# Environmental and Social Management Plan (ESMP)

*FOR*

**FEED CONDITIONING UNIT (FCU2) IN IEFCL-TRAIN2 PROJECT**

*WITHIN*
**INDORAMA COMPLEX**
**ELEME, PORT HARCOURT, RIVERS STATE**

**BY**

**INDORAMA ELEME FERTILIZER & CHEMICALS LTD,**
**ELEME, PORT HARCOURT, RIVERS STATE, NIGERIA**

**2019**

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**ABBREVIATIONS**

| | |
|---|---|
| % | Percentage |
| BOD | Biochemical Oxygen Demand |
| $CO_2$ | Carbon-Dioxide |
| CO | Carbon-Monoxide |
| COD | Chemical Oxygen Demand |
| CPI | Corrugated Plate Interceptor |
| CxHy | Total Hydrocarbon |
| DCS | Distributed Control System |
| DO | Dissolved Oxygen |
| E | East |
| EIA | Environmental Impact Assessment |
| EIS | Environmental Assessment Statement |
| EMP | Environmental Management Plan |
| ESD | Emergency Shutdown System |
| ESMS | Environmental and Social Management System |
| ESMP | Environmental and Social Management Plan |
| ETP | Effluent Treatment Plant |
| FCU | Feed Conditioning Unit |
| F&G | Fire and Gas |
| FMEnv | Federal Ministry of Environment |
| GHG | Greenhouse gas |
| HC | Hydrocarbons |
| $H_2S$ | Hydrogen Sulphide |
| HT | High Temperature |
| EHS | Health Safety and Environment |
| IEFCL | Indorama Eleme Fertilizer Company Limited |
| IEPL | Indorama Eleme Petrochemicals Limited |
| IFC | International Finance Corporation |
| IPCC | Intergovernmental Panel on Climate Change |
| JT | Joule-Thompson |
| KOD | Knock-out Drum |
| LGA | Local Government Area |
| LT | Low Temperature |

| | |
|---|---|
| MDEA | Methyl diethanolamine |
| MMSCFD | Million Metric Standard Cubic Feet a Day |
| Mol | Mole |
| M3/HR | Cubic meter per hour |
| N | North |
| NAOC | Nigerian Agip Oil Company |
| NESREA | National Environmental Standards Regulatory Agency |
| NG | Natural Gas |
| NOx | Nitrogen Oxide |
| $O_2$ | Oxygen |
| $O_3$ | Ozone |
| O&G | Oil and Grease |
| $^oC$ | Degree Celsius |
| PAC | Project Advisory Committee |
| PPEs | Personal Protective Equipment |
| Ppm | Part per million |
| Ppmw | Part per million weight |
| PM10 | Particulate Matter -10µm |
| PM2.5 | Particulate Matter -2.5µm |
| PO4 | Phosphate |
| SOx | Sulphur Oxide |
| SPM | Suspended Particulate Matter |
| TDS | Total Dissolve Oxygen |
| TSS | Total Suspended Solid |
| TPH | Ton Per Hour |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UOP | Universal Oil Products |
| USA | United State of America |
| VOC | Volatile Organic Carbon |
| Wt | Weight |

## EXECUTVE SUMMARY

The Environmental and Social Management Plan (ESMP) for the inclusion of FCU2 unit in ongoing construction of IEFCL-Train2 Project within Indorama Complex, Eleme, Rivers State is proposed by Indorama Eleme Fertilizer & Chemicals Limited. The construction and operation of FCU2 shall be a part of IEFCL-Train2 project. IEFCL have ESIA approval for IEFCL-Train2 Project and the FCU2 unit shall be a precursor of the IEFCL-Train2 Ammonia and Urea Plants. IEFCL also have the approved EMP for inclusion of FCU2 in IEFCL-Train2 project.

IEFCLs Train 1 Fertilizer is already equipped with FCU unit which, has proven very successful in removing $CO_2$, $H_2S$, Sulphur compounds and heavies from the Natural Gas and has proven the environmental, social and economic sustainability by reducing stack and greenhouse gas (GHG) emissions, waste generation and enhancing cleaner operations and productivity. The advantage of this technology therein, have to be transferred to IEFCL-Train2 Project.

The FCU2 will be located adjacent to FCU1 and very close to the gas receiving station of IEFCL-Train2 with a land take of 0.96 hectares within the Indorama Complex in Eleme Local Government of Rivers State, Nigeria, geographically within Latitude 4°49'N and Longitude 7°6'E. Considering the sensitivity of the location and the nature of business to be carried out by inclusion of this unit, all applicable State and Federal Government of Nigeria and International Regulations/Laws/Conventions were reviewed. Also the Institutional Agencies and FMEnv, were adequately consulted.

The description and scope of the FCU2 unit activities were undertaken after study of tentative compositions and quantification of input and output of the process and existing facilities, so as to clearly show the physical linkage and synergy that would be derived during additional works and operations of the FCU2. Appropriate drawings and sketches were used to enhance the understanding of proposed additional works and the processes/control systems to be adopted. Capacities of proposed works including manpower demands as well as duration of works, were adequately addressed. The process was reviewed in terms of reduction of GHG emissions and estimated that inclusion of FCU2 unit in IEFCL-Train2 shall reduce GHG emissions by approximately 112,000 TPA CO2e.

The environmental and social studies indicate good climatic conditions with distinct dry and wet season influenced by wind directions. The seasonal wind shift that brings rain (wet monsoon) via South-Westerly wind between March to early November and usher in dry season (dry monsoon) via North-Easterly wind between December to February. The ambient air quality is good and quality parameters are within specified limits. The ambient air quality in the area is controlled by local weather condition and particularly the strength of the North-East and South-West trade winds that are prevalent in the area during the dry and wet seasons respectively. Day and night noise level monitored are within the limits. The gaseous emissions are discharged via stack at an appropriate height and quality parameters monitored are within the specified limits. The soils quality of the area characterized with very good physical features, poor inherent fertility status, low degree of acidity, low cation exchange capacity and predominant sandy texture. The nearest water body is Okulu stream which is the recipient of complex water, located approximately 1.5km from the complex, the water and sediment quality and; hydrological exhibit the good carrying capacity of water body. The groundwater quality is good with West to East flow direction. Endangered and endemic species as per the list of International Union for Conservation of Nature (IUCN 2009), are not present in the area.

Four communities namely, Agbonchia, Aleto and Akpajo in Eleme Local Government Area and Elelenwo in Obio/Akpor were surveyed for socio-economic and health study. Settlement pattern in communities are nucleated. All the settlement layouts are densely built and occupied with streets and lengthy roads. The estimated population with growth rate of 3.4%; Agbonchia - 25,876, Elelenwo 24,491, Akpajo 14,404 and Aleto 17,678 in 2017. The male population is 57% and female is 43%. The occupation distribution, 48% for self-employed, 21% for those who work in government offices, 12% for company workers and 19% unemployed. Under the category of self-employed 56% are business men & women and contractors, those involved in farming represents 29%, trading 12% and others 3%. The mean daily income of people is ₦1000, which higher than the national minimum wage. Outside the large industries in Eleme local government area, the other common enterprises are contractors, vendors, welding/ fabrication workshops, sand mining, and traditional food processers. The domestic water source is mainly shallow boreholes. The means of transportation in communities are motor, bicycles, 2-stroke tri-cycles and buses.

Every community has model primary and secondary school. Adult literacy rate in the study communities is commendable. Mostly, residents are live in their own houses. Majority of the houses are constructed with concrete blocks and roofed with corrugated iron sheets. The four activities dominate the cultural calendar of communities namely; wrestling, traditional marriages, new yam festival and dances; and the social affiliation in the societies includes politics, co-operatives, social clubs, education, religion and cultural associations. The Health Assessment was conducted in and around the facilities and the communities to determine the characteristics of the health status of area. These communities were sampled by the health personnel to obtain information regarding mortality and morbidity rates, types of health hazards, most prevalent diseases, disease vectors, nutrition, health facility infrastructure capability and usage, average family size, sexual reproductive health, immunization status and coverage, sewage and waste management system, air quality, water quality, radiation sources and levels. The state of health delivery facilities/services in the study area is below standards expected of an urban area. The principal communicable diseases in the area are Malaria, Diarrhea, skin rashes, upper respiratory tract infections and STIs. While prevalent non-communicable diseases in the area are hypertension, food poisoning and occupational injury.

The assessment of potential/associated impacts, positive and negative were identified considering the IEFCL-Train2 project approved ESIA report. The positive impacts such as reduction in greenhouse gas emission (GHG), employment and Skills acquisition opportunities, enhancement of commercial businesses, benefits from corporate social projects were adjudged to be of long term. Negative impacts such as Noise from Vehicular movement and ambient air quality disruption were adjudged to be short term and not significant.

Mitigation measures were proffered for all negative impacts during Construction phase of FCU2 activities and also during Operations and Decommissioning/ Abandonment phases. The FCU2 is being designed for design life of thirty (30) years, although strict adherence to Standard Operating Procedures and the Environmental Monitoring Plan proposed could extend the lifespan of the Project to 35-40 years.

The proposed FCU2 unit will be a part of IEFCL-Train2 Project, which is under construction. The Environmental and Social Management System (ESMS) and Plans (ESMP) proffered in IEFCL-Train2 approved ESIA, shall be followed during construction and operation of FCU2 unit. Additionally, this ESMP report indicate that the committed and dedicated adherence to the Management Guidelines, Mitigative measures and Monitoring plan proffered in the ESMP will indeed limit the negative impacts identified and improve IEFCLs Management decisions for sustainability of the project in a sustainable environment.

## ACKNOWLEDGEMENT

The management of Indorama Eleme Fertilizer & Chemicals Limited (IEFCL) wishes to acknowledge the opportunity granted by the Government of Federal Republic of Nigeria through the Ministry of Environment to conduct this ESMP for the proposed inclusion of Feed Conditioning Unit (FCU2) in ongoing construction of IEFCL-Train2 Project.

We appreciate the cordial working relationships we had with the Federal Ministry of Environment, the Rivers State Ministry of Environment in the course of the project.

Thank you

IEFCL Management

# CHAPTER ONE

# INTRODUCTION AND BACKGROUND INFORMATION

## 1.0 Introduction

Indorama Eleme Fertilizers & Chemicals (IEFCL) is proposing to install Feed conditioning unit (FCU2) as the precursor of Ammonia and Urea Plants in the upcoming IEFCL-Train2 Project.

Indorama had installed FCU1 as part of IEFCL-Train1 project and is already a part of the operation in IEFCL-Train1 and has proven to be very successful in removing Carbon Dioxide, Sulphur compounds and heavy hydrocarbons from the Natural Gas received from NAOC. The benefits of the addition of FCU in to IEFCL-Train1 ensured efficient and clean feed of natural gas to ammonia process and hence enhancing the productivity. The separation of Carbon Dioxide from Natural gas and use in Urea production, resulting in reduction of greenhouse gas emission. The advantage of this technology and benefits therein, are being transferred to IEFCL-Train2 project.

“This ESMP is one of the outcomes of the ESIA study that was carried out for the IEFCL-Train-2 facility. For clarity and consistency, it should be reviewed concurrently with the ESIA report of the IEFCL-Train-2 Project”

## 1.1 Background information

Indorama Eleme Fertilizer & Chemicals Limited (IEFCL) is a group company of Indorama Corporation. The Proponent (IEFCL) successfully completed construction of the first Train in December 2015 while commissioning activities were concluded in June 2016 and the commercial production started in Oct 2016. The IEFCL-Train1 Plant includes Feed conditioning Unit (FCU), 2,300 Metric Tons Per day (MTPD) ammonia plant, 4,000 MTPD Urea granulation plant and associated offsite and utilities. The fertilizer plant is well supported by port terminal at the nearby Onne port, and a gas pipeline of 83.5KM for gas supply.

The proven technology from international technology licensors were employed in the IEFCL-Train1 facilities which are already in operation. The IEFCL-Train1 plant has also proven to be

economically viable, with a minimal environmental, social and health impacts to personnel and the environment.

Considering the facts, the proponent decided for expansion of fertilizer production capacity by adding one more line IEFCL-Train2 of same capacity and same technology. IEFCL-Train2 project will be a replica of the IEFCL-Train1 plant. Post commissioning of IEFCL-Train2, the total production capacity shall be 8,000 MTPD of granular Urea.

For IEFCL-Train2 project, the proponent have approved ESIA from Federal Ministry of Environment (FMEnv). The proposed FCU2 unit shall be a part of IEFCL-Train2 project and for addition of FCU2 unit in ongoing construction of IEFCL-Train2 project, the FMEnv has approved the EMP. The approved EMP shall be merged with ESMP of approved ESIA of IEFCl-train2 project.

## 1.2 Technology Advantage

The installation of FCU as a precursor of fertilizer manufacturing process will help in ensuring the environmental, social and economical sustainability of the IEFCL-Train2 Project, as explained below.

- In FCU, Carbon Dioxide will be separated from the incoming Natural Gas and sent directly to the Urea Plant for Urea synthesis. The FCU provides IEFCL the technical viability to separate the Carbon Dioxide from the Natural Gas supplied by TOTAL. At the TOTAL's gas processing station, there is no facility to separate the $CO_2$ from Natural gas. By feeding the raw natural gas directly to ammonia plant, $CO_2$ in the fuel gas gets carried thru the reformer and gets released to atmosphere. Therefore need exists for the installation of FCU at IEFCL end to capture Carbon Dioxide in the Natural Gas before feeding the gas to Ammonia Plant. The separated Carbon Dioxide, which is a greenhouse gas (GHG) is supplied to Urea plant to react with Ammonia and produce Urea. This helps in reducing GHG emission and thus contribute positively to Nigeria's Nationally Determined Contributions to the Paris Climate Change Agreement & Nigeria's National Policy on Climate Change.

