evaluation

The real and potential impacts of the operations of the factory on the environment are through the following:

Wastewater

The wastewater is generated from process, utilities, and cloakroom. The black water from toilet is channeled into septic tanks. The tanks are evacuated when required by OGWAMA accredited waste managers to appropriate waste dumpsite.

The result of wastewater analyzed revealed low pH, high total suspended solids, sulphate, COD, and total plate count as against the effluent limitation standard for disposal into the environment.

The quality of wastewater discharged should be improved by installing Effluent Treatment Plant (ETP) for proper treatment of wastewater or immediately implementing the wastewater recovery plan to prevent further discharges into the environment [13].

The quality of the drainage wastewater should be monitored monthly by an accredited environmental consultant and results submitted to NESREA and OGEPA.

Solid Waste

Solid wastes generated would cause a mild adverse impact on land based on the management strategies. Please see table 4.1 and 4,2 for details. Solid waste streams are properly disposed of by OGWAMA assigned waste managers to government approved dumpsite.

Recommendation:

Standard central waste collection point with concrete base and shed should be constructed at a designated location within the factory.

Handling and storage of alum sludge should be improved upon by installing shed over the sludge storage unit.

Management should ensure prompt evacuation of solid waste by OGWAMA waste manager.

Routine tracking of the waste collected from factory premise is part of the responsibilities of the Drury to ensure proper disposal at designated dumpsite.

Air Quality

Gaseous emissions from the machineries would have a negative impact on the environment if not responsibly managed.

From the result of analysis and field studies carried out during the exercise, it was observed that there is likelihood of accumulation of particulate matter in the area. PM10 and Total Particulate Matter (TPM) values in most locations in the factory were lower than the FMEnv/NESREA specification of 50 mg/Nm^3 except at the Alum Plant (Milling, Crushing/Bagging unit) and Acid plant (Sulphur melting unit). These were however, localized to a large extent within the areas of generation. Meanwhile air quality survey of strategic locations within the factory indicated that most of the parameters analyzed for were within statutory limits. Please see tables 3.6 and 3.7 for details.

Recommendation:

Required and basic PPE must be mandated for use in the production area.

Pollution control abatement should be regularly serviced.

Noise

Noise generation in the factory would have a significant negative impact on the staff if appropriate control measures were not put in place. Noise levels in most of the locations within production floors were within FMEnv/NESREA specifications except at the Boiler house and Generator house which were above the limit.

Recommendation:

The unit should be tagged high noise area.

PPE should be mandated for use in the area.

Generators and boilers should be regularly serviced.

The generator should be installed on the dampers to reduce vibration and noise.

Environmental Monitoring Plan and Implementation

The overall objective of (performance) monitoring shall be to identify any unanticipated changes to the biophysical, health and social environment brought about by Drury Industries Limited operational activities.

Drury shall ensure that deviations from baseline and research findings beyond reasonable limits shall trigger corrective actions so that monitoring becomes a dynamic activity as opposed to a passive collection of data.

This environmental monitoring plan has been formulated with the aim of ensuring that all the identified significant impacts from the project are mitigated to as low as reasonably possible and that key performance indicators are monitored periodically to track how effectively mitigation measures are implemented. It specifies the mitigation measures, monitoring requirements, duration and frequency of the monitoring, action parties to manage the biophysical, social and health environment at the various phases of the project and the financial implications [14].

The plan relates to the handling of hazardous materials and wastes, emission and discharge monitoring, site inspection and auditing, adverse weather preparedness, and decommissioning. In formulating this plan. Drury Industries Limited ensured that the plan takes account of national and international standards for (environmental) planning, such as the ISO, HSE-MS, NESREA and FMEnv Regulatory control measures and self-imposed standards. The national regulatory agencies in conjunction with the relevant states and local government authorities shall conduct routine impact mitigation monitoring visits as and when due [15].

Generally, «Green Auditing", an umbrella term, also known as "Environmental Auditing" should be adopted to secure the health safety and optimize productivity of most establishments. The 'Green Audit' aims to analyze environmental practices within and outside the appropriate establishments, which will have an impact on the eco-friendly ambience to sustain economic growth [16].

Conclusion

In conclusion, the recommendations outlined highlight the necessity for Drury Industries Limited to adopt a proactive approach in managing noise and environmental impacts associated with its operations.

By designating the unit as a high-noise area and mandating the use of personal protective equipment (PPE), the company can significantly enhance worker safety and well-being. Regular servicing of generators and boilers, along with installing dampers to mitigate vibrations, will further reduce noise pollution and promote a healthier work environment.

The proposed Environmental Monitoring Plan is crucial for tracking the impacts of operational activities on the biophysical, health, and social environments. By establishing a dynamic monitoring system that triggers corrective actions for any deviations beyond acceptable limits, Drury Industries will ensure that environmental management is an ongoing, responsive process rather than a static obligation.

Ultimately, adopting a «Green Auditing» approach will not only safeguard the health and safety of personnel but also optimize productivity and foster a sustainable operational model. This commitment to environmental stewardship aligns with national and international standards, ensuring compliance and contributing to the broader goal of eco-friendly economic growth.

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