- The raw Natural gas normally contains organic and inorganic sulphur compounds. Part of the sulfur compounds will also be present in the $CO_2$ separated in FCU. In FCU, the separated $CO_2$ is further treated for the separation of $H_2S$ and mercaptons (acid gas). The acid gas undergoes catalytic conversion of organic sulphur compounds to Hydrogen Sulphide, which in subsequent Zinc Oxide bed is absorbed and sulphur free $CO_2$ will be supplied for the urea synthesis in Urea plant. Ammonia plant in IEFCL-Train2 is equipped with organic & inorganic sulfur removal equipment. Together with FCU, harmful sulfur compounds are completely removed from gas reliving TOTAL, the gas supplier of the burden of processing Natural Gas for the removal of Sulfur. In the alternative, options available to TOTAL to handle the embedded Sulphur compounds in Natural Gas may be open to atmospheric venting. Hence, the installation of FCU will help in reduction of Sulphur compounds/Sulphur Dioxide emission and finally improve ambient air quality.

- Through FCU the heavy hydrocarbons entrained in the Natural gas get separated and sent to the adjacent Olefin Plant of IEPL. At Olefins plant the recovered heavies will be mixed with other Feed Stock of IEPL and cracked to produce Ethylene and Propylene. This will augment the short fall of feed stock to Olefins and will help to achieve the name plate production capacity of Petrochemical plants.

- In Ammonia Plant Process, the operating conditions of Primary Reformer are adjusted as per the feed Natural Gas (NG) composition. In primary reformer steam reforming of Natural Gas takes place and it is highly endothermic process. The variable composition of feed NG will result in high energy consumption. Therefore installation of FCU as a precursor of Ammonia Plant of fertilizer production process will ensure clean and steady composition of feed gas, which will guarantee smooth and cleaner operation in Ammonia Plant and reduce specific energy consumption and hence reduce stack and greenhouse gas emissions.

- The steady composition of feed Natural Gas will reduce the frequent changes in operating parameters improving the operability of plants by reducing breakdowns. This will also improve the life and performance of mechanical, electrical,

instrumentation etc. installations and overall will improve the life span of the manufacturing units. The reduced breakdowns and maintenance activities will also help in reducing waste generation volume.

- The improved steady state operation will extend the life and performance of various catalysts being used in Ammonia Process and hence will reduce the volume of spent catalyst generation significantly.

- The cleaner technology and process ensuring better environmental conditions by improving ambient air quality, will enhance the trust of stakeholder and hence will enrich the social sustainability of the IEFCL-Train2 project.

### 1.3 ESMP Objectives

The objectives of the ESMP are to:

- Establish specific control measures to minimize impact on environment and society
- Ensure project sustainability in relation to environmental, social and climate change aspects,
- Ensure the implementation of the proposed unit activities within the principal components of design, construction, commissioning, operation & maintenance and decommissioning is carried out in accordance with appropriate environmental statutory requirements;
- Ensure the proposed unit activities are successfully and safely implemented with minimal harm to the biophysical, ecological, socio-cultural and health environment;
- Recommend reasonable and cost effective measures, procedures and practices to be followed during construction and operations to ensure that the environmental and social effects are mitigated, minimized or avoided and beneficial impacts are enhanced.

#### 1.3.1 Scope of ESMP and Applicability

**Scope**

- This Environmental and Social Management Plan (ESMP) is extracted from approved ESIA of IEFCL-Train2 Project, as the proposed FCU unit shall be a part of IEFCL-Train2

project. This ESMP aimed to ensure safe construction and sustainable operations of FCU unit of IEFCL-Train2 Project.

- This ESMP emphasis on incorporation of environmental, occupational health & safety, climate change and social aspects associated, in construction and operational activities of FCU2 unit.
- This ESMP is in line with the applicable national laws, international guidelines and best practices adopted internationally. The ESMP complies with the applicable national employment & social, Health & Safety and Environmental Standards, Codes and Regulations. The information contained in this ESMP will be supplemented with procedures addressing ESMP specific matters and requirements to be complied with and maintained throughout the construction and operation of the unit.

**Applicability**

- The content of this ESMP covers all activities during construction, operational and decommissioning phases and shall be implemented in order to ensure that all Environmental and Social impacts are identified and mitigated/controlled.

## 1.4 Relevant Institutional/Regulatory Framework

Following documents were assumed as reference for the present report:

- EIA Procedural Guidelines, 1995, Federal Environmental Protection Agency of Nigeria;
- EIA Sectoral Guidelines, Oil and Gas Industry Projects, Sub-sectoral Guidelines for Petrochemicals, 1995, Federal Environmental Protection Agency of Nigeria;
- EIA Sectoral Guideline, Manufacturing Industry, 1995;
- EIA Act 86 of 1992;
- Guidance on EIA, EIS review, June 2001, European Commission;
- Equator Principles, June 2013, Equator Principles Association;
- International Finance Corporation (IFC) Sustainability Framework, 2012 Edition, Performance Standards 1 to 4;
- Environmental, Health and Safety Guidelines, April 2007, World Bank Group and IFC.
- African Development Bank Group's, Safeguards and Sustainability Series, Volume1, issue1, Dec 2013 - Integrated Safeguards System,
- African Development Bank Group's, Operational Safeguards (OS); OS1, OS4 & OS5.

### 1.4.1 Main Regulatory Documents Considered For ESMP

**International Regulatory Documents**

Following main regulatory documents (conventions, guidelines, acts, regulations, etc.) have been considered at different territorial levels to adequately conduct Environmental and Social Management Plan report for the unit:

- Convention concerning the Protection of Workers against Occupational Hazards in the Working Environment Due to Air Pollution, Noise and Vibration, Geneva, 1977.
- Convention Concerning Occupational Safety and Health and the Working Environment, Geneva, 1981.
- Convention Concerning Safety in the use of Chemicals at work, Geneva, 1990.
- United Nations Framework Convention on Climate Change (UNFCCC) 1992.
- Intergovernmental Panel on Climate Change (IPCC), 1988.

**National Regulatory Documents**

Following relevant national regulatory documents have been considered at different territorial levels to adequately conduct Environmental and Social management plan activities for the unit, since standards and regulations derive from their establishment:

- National Guidelines and Standards for Environmental Management System in Nigeria 1999.
- National Guidelines and Standards for Environmental Audit in Nigeria 1999.
- Harmful Wastes (Special Criminal Provisions) Act of 1988
- National Environmental Standards and Regulations Enforcement Agency (NESREA) Act 25 of 2007.
- National Environmental Impact Assessment Decree No. 86 of 1992.
- Factories Act CAP F1 LFN 2004
- NSITF Employee's Compensation Act 2010
- Abandonment Guidelines, 1995
- The Constitution of the Federal Republic of Nigeria 1999, Section 20 which provides thus "The State shall protect and improve the environment and safeguard the water, air and land, forest and wildlife in Nigeria".

**State Regulatory Documents**

The provisions of the following Laws of Rivers State will also affect the siting and operation of the Project within IEFCL facility in Eleme, Rivers State.

- Rivers State Environmental Protection as Amended 2019
- Rivers State Waste Management Agency Act 2010
- Policies on Environmental Pollution Control and Management in Rivers State, 2010
- Rivers State Guidelines, Standards and policies on Environmental Pollution Control and Management in Rivers State 2010

### 1.4.2 Institutional Arrangement

**Proponent**

IEFCL has a well-established QEHS Policy, EHS & Social Management system and as the proponent shall retain the primary responsibility of ensuring that environmental and social commitments are met throughout the project lifespan which is expected to be 30 years. The implementation Organogram defining the line of Communication is presented below.

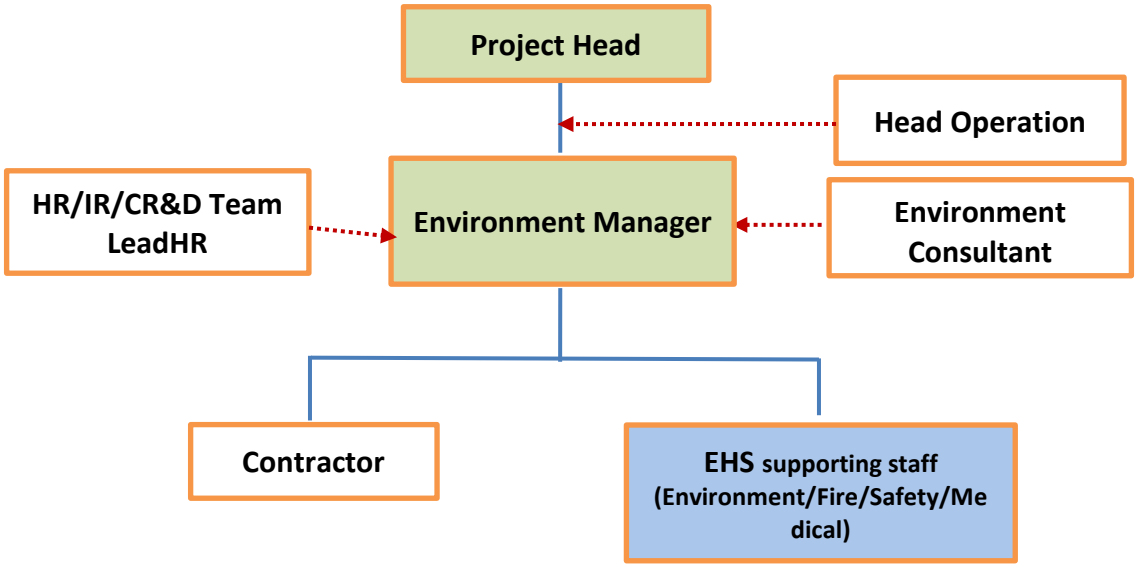


Figure 1.1: Organogram

**Federal Ministry of Environment**

The Ministry through its relevant department shall ensure various compliances during the construction and operational phase via Environmental compliance monitoring of relevant environmental components and associated activities generating waste within the facility to ensure strict compliance to the approved ESMP. The organizational structure of IEFCL

schematically presented in figure1 will be the link with the supervising Regulator to ensure successful implementation of the ESMP.

**Contractor's Obligation**

The Contractors shall be responsible for carrying out the work at the facility in full compliance with this ESMP and applicable Nigerian laws and regulations governing environmental and social impact management, pollution control, waste management, and occupational health and safety. The contractors shall either follow their EHS & S procedures approved by IEFCL or shall follow the IEFCL's EHS & S procedures.

## 1.5 Value of the Unit

The total estimated value of the FCU2 is approximately 160 Million USD based on the preliminary estimate. This value includes procurement and transportation of equipment and related ancillary items, engineering, construction, pre-commissioning, commissioning and spare parts. This also includes the cost of engineering controls to be put in place to cover the EHS aspects. The above value includes cost incurred toward ESMP compliance for FCU2 unit and shall be synonymous with IEFCL-Train2 compliance.

## 1.6 Report writing format

This report is considered with developing a management plan that will focus on addressing any environmental and social issues that may arise from construction and operation of FCU2 unit. The ESMP report is structured as below:

Chapter One : Introduction and Background Information
Chapter Two : Project Description
Chapter Three : Description of the Biophysical Environment
Chapter Four : Environmental aspects, Potential Impacts and Mitigation Measures
Chapter Five : Environmental and Social Management Plan
Chapter Six : Conclusion
References

## 1.7 Report Preparers and Approver

This ESMP is prepared by the Environment Consultant in consultation with Indorama's FCU2 Project and HSE Team. The same has approved by the Federal Ministry of Environment (FMEnv), Abuja, Nigeria.

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Consulting Firm: M/s Environmental & Chemical Services Limited, Flat 13, Chinda Estate, Off RSUST Road, Port Harcourt, Rivers State, Nigeria.

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**CHAPTER TWO**

# PROJECT DESCRIPTION

## 2.0 INTRODUCTION

In line with information contained in the background information, the FCU2 shall be a part of IEFCL-Train2 project, which is under construction. The FCU2 unit will be located adjacent to existing operational FCU1 unit of IEFCL-Train1.

## 2.1 Location

The proposed FCU unit will be within Indorama Complex, which is located geographically Latitude $4^0$49'N and Longitude $7^0$6'E. The land take for FCU2 will be 0.96 heaters. The location of Indorama Complex within Eleme LGA presented in figure 2.3, the location of Eleme LG within Rivers State showing in figure 2.2 and the administrative map showing Rivers State in Nigeria is presented in figure 2.1. The location of FCU2 unit will be adjacent to existing FCU1 and very close to new gas receiving station at North-East location of the Indorama Complex. The FCU2 location is marked in red lined box on Indorama Complex Plot Plan (figure 2.4).

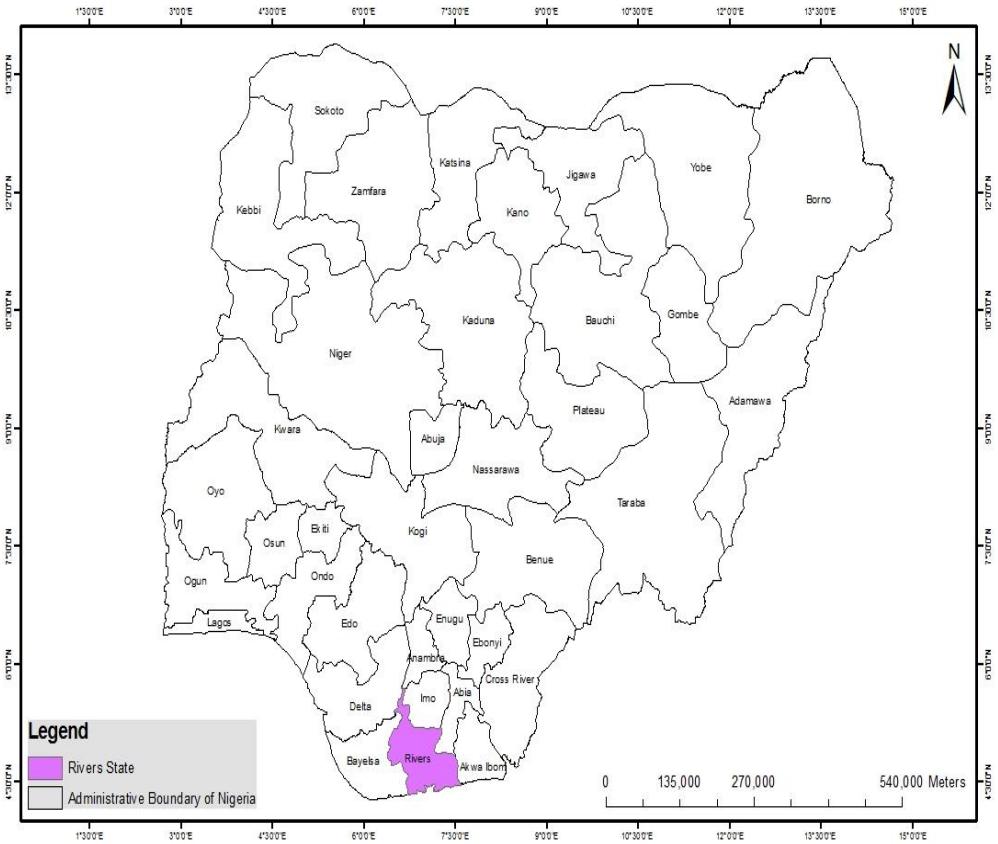



Figure 2.1: Administrative Map of Nigeria Showing Rivers State

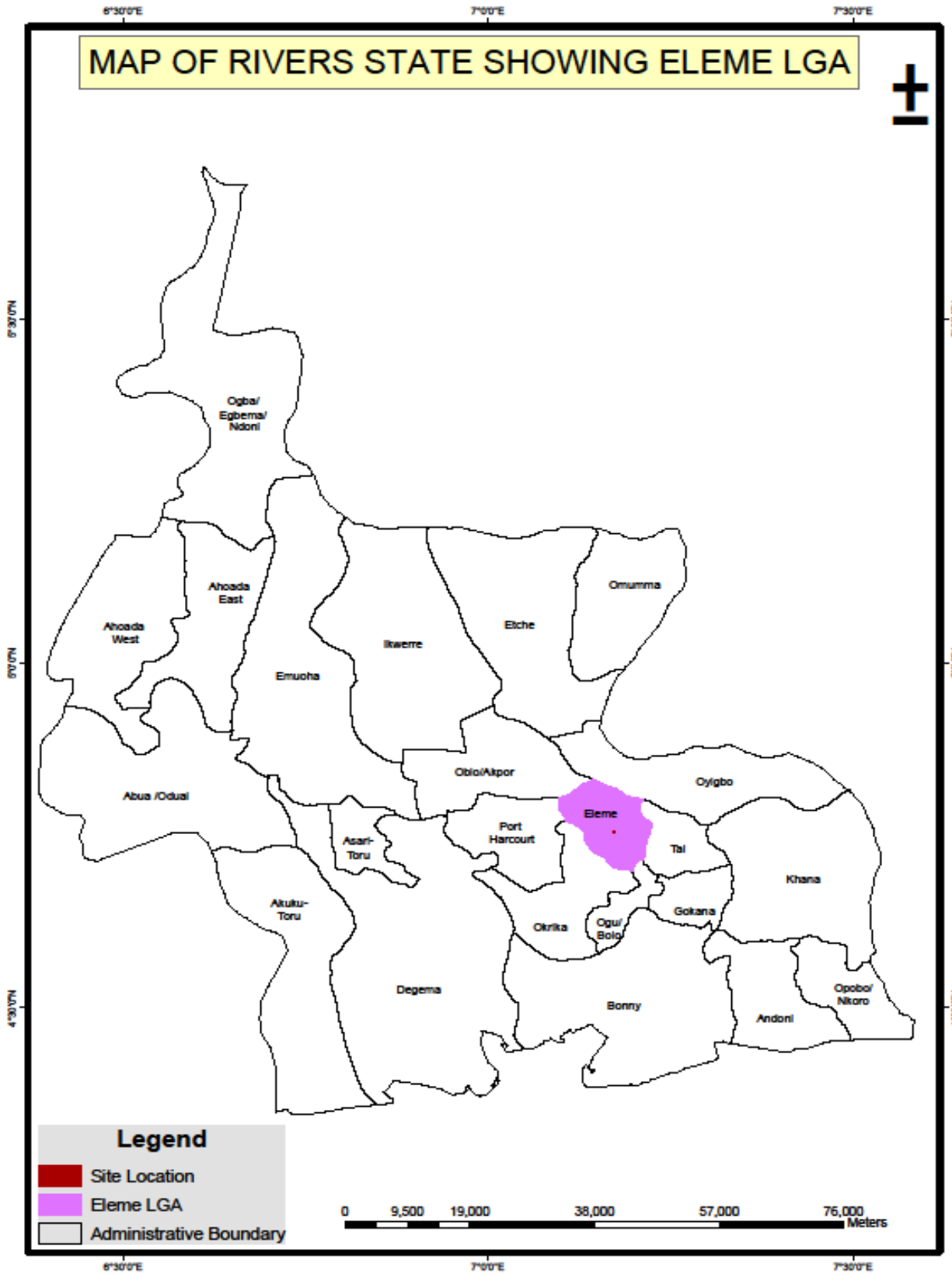



Figure 2.2: Administrative Map of Rivers State showing Eleme LGA

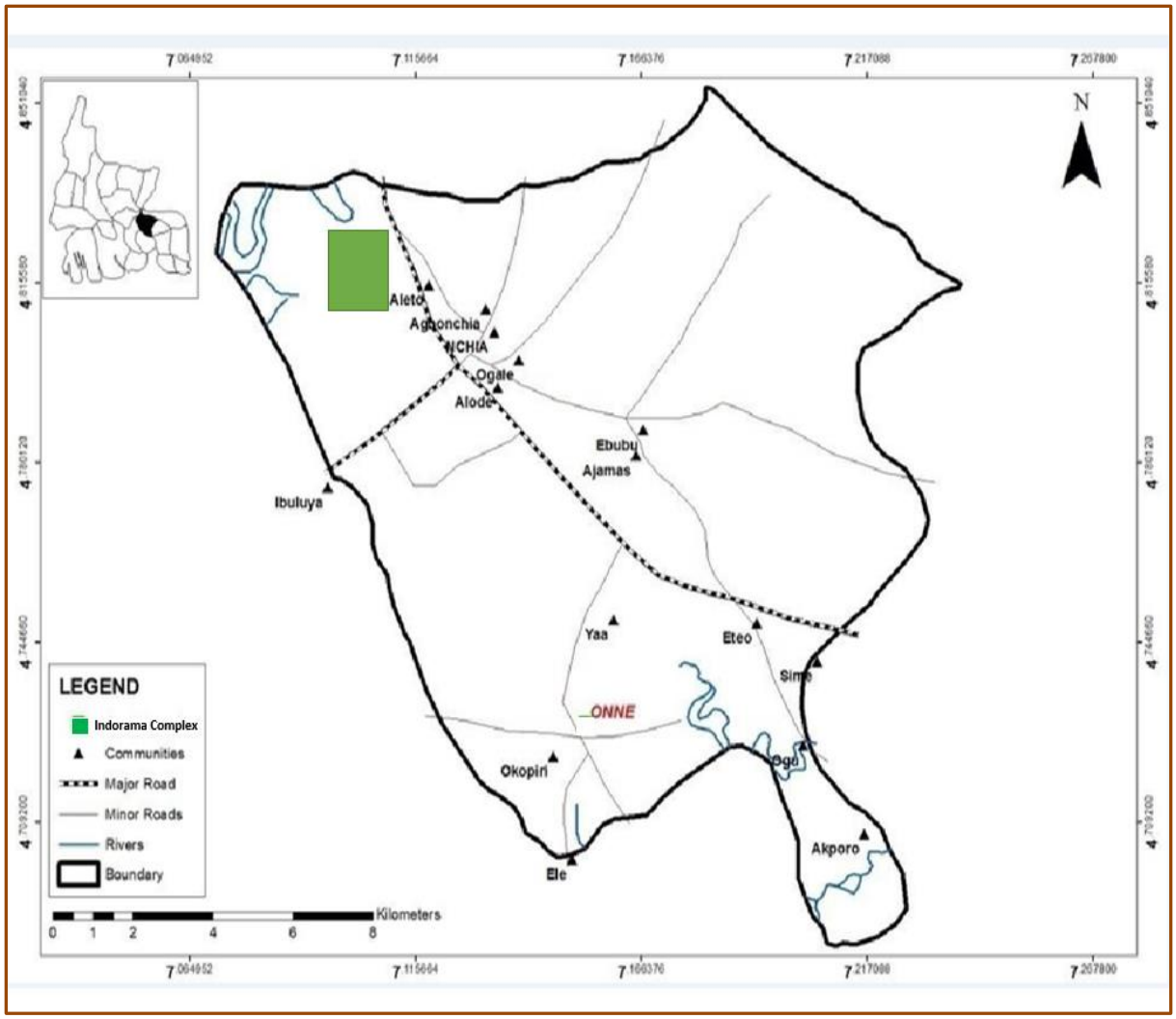



Figure 2.3: Administrative Map of Eleme LG showing the Indorama Complex

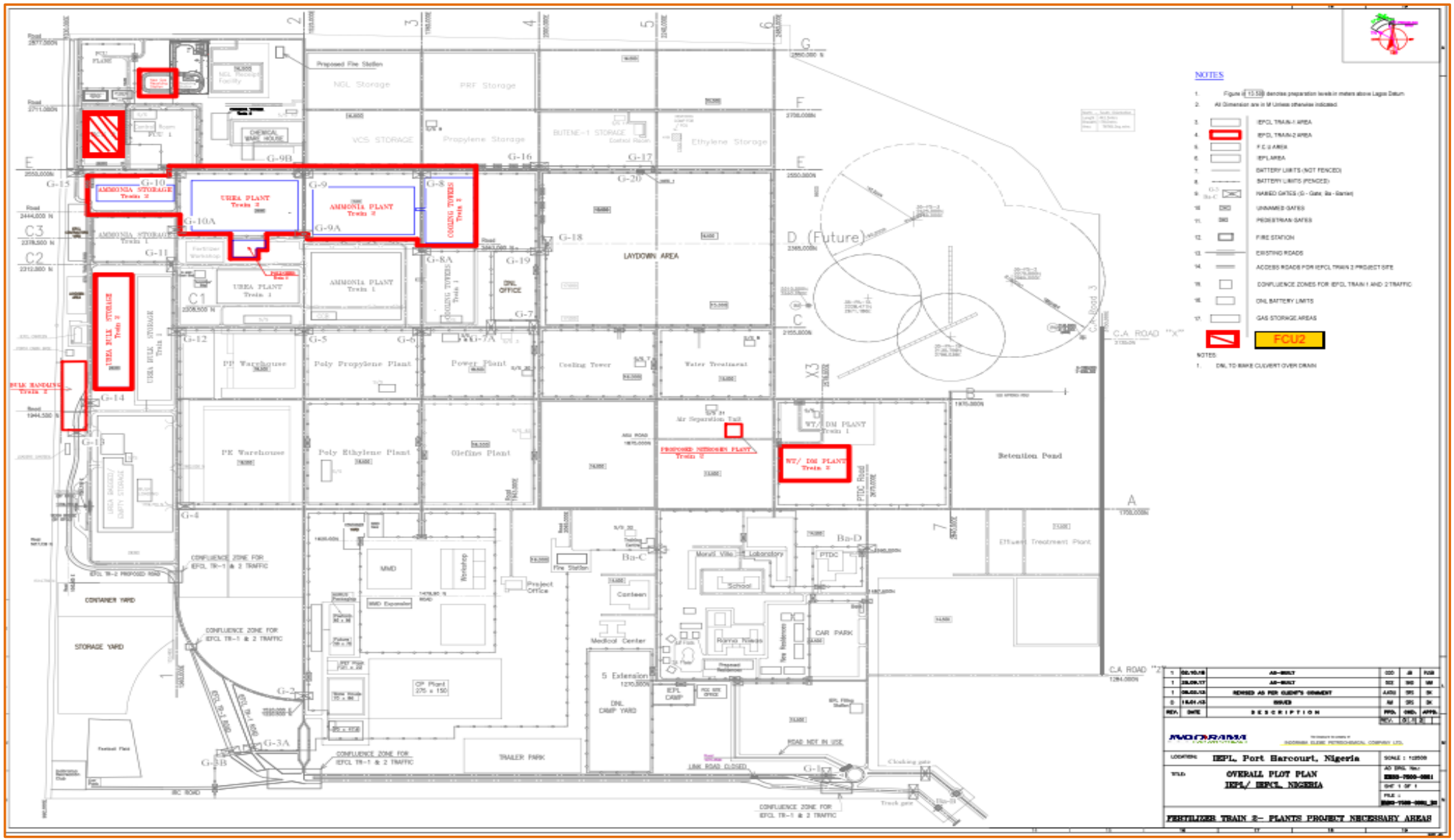



Figure 2.4: Indorama Complex Plot Plan showing FCU2 Unit

## 2.2 Scope

The scope of this inclusion in IEFCL-Train2 project is limited to construction of FCU2 with ongoing construction of IEFCL-Train2 project. The supply of gas to FCU2 will not jeopardize the supply of gas to the existing FCU1, as the IEFCL-Train2 have separate gas receiving station supplied by separate gas pipeline. The site has well established off-sites infrastructures and other related facilities within Indorama Complex to support efficient operations.

The proposed FCU2 shall have the capacity to process 160 MMSCFD of Natural gas and the plant is designed to process 107 MMSCFD during Initial operation. The life span of the project is 30 years, however with adherence to standard operating procedures and best maintenance procedures, the file span can be extended to 35-40 years. The process licenser is UOP, USA. The tentative composition of feed Natural gas and composition of separated heavies, carbon dioxide and remaining conditioned gas is presented in table 2.1.

Table 2.1: Tentative composition of Feed NG, Conditioned gas, $CO_2$ and Heavies

| Composition | Mol%/*ppm | Mol%/*ppm | Mol%/*ppm | Wt%/*ppmw |
|---|---|---|---|---|
| | Feed Gas | Conditioned Gas | Carbon Dioxide | Heavies |
| Nitrogen | 0.140 | 0.152 | 0.035 | 0.000 |
| Carbon dioxide | 1.219 | *< 10 | 94.731 | * < 100 |
| Methane | 91.950 | 99.805 | 0.357 | 0.500 |
| Ethane | 3.888 | 0.043 | 0.030 | 44.553 |
| Propane | 1.759 | 0.000 | 0.011 | 29.891 |
| i-Butane | 0.270 | 0.000 | 0.004 | 6.055 |
| n-Butane | 0.360 | 0.000 | 0.000 | 8.071 |
| i-Pentane | 0.110 | 0.000 | 0.000 | 3.061 |
| n-Pentane | 0.080 | 0.000 | 0.000 | 2.230 |
| n-Hexane | 0.170 | 0.000 | 0.000 | 5.627 |
| n-Heptane | 0.000 | 0.000 | 0.000 | 0.005 |
| n-Octane | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Nonane | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Decane | 0.000 | 0.000 | 0.000 | 0.000 |
| Water | *531 | < *1 | 4.832 | < *1 |
| Hydrogen sulfide | *10 | < *1 | < *1 | < *4 |

** Data corresponds to 107 MMSCFD, 92% mol methane case

The expected volumes of process outcome of FCU2 are presented in table 2.2. The expected outcome is considered in two conditions i.e. at 30°C (High Temperature) and 15°C (Low temperature) of feed natural gas for processing

Table 2.2: Process output of FCU2 Unit

| NG Feed flow | Heavies | Conditioned Gas | Recovered $CO_2$ | Remarks |
|---|---|---|---|---|
| MMSCFD | M3/HR | MMSCFD | TPH | Temp of feed |
| 107- Initial operation | 29.71 | 98.53 | 4.6 | HT Case-30deg.C feed |
| 107- Initial operation | 31.86 | 98.61 | 4.6 | LT Case-15deg.C feed |

The separated heavies shall be sent to IEPL Olefins plant, the Carbon dioxide will be sent to Urea Plant of IEFCL-Train2 project and 90 MMSCFD conditioned gas (Natural gas, mainly containing Methane) will be used in IEFCL-Train2 Ammonia Plant and balance conditioned gas shall be used for operation of IEFCL-Train2 steam boiler.

## 2.3 Manpower Deployment

During Construction : Skilled: 24 months x 200 workers = 4800 man-months

: Unskilled: 24 months x 400 workers = 9600 man-months

During Operations : Skilled: 47 numbers

In line with the State Government Policy on employment and local content rules, special preference shall be given to host communities for employment with emphases on their skills and experience.

## 2.4 Proposed Additional Development

The Proposed Additional Development of FCU2 Unit in IEFCL-Train2 Project will comprise following phases and entails:

***Pre-construction Phase***

- Engineering, design and procurement
- Mobilization of Equipment/manpower to site
- Site preparation

***Construction Phase***

- Foundation works
- Erection of Pre-fabricated steel structures
- Civil/Electrical/Mechanical/Instrumentation work and equipment Installation
- Commissioning
- Demobilization of Contractors

***Operation Phase***

- Processing of Natural Gas
- Office activities
- Effluent and Solid Waste management
- Maintenance

***Abandonment/Decommissioning/Restoration***

- Decommissioning Plan
- Dismantling and demolishing
- Land rehabilitation/restoration
- Post operational Environmental Study

**2.5 Work Schedule**

| FCU2 Work Schedule-Preliminary | | | | |
|---|---|---|---|---|
| **SN** | **Details** | **Duration in weeks** | **Period** | |
| 1 | UOP- Engineering & Equipment supply- NTP | | 1-Jul-19 | -- |
| 2 | Geotechnical survey for FCU-2 area | 6 | 1-Jul-19 | 12-Aug-19 |
| 3 | UOP- Critical documents- first issue & review | 14 | 1-Jul-19 | 7-Oct-19 |
| 4 | DEC -Detailed engineering contractor for BOP- NTP | 1 | 14-Oct-19 | -- |
| 5 | UOP- Equipment delivery | 74 | 1-Jul-19 | 30-Nov-20 |
| 6 | MR for BOP equipment | 24 | 14-Oct-19 | 30-Mar-20 |
| 7 | Ordering of equipment | 12 | 30-Mar-20 | 22-Jun-20 |
| 8 | Bop Equipment arrival at site | 52 | 22-Jun-20 | 21-Jun-21 |
| 9 | Construction Tender & SOQS | 52 | 14-Oct-19 | 12-Oct-20 |
| 10 | Construction contractor -NTP (Notice to period) | 8 | 17-Aug-20 | -- |
| 11 | Mechanical Completion | 78 | 17-Aug-20 | 14-Feb-22 |
| 12 | Pre-commissioning & Commissioning | 12 | 14-Feb-22 | 9-May-22 |
| 13 | Plant start-up and PGT | 12 | 9-May-22 | 1-Aug-22 |

## 2.6 Process Description

The FCU involves the removal of $CO_2$, $H_2S$ and other impurities present in the Natural Gas to get Conditioned Gas, carbon Dioxide and Heavies product. Since the Methane component in the feed gas can vary from 85% to 92%, main purpose of the FCU unit is to process this feed gas and supply a steady feed composition of 99.8% Methane to IEFCL-Train2 plants. This helps in the stable operation of the Ammonia plant Reformer. The material balance and process flow of Feed Condition Unit (FCU) is presented in figure 6 & 7 respectively and the various process steps are described below.

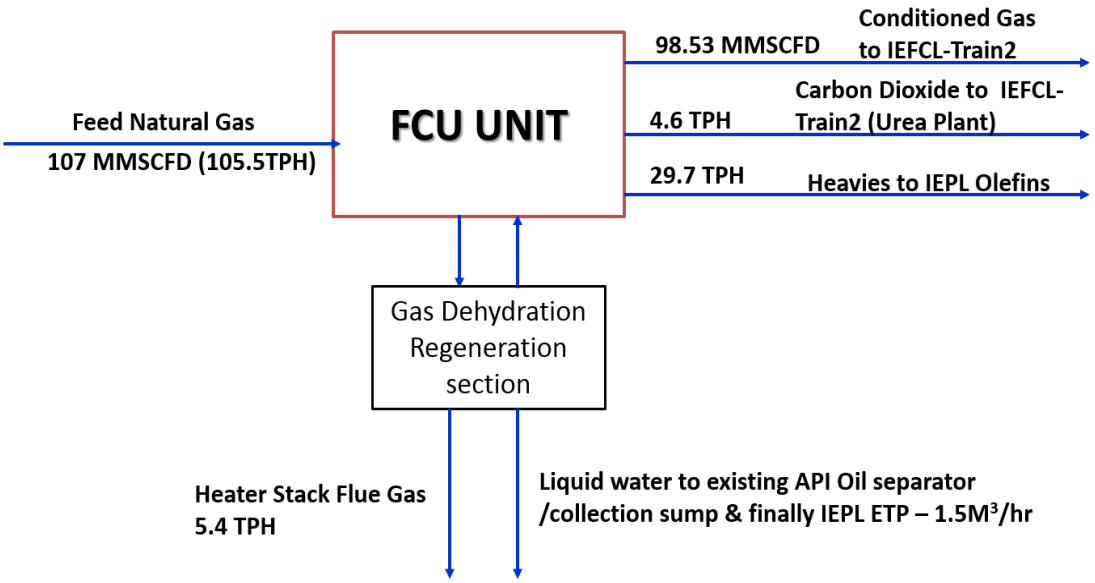



Figure 2.5: Material flow Block diagram of Feed Conditioning Unit (FCU2)

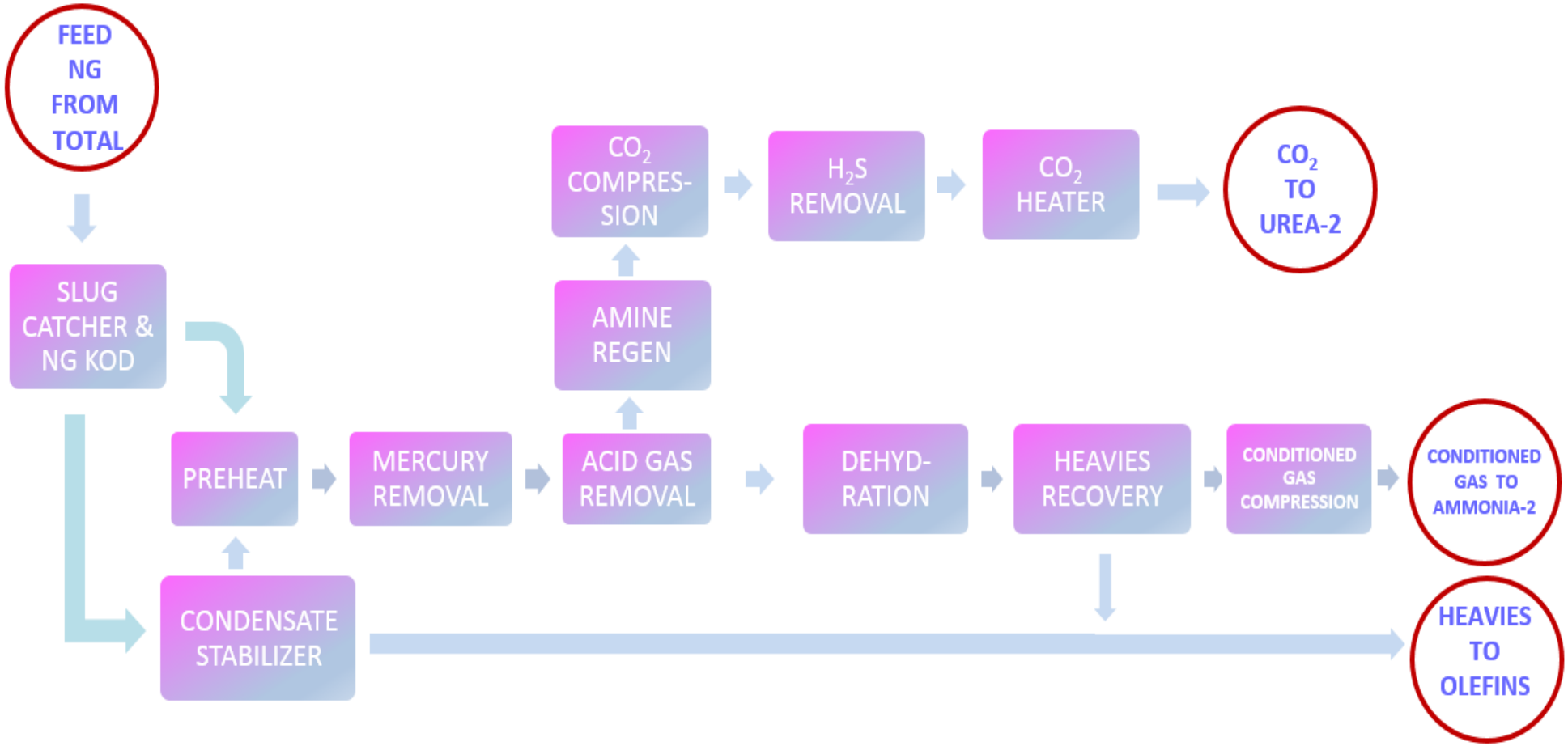



Figure 2.6: Process Flow Diagram of Feed Conditioning Unit (FCU2)

***Slug Catcher and NG NOD***

Slug catcher section consists of two pressure vessels and a metering skid. The Natural Gas from pipeline enters first vessel called slug catcher where the liquid hydrocarbon settle at bottom, the gas leaving from top flows through metering skid and enters second vessel called Natural Gas KOD. In KOD the pressure is reduced to the operating level, which results in the condensation of heavy HC and settle at bottom. The gas leaving the KOD is pressure controlled and sent to FCU2 for further processing. The liquid HC from the slug catcher & NG KOD is combined & sent to the condensate stabilizer unit along with the liquid feed from the FCU1 inlet separation section.

***Condensate Stabilizer***

The condensate stabilizer unit takes the liquids from FCU1 and FCU2. All the three streams are filtered, mixed and heated by cross exchange with Stabilizer Pre-heater and then sent to Stabilizer Flash Tank. Here the gas is separated and sent to Off-Gas Compressor Suction Drum under pressure control. The liquids are feeding the Condensate Stabilizer which uses a re-boiled column to separate the vapor and liquid fractions. Overhead vapor is returned to the gas processing train upstream of the FCU2 inlet feed heater for further processing, while bottom heavy HC liquid is sent to the heavy HC pipeline along with recovered heavies from FCU2, then to IEPL Olefins plant.

***Mercury Removal***

The feed natural gas enters the mercury bed which adsorbs mercury, in case present in the feed gas. In the presence of a pre-sulfide catalyst, the mercury is converted into mercury sulfide which is retained by the catalyst.

***Amine System – Inlet Gas Treating***

The feed natural gas is treated in the Amine contactor for the removal of $CO_2$ & $H_2S$ predominantly by using the GT Amine MDX3. MDX3 absorbs selectively $CO_2$, $H_2S$, & Mercaptons and hydrocarbons in a lesser extent; this solution is called Rich Amine. After removal of $CO_2$, $H_2S$ & Mercaptons, the gas is fed to Treated gas separator to remove any water that condenses out of the treated gas. This reduces the load on the downstream Treated Gas Filter Coalescer and the Dehydrators.

***Amine System - Regeneration***

The Amine Flash Drum is designed to eliminate as much hydrocarbons (HC) as possible from the rich amine solution coming from Amine contactor, separate the flashed gas from the liquid and separate any liquid hydrocarbons from the liquid amine. The differential pressure causes the majority of the entrained or absorbed hydrocarbons in the rich amine to flash within the vessel leaving heavier hydrocarbons and the amine solution in the bottom. The Amine Regenerator is designed to regenerate the rich amine solution to a lean state by separating the carbon dioxide and hydrogen sulfide from the rich amine. The lean amine from bottom of Regenerator is pressure boosted by booster pump, exchanging heat with rich amine in lean-rich amine heat exchanger followed by lean amine cooler, then filtered through series of filters namely pre-carbon, carbon , after-carbon filters and fed in to the suction of amine circulation pump. The amine circulation pump feed the lean amine to Amine contactor.

***Gas Dehydration System***

Gas Dehydrators contains molecular sieves designed to reduce the water content of the inlet gas to 0.1ppm to prevent hydrate formation before passing the gas to the heavies' recovery system which operates at cryogenic temperatures.

***Regeneration Gas Heater***

The Regeneration Gas Heater is designed to provide the heat required to the regeneration gas stream to properly regenerate the Dehydrators. The Regeneration Gas Heater, a fired heater, uses fuel gas from the Fuel Gas Scrubber system to provide the required heat. Fuel gas is also generated by letting down the feed gas if required.

***Heavies Recovery System***

**Gas/Gas Exchanger & De-Methanizer reflux Exchanger:** These Exchangers are used to exchange heat between the cold processed residue gas stream from top of De-Methanizer with the inlet gas stream and recycled residue reflux stream. These exchangers are used to improve the overall efficiency of the cryogenic process.

**Cold Separator:** The Cold Separator is designed to separate the gas/liquid mixtures coming from the Gas/Gas Exchanger and The Demethanizer Re-boiler.

**Expander/Compressor:** The purpose of the Expander/Compressor is to remove heat (in the form of work) to generate a very low Temperature, dramatically improving the efficiency of the process, as compared with the expansion across a Joules-Thompson (JT) control valve. The expander is used to lower the enthalpy of the gas by reducing the gas pressure and extracting some work which is applied to the coupled Expander/Compressor. This expansion process approaches an isentropic path where the gas leaving the expander at lower pressure is partially condensed due to the reduction in temperature and pressure. The energy derived from the expander is converted into horsepower to drive the compressor.

**Demethanizer:** The Demethanizer is designed to fractionate the tower feeds making a cut between methane and ethane plus components. The recovery of ethane is 98% with a propane recovery of 99.5%. Essentially 100% butane plus components are recovered. Heavies' recovered (C2+ components) is then sent to the Olefins Plant.

**Inlet Gas/Product Exchanger & De-Methanizer Re-boiler:** The Inlet Gas/Product Exchanger is used to exchange heat between the warm inlet gas stream & the heavies' product leaving the De-Methanizer bottom. The De-Methanizer Re-boiler is used to exchange heat between the warm inlet gas stream and the cold liquids drawn from side and bottom chimney trays of the Demethanizer. These exchangers are used to improve the overall efficiency of the cryogenic process by removing heat from the inlet gas stream and add heat necessary to demethanize the heavies' product.

***Conditioned Gas/Lean Gas Compression System***

The Conditioned/Lean Gas Compressor Suction Scrubber is designed to ensure the compressor feed gas is free of entrained liquids. The purpose of the Conditioned/Lean Gas Compressor is to compress the conditioned/Lean gas from the heavies' recovery system to the desired battery limit pressure of IEFCL-Train2.

***Carbon Dioxide Gas Compression System***

The purpose of the $CO_2$ Gas Compressor is to compress the $CO_2$ gas from the Amine System – Regeneration section to the desired battery limit pressure of Urea Plant of IEFCl-Train2.

***Acid gas Sulphur Treatment System***

The purpose of the Acid Gas Sulfur Treaters is to remove any sulfur ($H_2S$) present in the separated carbon dioxide before sending to Urea Plant of IEFCL-Train2.

***Pre-mixed amine (MDX3)***

- Pre-mixed fresh amine
- Amine drain drum
- Methanol Tank
- Antifoam system
- Fuel Gas Scrubber
- Amine Contaminated water and Disposal System

**Pre-mixed amine (MDX3) storage system:** For initial charging of pre-mix amine storage tank, a drum pump will be used for loading premixed amine (MDX3) from 200 liter drums. Through the Amine transfer pump, fresh premixed amine can be routed either to amine Flash drum or to Amine surge drum. The contents of the Amine drain drum can also be transferred to Pre-mixed amine storage tank, if required.

**Amine drain drum:** Amine drained from equipment of amine system (pumps, columns etc.) shall be collected into underground amine drain drum and recovered back to Pre-mixed amine system storage tank for reuse.

**Methanol Tank:** Methanol from 200 liter drums will be loaded to methanol tank using drum pump. Methanol dosing will be required to remove if any hydrate gets formed in the Cryogenic De-methanizer/heavies recovery section of the plant.

**Antifoam Tank:** Antifoam from 200 liter drums will be loaded to Antifoam dosing tank using drum pump. Antifoam is dosed to Amine contactor only when the contactor gets affected due to foaming problems.

**Amine contaminated water and Disposal System:** The sources of amine contaminated water are from curbed area around Amine handling equipment and Dyked area of Fresh Pre-Mixed Amine storage tank.

Catch basin in curbed area around Amine handling equipment will collect the amine contaminated water and route it through underground pipes to Amine contaminated water pit. Contaminated water from inside of the Dyked area shall be collected through trenches sloping towards a pit at one corner. From the corner pit (inside Dyked area), water will be routed through underground pipes to Amine contaminated water pit. From pit the collected water will be sent to IEFCL-Train1 effluent treatment facility for further treatment. The generation of amine contaminated water is intermittent and minimal. For FCU2 the existing system shall be used, as the existing infrastructure is capable to handle the additional minimal volume.

***Effluent Generation and Management***

While condensing the hot conditioned gas used to remove the moisture from molecular sieve bed produces some condensate. This condensate is flashed to remove entrained hydrocarbons which gets flared. The condensate is sent to existing FCU 1 flare knockout drum. For FCU 2, no new flare is envisaged as existing FCU 1 will be more than sufficient.-The Knock-out drum drain water containing traces of hydrocarbons (O&G) is sent to CPI oil separator before sending to collection pit. The CPI is designed to maintain <10ppm Oil & Grease content in outlet water. From collection pit, the collected effluent is intermittently sent to IEPL ETP for further treatment. For FCU2, the existing system shall be used, as the existing infrastructure is capable to handle this minimal volume of effluent generated.

***Fire & Gas Detection and Response System***

The FCU2 unit shall be equipped with fire & gas detection and alarm system, automatic deluge system, FM200 flooding system, fire extinguishers and fire hydrant network. All relief valves and pressure control devices are designed for worst cases and connected to existing dedicated flare and the unit is designed with minimum fugitive emissions having seamless piping and special material selection wherever required. Additionally, the newly commissioned Fire Station, which is manned round the clock, is in close vicinity to the existing and proposed FCU unit and well equipped to handle any emergency situation.

***Distributed Control and Emergency Shutdown System***

Distributed Control System, DCS, the most modern Control Platform is used for the FCU unit Control System. DCS centralizes unit operations to provide flexibility and simplicity by allowing central control, monitoring and reporting of individual components and processes. The redundancy within DCS facilitates high system availability and reliability. The DCS Controllers and associated inputs / outputs are connected through integrated redundant communications network to operating and engineering stations. The stations have graphical displays, easy-to-use displays for data monitoring, data logging, alarming and control. Field devices are directly connected to input / output modules that communicate with assigned controllers while reading and reporting real parameters.

DCS, ESD & F&G systems will be connected on an integrated redundant control network, Vnet/IP, that is used as real time control network connecting all active DCS, ESD & F&G components. Emergency Shut-Down System, ESD, or the safe-guarding system, shall automatically bring the relevant equipment or part of the plant to a safe condition, when a critical process variable reaches the limit of an acceptable value.

## 2.7 Construction Waste generation and management

Table 3 below discusses types and weight estimate of waste expected to be generated during the construction period. The construction waste shall be managed following the Waste Management Plan of IEFCL-Train2 Project.

Table 2.3: Estimated waste generation during Construction

| **Waste** | **Estimated Volume/weight** | **Disposal methods** |
|---|---|---|
| **Solid** | | |
| Cement / concrete - concrete debris, soil containing cement | 1000 MT | The material shall be used within complex for landfill |
| Wooden scrap | 50MT | Resale |
| Empty Cement bags | 2000 Nos | Reuse/Recycle |

| Waste | Estimated Volume/weight | Disposal methods |
|---|---|---|
| Used PPE - goggles, gloves, oil soaked cotton etc. | 5MT | Incineration |
| Metal scraps, broken tools, rag, old parts, etc | 100MT | Stored in skips, segregated and recycled for future use or Resale |
| Maintenance wastes (oil and fuel/diesel filter, wires etc.) | 5 MT | Collect in designated bins and transport to recycling unit/facilities |
| Empty oil/chemical containers | 1000 Nos | Containers shall be properly washed, detoxified and cleaned of residues before being re-used. It may also be crushed and recycled after washing. |
| Scrap packing material includes wood and plastic / PVC | 50MT | Reuse / Resale |
| Food wastes | 20kg/day | Segregate and disposed in government approved dump sites |
| **Liquid** | | |
| Used lube/engine oils | 500 lit/month | Stored in carboys and sent to recycling units or at waste management facility for incineration. |
| Sanitary waste | 5KL/day | Sewage will be treated at site in existing treatment facility. |

## 2.8 Operational Phase - Gaseous emission and Effluent management

***Gaseous Emission***

The only source of gaseous emission in FCU2 is Regeneration Gas Heater Stack. The Regeneration gas heater shall equipped with low NOx burners and shall have rated heat input capacity of 2.8 Megawatt thermal (MWth), which is less than the Small Combustion Facilities as per the IFC General EHS Guidelines.

***Effluent Generation and Management***

About 1.5m3/hr effluent (99.9% water + Traces of Hydrocarbons) shall be generated from the regeneration gas dryer system which shall be collected in OWS sump having CPI oil separator. The CPI is designed to maintain <10ppm Oil & Grease content in outlet water. From OWS sump, the collected effluent shall be intermittently sent to IEPL ETP for further treatment. For

FCU2, the existing FCU 1 infrastructure shall be used, as the existing infrastructure is capable to handle this minimal volume of effluent generated.

The generation of amine contaminated water is intermittent and minimal. This shall be collected in existing FCU 1 pit, which will be transferred to IEFCl-Train1 effluent treatment facility for further treatment.

### 2.9 Operational Phase – Reduction in GHG emission

The recovery of the acid gas in FCU2 and supply to the urea plant results in reduction in $CO_2$ emissions. It is anticipated that all the $CO_2$ in the raw gas will be captured and used for urea production. Without the FCU2, the $CO_2$ in the fuel gas to the reformer would be released to the atmosphere along with the flue gas. Furthermore, the reduction in GHG emissions through $CO_2$ recovery in FCU2, by reducing the venting of $CO_2$ to the atmosphere from the primary reformer flue gas, will be of 0.02 metric ton $CO_2$ / metric ton of urea. Thus, the proposed FCU2 unit will reduce emissions from IEFCl-Train2 by approximately 94,000 tpa CO2e.

* Due to recovery of $CO_2$ at FCU2, there is a potential savings of feed and fuel in the primary reformer of the IEFCL-Train2 ammonia plant of approximately 2.3 Million MMBTU/yr. This will reduce annual GHG emissions of IEFCL-Train2 by 24,000 tpa CO2e.

Marginal gross GHG annual emissions associated with the operation of FCU2 are estimated approximately 6,400 tpa CO2e.

**Therefore, the net non-tangible benefit of FCU2 is to reduce GHG emissions by approximately 112,000 tpa CO2e.**

**CHAPTER THREE**

# DESCRIPTION OF THE BIOPHYSICAL ENVIRONMENT

## 3.0 GENERAL

The FCU2 unit is a part of IEFCl-Train2 project. The description of biophysical environmental covering environmental and social aspects presented here is extracted from the approved ESIA of IEFCL-Train2, in-house monitoring and compliance reports. The source of data and information is suitably referenced.

The environment is classified as biophysical, social and health. The baseline conditions of the biophysical environment (physical, chemical and biological) of the proposed field development area, and the socio-economic and health conditions of the communities within the project area are described.

## 3.1 STUDY APPROACH

### 3.1.1 Data Acquisition Methods

The approach adopted was to obtain physical and biophysical baseline data from in-house monitoring, compliance reports, desktop review, field and laboratory studies, interviews and consultations with individuals / representatives of the host communities. For socio-economic & health studies, informal/formal; focal group discussion and structured questionnaires were administered to an acceptable percentage. This approach would provide adequate information for establishing the baseline status of the environment of the study area.

### 3.1.2 Description of Sampling Locations

The Sampling points were geo-referenced by means of Global Positioning System (GPS) on the field. Judgment sampling was applied in the selection of study stations, taking into account ecological features, geographical location of communities and control points in apparently undisturbed areas. The four (4) host communities were identified within the study boundary. The map showing the study area with the sampling stations are shown in figure 3.1.

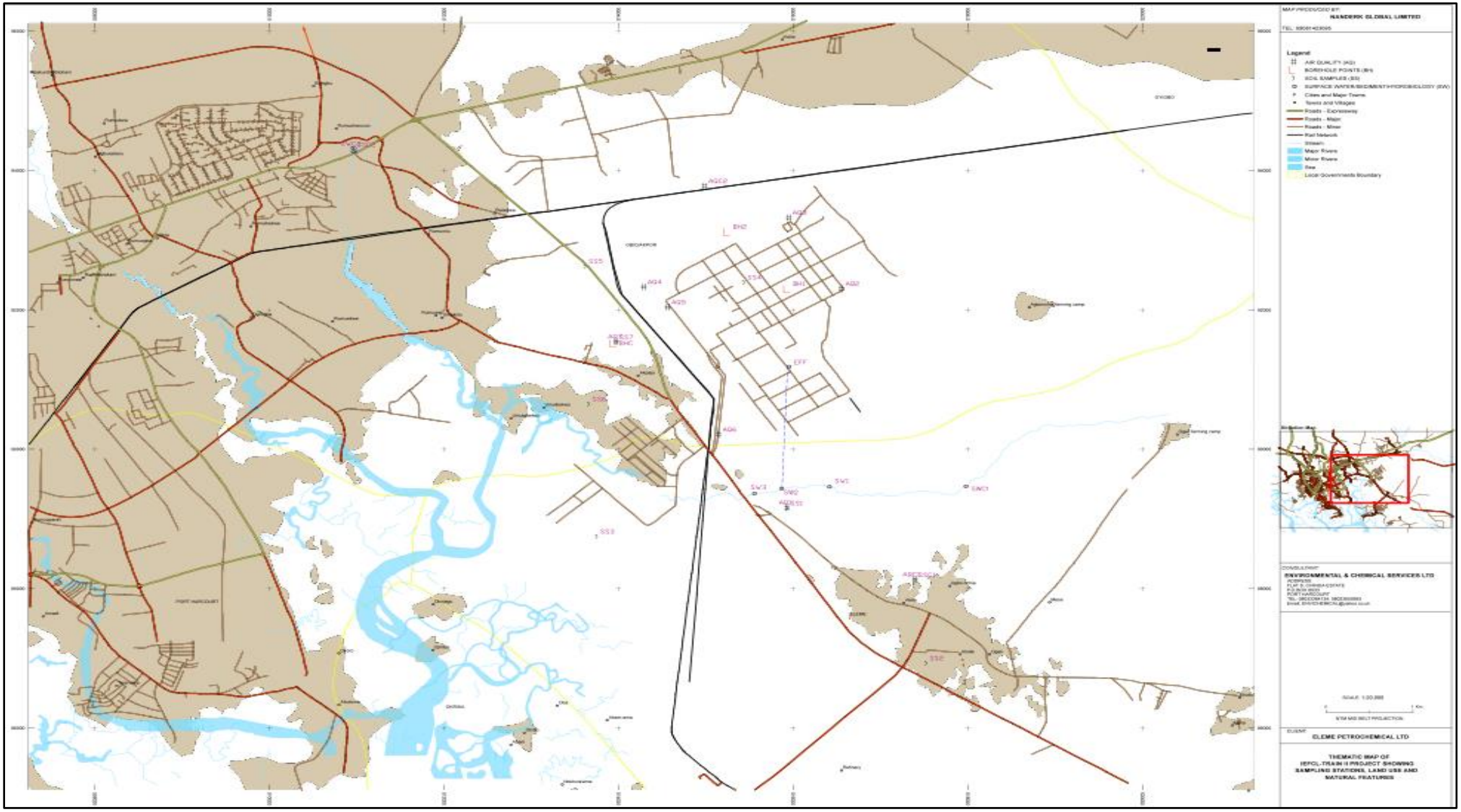



Figure 3.1: Sampling Map

Table 3.1: Study Communities

| STATE (1) | LOCAL GOVERNMENT AREA (2) | COMMUNITY (4) |
|---|---|---|
| Rivers State | Eleme<br>Obio-Akpor | Aleto; Agbonchia; Akpajo<br>Elelenwo |

Table 3.2 GPS coordinates of Sampling Stations

| STATIONS | DESCRIPTION | COORDINATES | |
|---|---|---|---|
| **AIR QUALITY/NOISE/METOROLOGY** | | | |
| AQ1 | Near Main Gate | N04$^0$48'54.48“ | E07$^0$05'54.10" |
| AQ2 | Near W/Bridge | N04$^0$50‘02.25“ | E07$^0$05‘29.46" |
| AQ3 | Flare Stack (N) | N04$^0$50'3.42“ | E07$^0$06'39.8" |
| AQ4 | Near AGIP Metering Station | N04$^0$50'33.33“ | E07$^0$06'21.70" |
| AQ5 | Near Urea Bagging | N04$^0$50’25.71” | E07$^0$05’51.96 |
| AQ6 | Near Workshop | N04$^0$50’24.01” | E07$^0$06’01.33” |
| AQ7 | Axis of Akpajo /Elelenwo | N04$^0$49'37.90“ | E07$^0$05'15.80" |
| AQ8 | Axis of Aleto /Agbonchia | N04$^0$47'64.40“ | E07$^0$06'98.10" |
| AQ9 | Agbonchia Area | N04$^0$47‘23.14“ | E07$^0$07‘10.81" |
| AQ10 | Aleto Area | N04$^0$49‘12.64“ | E07$^0$05‘41.66" |
| **STACK MEASUREMENTS (POINT SOURCE EMISSIONS)** | | | |
| STID 1 | Olefins-Furnace B | N04° 50’ 97.0” | E007 ° 06’24.7” |
| STID 2 | Boiler A | N04° 50’ 41.3” | E007 ° 06’25.4” |
| STID 3 | Boiler B | N04° 50’ 41.3” | E007 ° 06’25.4” |
| STID 4 | GT 2 | N04° 50’ 82.0” | E007 ° 06’36.0” |
| STID 5 | GT 3 | N04° 50’ 82.0” | E007 ° 06’36.0” |
| STID 6 | Sludge Incinerator | N04° 49’ 14.8” | E007 ° 06.24.7” |
| STID 7 | Package boiler | N04$^0$ 50’ 55.9” | E007$^0$ 05’ 58.3” |
| STID 8 | Reformer | N04$^0$ 50’ 55.5” | E007$^0$ 05’ 58.7” |
| **SURFACE WATER / SEDIMENTS** | | | |
| SW1 | Up Stream | N04$^0$48’43.70’’ | E07$^0$06’42.60’’ |
| SW2 | Midstream | N04°48’43.70” | E07°06’42.60” |
| SW3 | Down Stream | N04$^0$48’27.40’’ | E07$^0$06’04.30’’ |
| SWC1 | Agbonchia Stream | N04$^0$48’33.80’’ | E07$^0$07’27.50’’ |
| SWC2 | Rumukrushi | N04$^0$51’07.60’’ | E07$^0$03’38.00’’ |
| **GROUNDWATER** | | | |
| BH1 | Indorama complex, Flare area | N4$^0$ 50'02.65" | E07$^0$ 06'19.93" |
| BH2 | Indorama complex, water treatment plant | N04$^0$50’29.20’’ | E07$^0$05’57.60’ |
| BHC | Akpajo | N04$^0$49'37.24" | E007$^0$05'15.30" |
| **TREATED EFFLUENT STREAM** | | | |
| Eff. | Indorama Sluice Gate | N04$^0$49’25.70’’ | E07$^0$06’20.50’’ |

### 3.1.3 Spatial Boundary for the Study

Following spatial boundaries are considered for data collection and studies:

- 2km radius for biophysical sampling
- 4km spatial boundary for socio-economic and health assessment
- 5km for Control samples

### 3.1.4 Environmental components of the Study

A comprehensive description of the baseline conditions of the study area were studied and the detailed scope of the data acquisition included:

- Meteorology
- Air Quality and Noise
- Soil, Land use and land cover
- Vegetation and Wildlife
- Geology/Hydrogeology
- Surface water and sediment quality
- Groundwater Quality
- Socio-economics and Human Health

### 3.1.5 Study Design and Methodology

**Biophysical Components**

Field sampling and observations involved using standard methods such as:

- In-situ measurements with appropriate equipment having certified calibration;
- Laboratory analysis of samples using standard methods;
- Quality assurance and quality control management principles.

**Socioeconomics and Health Components**

Key methods have been used:

- Informant interviews; Focus Group Discussion (FGD); Direct observation;
- Administration of structured questionnaires and Collection of secondary data.

The field procedures adopted for data collection are in compliance with statutory requirements and in line with national and international policy on the protection and conservation of the environment.

### 3.1.6 Quality Assurance / Quality Control

The QA/QC programmes covered all aspects of the study, including sample collection and handling, laboratory analyses, generation of data and coding, data storage and treatment as well as report preparation. The quality assurance programme used in the fieldwork and laboratory analyses is in accordance with international and National regulatory recommendations such as:

- Ensuring that only experienced and qualified personnel are engaged in the study;
- Ensuring proper sampling in pre cleaned sample containers and after sampling proper labelling by capturing sample name, location and date.
- Carrying out field calibrations of equipment and running distilled water blanks to reduce errors that could arise from field measurements;
- Ensuring that replicate samples are collected and used as checks on measurements;
- Carrying out field analytical operations in a defined sequence to avoid cross contamination of instruments.
- It is also be noted that the collected samples were submitted in due time to FMEnv approved laboratories, which are well equipped with latest sophisticated instruments and managed by well experienced professionals.

Parameters such as temperature, pH, turbidity, electrical conductivity and dissolved oxygen were determined *in situ* because of their rapid change due to deterioration of samples due to microbial degradation and transformation. They were therefore analysed at minimum time after collection.

## 3.2 RESULTS AND DISCUSSION

### 3.2.1 Climate / Meteorology

The Climate assessment for the study environment tends to highlight the atmospheric pattern of the study area. The climatic parameters such as rainfall, temperature, wind speed & direction, relative humidity and cloud cover are being recorded at site. According to Ayoade (2008), the weather condition of study environment is determined by the monsoon; a seasonal wind shift that brings rain (wet monsoon) via South-Westerly wind between March and early November and usher in dry season (dry monsoon) via North-Easterly wind between December and February. Rainfall is the main climatic variable and there is marked alternation

of wet and dry seasons in the study area. Two air masses controls rainfall – moist Northward moving maritime air coming from the Atlantic Ocean and the dry continental air coming from the African Landmass. The climate of Niger delta is affected by ocean and atmospheric interactions both within and outside its environment, in which the Inter-Tropical Convergence Zone (ITCZ) plays a controlling factor. The movement of the ITCZ is associated with the warm humid maritime Tropical air mass with its South-Western winds and the hot and dry continental air mass with its dry North-Easterly winds.

The micro-meteorological data recorded at site during wet season (June/July'2018) and dry season (Jan/Feb'2019) are summarized in Table 3.3. The graphical presentation of diurnal temperature and relative humidity variations, diurnal wind rose pattern and diurnal wind speed record is shown in subsequent figures.

Table 3.3: A Mean Diurnal Weather pattern for Wet and Dry Season

| | Wet Season (June/July 2018) | | | | | | Dry season (Jan/Feb 2019) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Local Time | Air Temp (°C) | RH (%) | Air Pressure (mbar) | Solar Radiation (W/m²) | Wind Speed (m/s) | Wind Direction | Air Temp (°C) | RH (%) | Air Pressure (mbar) | Solar Radiation (W/m²) | Wind Speed (m/s) | Wind Direction |
| 12:30 AM | 24.9 | 88 | 1017.9 | 0 | 1.4 | S | 26.1 | 90 | 1014 | 0 | 2.1 | S |
| 1:00 AM | 24.8 | 89 | 1017.9 | 0 | 1.3 | SSE | 25.9 | 90 | 1014 | 0 | 1.4 | SSW |
| 1:30 AM | 24.7 | 89 | 1017.8 | 0 | 1.5 | SSE | 25.6 | 91 | 1014 | 0 | 1.4 | SW |
| 2:00 AM | 24.6 | 89 | 1017.6 | 0 | 1.4 | SSE | 25.4 | 91 | 1014 | 0 | 1.4 | SW |
| 2:30 AM | 24.6 | 89 | 1017.5 | 0 | 1.3 | SSE | 25.3 | 91 | 1013 | 0 | 0.7 | SW |
| 3:00 AM | 24.5 | 90 | 1017.3 | 0 | 1.3 | SSE | 25.1 | 92 | 1012 | 0 | 0.7 | SW |
| 3:30 AM | 24.4 | 90 | 1017.1 | 0 | 1.3 | SSW | 24.7 | 92 | 1012 | 0 | 0.7 | S |
| 4:00 AM | 24.4 | 90 | 1016.9 | 0 | 1.4 | SSE | 24.7 | 92 | 1012 | 0 | 0.0 | SE |
| 4:30 AM | 24.3 | 90 | 1016.7 | 0 | 1.3 | SSE | 24.7 | 92 | 1012 | 0 | 0.7 | ESE |
| 5:00 AM | 24.2 | 90 | 1016.6 | 0 | 1.4 | SSE | 24.6 | 92 | 1012 | 0 | 0.7 | ENE |
| 5:30 AM | 24.2 | 91 | 1016.6 | 0 | 1.3 | SSE | 24.7 | 92 | 1012 | 0 | 0.0 | ENE |
| 6:00 AM | 24.1 | 91 | 1016.7 | 0 | 1.1 | ESE | 24.7 | 92 | 1012 | 0 | 0.0 | NE |
| 6:30 AM | 24.1 | 91 | 1016.8 | 0 | 1.1 | SSE | 24.7 | 92 | 1012 | 0 | 0.7 | NNE |
| 7:00 AM | 24.0 | 91 | 1016.9 | 0 | 1.1 | SSW | 25.2 | 92 | 1012 | 5 | 1.4 | N |
| 7:30 AM | 24.0 | 91 | 1017.1 | 0 | 1.2 | SSE | 25.7 | 91 | 1013 | 22 | 0.7 | N |
| 8:00 AM | 24.0 | 91 | 1017.3 | 1 | 0.9 | SSE | 26.8 | 87 | 1013 | 50 | 0.0 | NNE |
| 8:30 AM | 24.1 | 91 | 1017.6 | 12 | 1.1 | SSE | 27.2 | 84 | 1013 | 71 | 0.7 | N |
| 9:00 AM | 24.3 | 90 | 1017.9 | 32 | 1.0 | SSE | 27.6 | 83 | 1013 | 107 | 0.7 | WNW |
| 9:30 AM | 24.6 | 90 | 1018.2 | 62 | 1.3 | SSW | 27.9 | 82 | 1013 | 140 | 1.4 | N |
| 10:00 AM | 25.2 | 88 | 1018.4 | 110 | 1.3 | SSW | 28.7 | 79 | 1013 | 202 | 0.7 | ENE |
| 10:30 AM | 26.0 | 85 | 1018.6 | 146 | 1.3 | S | 29.6 | 77 | 1013 | 270 | 0.7 | NNE |
| 11:00 AM | 26.6 | 83 | 1018.6 | 182 | 1.7 | SSE | 29.9 | 75 | 1013 | 269 | 0.7 | S |

| Local Time | Wet Season (June/July 2018) | | | | | | Dry season (Jan/Feb 2019) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air Temp (°C) | RH (%) | Air Pressure (mbar) | Solar Radiation (W/m²) | Wind Speed (m/s) | Wind Direction | Air Temp (°C) | RH (%) | Air Pressure (mbar) | Solar Radiation (W/m²) | Wind Speed (m/s) | Wind Direction |
| 11:30 AM | 27.2 | 81 | 1018.6 | 175 | 2.0 | SSE | 30.3 | 74 | 1014 | 333 | 2.1 | WSW |
| 12:00 PM | 27.6 | 79 | 1018.5 | 215 | 2.3 | SSE | 30.8 | 73 | 1014 | 384 | 2.1 | SSW |
| 12:30 PM | 28.1 | 77 | 1018.4 | 253 | 2.7 | SSE | 31.1 | 72 | 1014 | 398 | 2.1 | SW |
| 1:00 PM | 28.3 | 77 | 1018.2 | 253 | 2.9 | SSE | 31.3 | 72 | 1013 | 397 | 2.9 | WSW |
| 1:30 PM | 28.4 | 76 | 1017.9 | 251 | 3.2 | SSE | 31.4 | 72 | 1013 | 392 | 2.9 | WSW |
| 2:00 PM | 28.4 | 76 | 1017.6 | 257 | 3.6 | ESE | 31.7 | 72 | 1012 | 387 | 2.9 | WSW |
| 2:30 PM | 28.4 | 76 | 1017.2 | 266 | 3.5 | ESE | 31.7 | 72 | 1012 | 378 | 3.6 | SSW |
| 3:00 PM | 28.6 | 76 | 1016.8 | 248 | 3.4 | ESE | 32.0 | 70 | 1012 | 384 | 4.3 | S |
| 3:30 PM | 28.5 | 77 | 1016.4 | 174 | 3.3 | ESE | 31.6 | 72 | 1012 | 316 | 2.9 | SSW |
| 4:00 PM | 28.5 | 76 | 1016.0 | 205 | 3.4 | ESE | 30.6 | 75 | 1012 | 287 | 2.9 | SSW |
| 4:30 PM | 28.4 | 77 | 1015.7 | 207 | 3.4 | SSE | 30.4 | 75 | 1011 | 219 | 3.6 | SSW |
| 5:00 PM | 28.2 | 77 | 1015.5 | 194 | 3.7 | SE | 29.7 | 77 | 1011 | 146 | 2.9 | SW |
| 5:30 PM | 28.1 | 78 | 1015.4 | 166 | 3.9 | SE | 29.7 | 78 | 1010 | 91 | 5.1 | SW |
| 6:00 PM | 27.7 | 79 | 1015.3 | 126 | 4.1 | SSE | 29.6 | 78 | 1010 | 41 | 5.8 | SW |
| 6:30 PM | 27.4 | 80 | 1015.3 | 94 | 3.6 | SSE | 29.6 | 77 | 1010 | 19 | 5.8 | SW |
| 7:00 PM | 27.3 | 80 | 1015.3 | 64 | 3.6 | SSE | 29.3 | 77 | 1010 | 8 | 5.1 | SSW |
| 7:30 PM | 27.0 | 82 | 1015.6 | 38 | 3.5 | SSE | 29.2 | 78 | 1011 | 0 | 4.3 | S |
| 8:00 PM | 26.5 | 84 | 1015.8 | 12 | 3.3 | SSE | 29.2 | 78 | 1011 | 0 | 5.1 | S |
| 8:30 PM | 25.9 | 85 | 1016.1 | 1 | 2.7 | SSE | 28.4 | 81 | 1011 | 0 | 3.6 | S |
| 9:00 PM | 25.7 | 86 | 1016.3 | 0 | 2.5 | SSE | 28.2 | 81 | 1012 | 0 | 3.6 | S |
| 9:30 PM | 25.5 | 86 | 1016.6 | 0 | 2.1 | SSE | 28.1 | 81 | 1012 | 0 | 2.1 | S |
| 10:00 PM | 25.5 | 86 | 1017.0 | 0 | 1.9 | SSE | 28.1 | 81 | 1012 | 0 | 2.1 | S |
| 10:30 PM | 25.4 | 87 | 1017.3 | 0 | 1.8 | SSE | 27.7 | 83 | 1012 | 0 | 2.1 | S |
| 11:00 PM | 25.2 | 88 | 1017.6 | 0 | 1.5 | SSE | 27.5 | 83 | 1012 | 0 | 2.1 | S |
| 11:30 PM | 25.1 | 88 | 1017.7 | 0 | 1.3 | SSE | 26.9 | 85 | 1012 | 0 | 2.0 | S |
| **Mean** | **26.0** | **84.6** | **1017.1** | **79.6** | **2.2** | **SSE** | **28.0** | **82** | **1012** | **113.1** | **2.2** | **SW/W** |

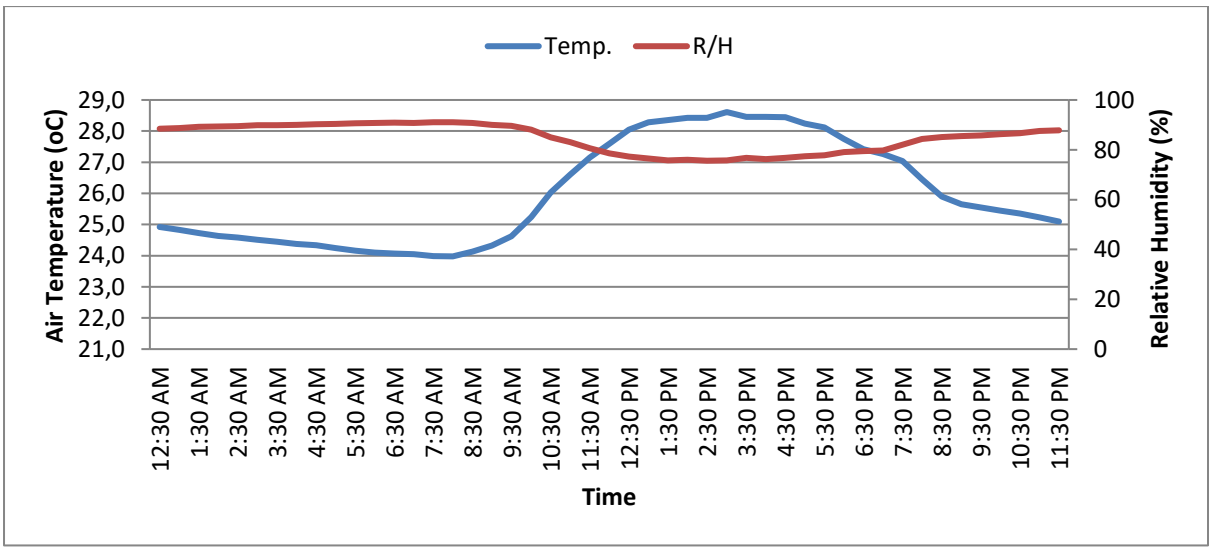



Figure 3.2: Diurnal temperature and relative humidity variations – Wet season

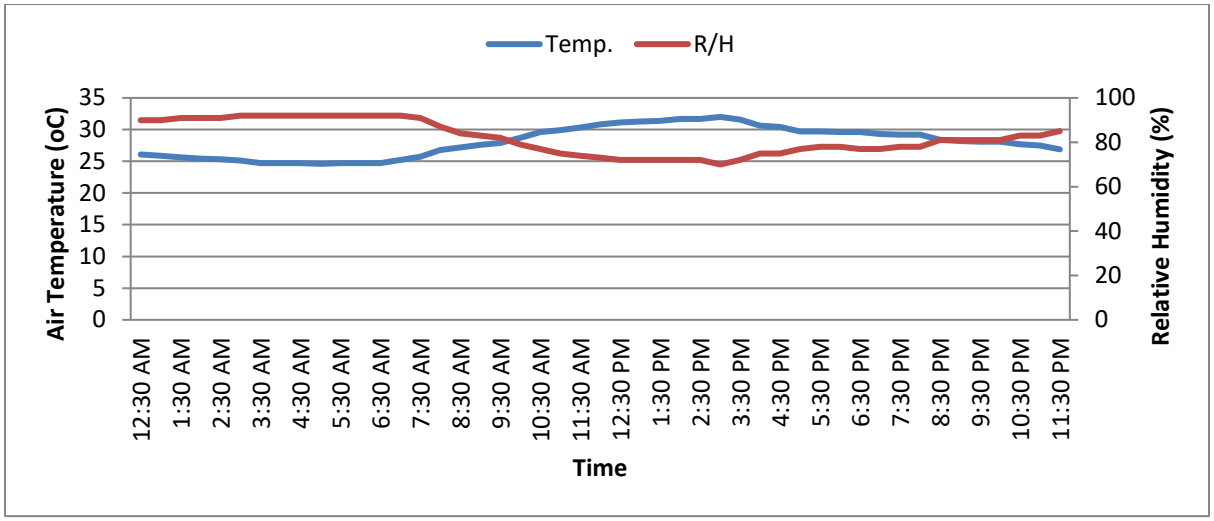
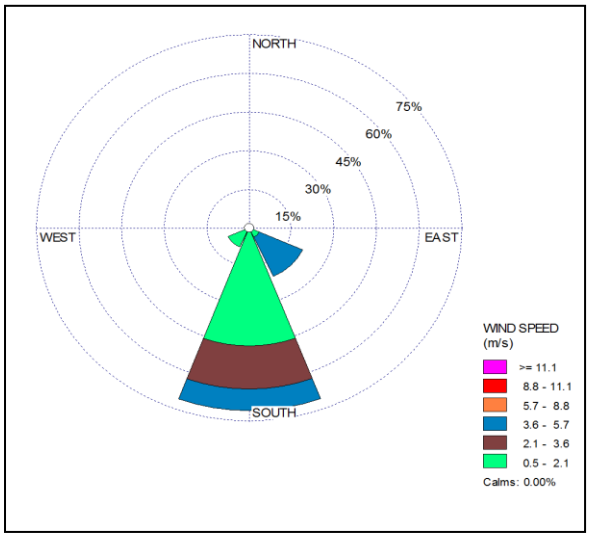



Figure 3.3: Diurnal temperature and relative humidity variations – Dry season



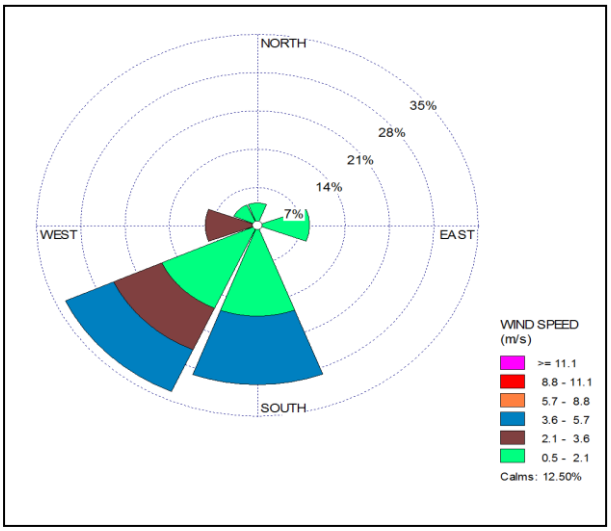
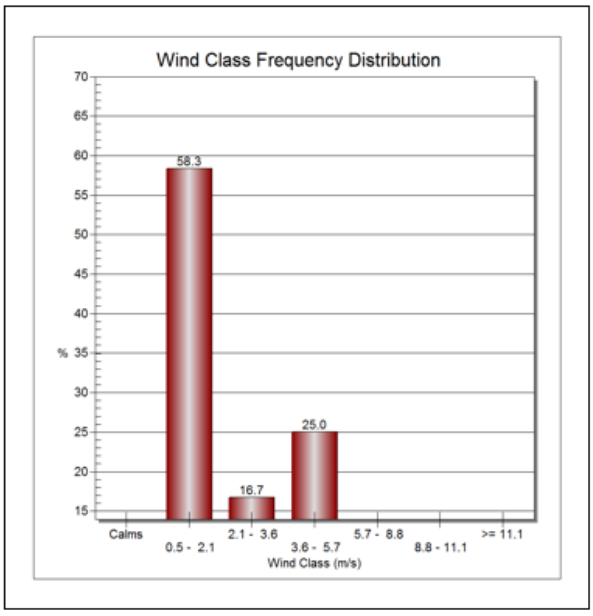




Figure 3.4 & 3.5: Diurnal wind rose pattern - June/July 2018 and January/February 2019



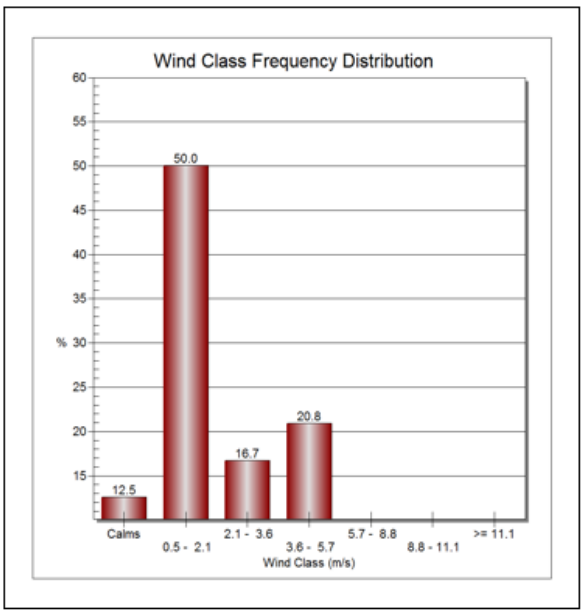




Figure 3.6 & 3.7: Diurnal wind speed record for June/July 2018 and January/February 2019

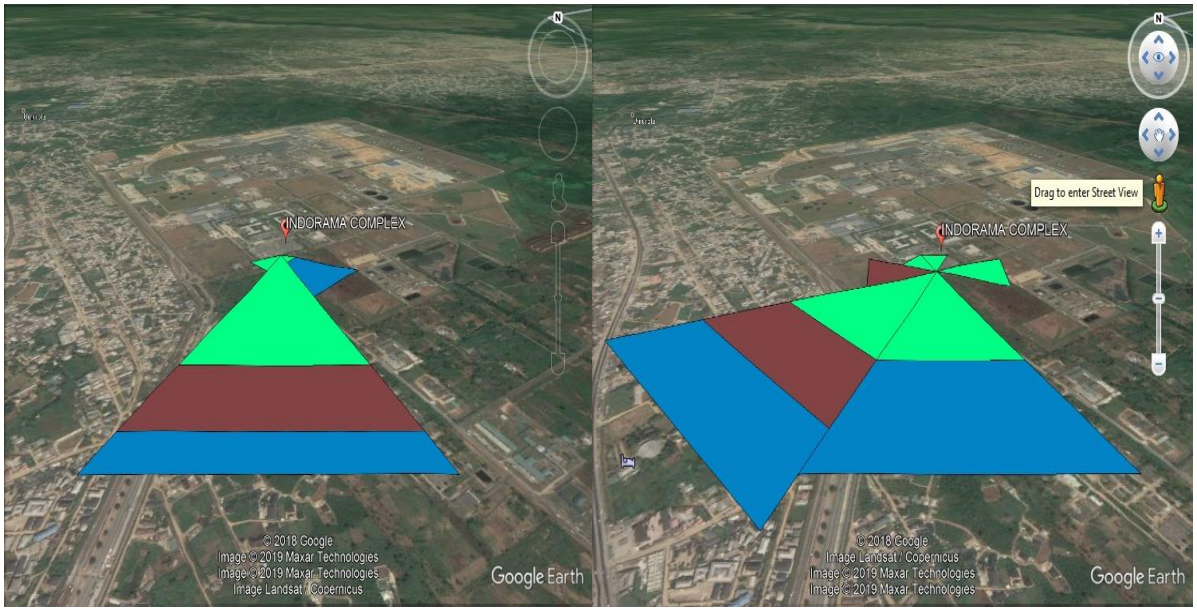


Figure 3.8 & 3.9: Aerial View of Wind Direction Pattern for Indorama Complex for June/July 2018 and Jan/Feb. 2019

### 3.2.2 Ambient Air Quality

The ambient air quality is being monitored monthly within Indorama complex and the surrounding communities. The low concentrations of gaseous pollutants obtained during dry and wet season' 2019 may be due to the compliance level of industrial operation in the area and the wind direction & wind speed.

The average values of ambient air quality monitored during first quarter' 2019 (Jan, Feb, March) presenting dry season and third quarter' 2019 (July, Aug, Sept) presenting wet season are presented in Table 3.4 and 3.5.

Table 3.4: Dry Season Ambient Air Quality

| Location/Parameter | | $SO_2$ (µg/m³) | $NO_2$ (µg/m³) | CO (µg/m³) | $H_2S$ (µg/m³) | THC (µg/m³) | VOCs (µg/m³) | $NH_3$ (µg/m³) | TSPM (µg/m³) | $PM_{10}$ (µg/m³) | $PM_{2.5}$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **AQ1** | Near Main Gate | 3.71 | 30.02 | 3.58 | 2.70 | 4.63 | 8.91 | 1.51 | 56.04 | 34.50 | 18.88 |
| **AQ2** | Near W/Bridge | 5.24 | 30.57 | 2.77 | 1.63 | 3.32 | 4.65 | 2.40 | 44.29 | 24.88 | 16.04 |
| **AQ3** | Flare Stack (N) | 4.58 | 28.61 | 2.34 | 1.96 | 2.45 | 6.51 | 0.64 | 48.50 | 28.92 | 17.58 |
| **AQ4** | Near AGIP Metering Station | 3.27 | 29.86 | 1.91 | 2.62 | 2.07 | 4.65 | 1.27 | 49.25 | 28.46 | 18.42 |
| **AQ5** | Near Urea Bagging | 4.36 | 25.00 | 1.57 | 1.72 | 0.71 | 4.52 | 0.41 | 51.92 | 31.33 | 18.54 |
| **AQ6** | Near Workshop | 4.58 | 26.73 | 1.14 | 1.96 | 2.86 | 4.39 | 1.27 | 47.92 | 28.79 | 17.79 |
| **AQ7** | Axis of Akpajo /Elelenwo | 2.18 | 25.71 | 2.00 | 2.13 | 2.51 | 2.79 | 0.26 | 50.33 | 29.33 | 18.79 |
| **AQ8** | Axis of Aleto /Agbonchia | 4.04 | 24.06 | 1.91 | 3.19 | 2.64 | 4.25 | 0.70 | 53.83 | 31.88 | 19.75 |
| **AQ9** | Agbonchia Area | 3.16 | 29.31 | 1.15 | 3.03 | 4.39 | 3.32 | 0.52 | 48.67 | 28.46 | 18.50 |
| **AQ10** | Aleto Area | 3.38 | 21.71 | 2.00 | 2.94 | 1.85 | 2.79 | 0.58 | 45.46 | 26.00 | 18.17 |
| | **Range** | **2.18 - 5.24** | **21.71-30.57** | **1.14-3.58** | **1.63-3.19** | **0.71-4.63** | **2.79-8.91** | **0.26-2.40** | **44.29-56.04** | **24.88-34.50** | **16.04-19.75** |
| | **Average** | **3.85** | **27.16** | **2.04** | **2.39** | **2.74** | **4.68** | **0.96** | **49.62** | **29.26** | **18.25** |
| | **FMEnv limit** | **26** | **75-113** | **22.8** | **N/A** | **160** | **6000** | **0.5-1.0** | **250** | **N/A** | **N/A** |
| | **IFC limit** | **20** | **200** | **N/A** | **N/A** | **N/A** | **N/A** | **N/A** | **N/A** | **50** | **25** |

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Table 3.5: Wet season Ambient Air Quality

| Location / Parameter | | $SO_2$ (µg/m³) | $NO_2$ (µg/m³) | CO (µg/m³) | $H_2S$ (µg/m³) | THC (µg/m³) | $NH_3$ (µg/m³) | VOCs (µg/m³) | TSPM (µg/m³) | $PM_{10}$ (µg/m³) | $PM_{2.5}$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **AQ1** | Near Main Gate | 5.35 | 29.23 | 3.53 | 4.99 | 5.45 | 5.05 | 2.09 | 60.33 | 37.42 | 21.00 |
| **AQ2** | Near W/Bridge | 4.36 | 33.54 | 2.53 | 2.62 | 3.27 | 3.99 | 1.68 | 43.71 | 25.92 | 16.00 |
| **AQ3** | Flare Stack (N) | 4.36 | 32.06 | 2.58 | 2.29 | 2.62 | 6.78 | 1.22 | 47.71 | 29.92 | 16.29 |
| **AQ4** | Near AGIP Metering Station | 2.73 | 29.78 | 0.95 | 5.97 | 3.68 | 4.92 | 1.27 | 40.67 | 22.96 | 16.00 |
| **AQ5** | Near Urea Bagging | 4.80 | 30.80 | 1.77 | 2.21 | 0.79 | 3.85 | 0.87 | 43.67 | 25.50 | 17.08 |
| **AQ6** | Near Workshop | 5.35 | 31.66 | 0.57 | 1.47 | 2.83 | 4.12 | 1.07 | 42.83 | 25.00 | 16.67 |
| **AQ7** | Axis of Akpajo /Elelenwo | 2.40 | 28.76 | 1.86 | 1.80 | 2.51 | 2.39 | 0.00 | 47.92 | 27.92 | 17.92 |
| **AQ8** | Axis of Aleto /Agbonchia | 4.80 | 24.84 | 1.91 | 2.78 | 3.02 | 2.92 | 0.46 | 59.08 | 35.58 | 21.17 |
| **AQ9** | Agbonchia Area | 4.47 | 27.67 | 1.57 | 1.80 | 2.73 | 3.06 | 0.93 | 47.04 | 27.29 | 17.92 |
| **AQ10** | Aleto Area | 1.96 | 28.14 | 2.19 | 3.35 | 2.18 | 2.53 | 0.43 | 48.63 | 25.92 | 22.17 |
| | **Range** | **1.96-5.35** | **24.85-33.54** | **0.57-3.53** | **1.47-5.97** | **0.79-5.45** | **2.39-6.78** | **0.00-2.09** | **40.67-60.33** | **22.96-37.42** | **16.00-22.17** |
| | **Average** | **4.06** | **29.65** | **1.95** | **2.93** | **2.91** | **3.96** | **1.00** | **48.16** | **28.34** | **18.22** |
| | **FMEnv limit** | **26** | **75-113** | **22.8** | **N/A** | **3-160** | **6000** | **0.5-1.0** | **250** | **N/A** | **N/A** |
| | **IFC Limit** | **20** | **200** | **N/A** | **N/A** | **N/A** | **N/A** | **N/A** | **N/A** | **50** | **25** |

### 3.2.3 Noise Survey

Noise measurement was carried out with ambient air quality monitoring at all the sampling stations in line with the FMEnv guidelines. The average values of noise monitored during first quarter' 2019 (Jan, Feb, March) presenting dry season and third quarter' 2019 (July, Aug, Sept) presenting wet season are presented in Table 3.6.

Table 3.6: Wet and Dry season Noise Level

| | Location | Dry season Noise Level (dB A) | | Wet season Noise Level (dB A) | |
|---|---|---|---|---|---|
| | | Day | Night | Day | Night |
| X1 | Near Main Gate | 64.3 | 60.3 | 67.8 | 61.1 |
| X2 | Near W/Bridge | 61.5 | 52.6 | 61.9 | 52.5 |
| X3 | Flare Stack (N) | 56.1 | 52.2 | 57.8 | 53 |
| X4 | Near AGIP Metering Station | 56.4 | 53.9 | 55.1 | 52.9 |
| X5 | Near Urea Bagging | 61.7 | 54.8 | 62.2 | 55.7 |
| X6 | Near Workshop | 62.8 | 61.1 | 63.1 | 61.3 |
| X7 | Axis of Akpajo /Elelenwo | 51.9 | 43.8 | 52.5 | 43.6 |
| X8 | Axis of Aleto /Agbonchia | 49.6 | 43.4 | 50.3 | 43 |
| X9 | Agbonchia Area | 51.4 | 44.3 | 51.3 | 44.5 |
| X10 | Aleto Area | 50.7 | 43.6 | 52.9 | 43.2 |
| | Range | 49.6-64.3 | 43.4-61.1 | 50.3-67.8 | 43.0-61.3 |
| | FMEnv limit dB(A) | 90 | | 90 | |
| | NESREA limit dB(A) | 85 | | 85 | |
| | NESREA limit (Industrial outside perimeter) LAeq dB(A) | 70 | | 70 | |
| | IFC limit LAeq dB(A) | 70 / 55 | 70 / 45 | 70 / 55 | 70 / 45 |

The FMEnv permissible noise limit for an 8-hour exposure is 90dB (A). The National Environmental Standards and Regulatory Agency (NESREA, 2009) has stipulated permissible noise level limit 85 dB (A) from a factory/workshop and a noise equivalent ($L_A$eq) limit of 70dB (A) for industrial outside perimeter fence in Nigeria. IFC specified noise equivalent ($L_A$eq) limit of 70dB (A) at industrial/commercial receptors in day and night hours and 55dB(A) in day hours & 45dB(A) in night hours for residential receptors. Noise levels measured during dry season ranged from 49.6 dB(A) to 64.3 dB(A) in day hours and 43.4 dB(A) to 67.8 dB(A) in night hours. The noise levels in the wet season ranged from 50.3 dB(A) to 74.4 dB(A) in day hours and 43.0 dB(A) to 61.3 dB(A) in night hours. The measured noise levels recorded in the area are within FMEnv limit of 90dB (A) on a weighted scale A.

### 3.2.4 Stack Emission

Flue/ Stack Gas monitoring is being carried out quarterly in accordance with the FMEnv guidelines. The flue gas monitoring was carried using Madura GT-21 and Testo 350 XL flue gas analyzer. A total of ten readings were taken for each stack at 5 minutes intervals. The mean values were calculated and then converted from ppm to mg/$Nm^3$ as presented in the table 3.8 below. The result revealed low concentration of priority parameters measured when compared to the FMEnv limit.

For monitoring of PM and ammonia in granulator stack flue gas, isokinetic sampling method was adopted, where the gas was sucked isokinetically and particulate matter collected in thimble. This collected mass is divided by normalized volume to get PM emissions in mg/$Nm^3$. To analyze ammonia, standard acid is used as absorbent and then concentration was determined through a back titration with 0.2N-NaOH. The gas volume is normalized by temperature and pressure correction, and ammonia calculated in mg/$Nm^3$. The granulator stack monitoring results are represented in table 3.7.

Table 3.7: Summary of Granulator stack monitoring results

| **Stack** | **Ammonia** | **PM** |
|---|---|---|
| Urea Granulator | 44.8 mg/$Nm^3$ | 10.5 mg/$Nm^3$ |
| IFC Limit | 50 mg/$Nm^3$ | 50 mg/$Nm^3$ |

Table 3.8: Summary of stack emission results from existing stacks in Complex

| **Stacks** | **$SO_2$ (mg/$Nm^3$)** | **$NO_2$ (mg/$Nm^3$)** | **CO (mg/$Nm^3$)** | **$CH_4$ (mg/$Nm^3$)** | **VOCs (mg/$Nm^3$)** | **$O_2$ (%)** | **$CO_2$ (%)** |
|---|---|---|---|---|---|---|---|
| Sludge Incinerator | 7.8 | 41.3 | 0.0 | 0.0 | 0.0 | 17.5 | 2.7 |
| Olefin Furnace B | 1.7 | 76.8 | 0.0 | 0.0 | 0.0 | 3.6 | 8.6 |
| GT 01 | 0.9 | 76.6 | 0.0 | 0.0 | 0.0 | 17.6 | 1.9 |
| GT 03 | 0.5 | 80.7 | 0.0 | 0.0 | 0.0 | 17.4 | 2.0 |
| Boiler A | 0.7 | 120.6 | 0.0 | 0.0 | 0.0 | 4.6 | 9.5 |
| Boiler B | 0.9 | 115.2 | 0.0 | 0.0 | 0.0 | 5.6 | 7.7 |
| Pack Boiler | 1.9 | 86.6 | 0.0 | 0.0 | 0.0 | 4.2 | 6.4 |
| Reformer | 2.1 | 71.2 | 0.0 | 0.0 | 0.0 | 4.0 | 6.6 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **FMEnv Limit mg/Nm3** | **30 -3000** | **350 -1000** | **-** | **50.00** | **0.00** | **0.00** | **-** |
| **IFC Limit mg/Nm3** | **500** | **300** | **-** | **-** | **-** | **-** | **-** |

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### 3.2.5 Soil Quality

**Sampling Stations**

The soil quality study is extracted from approved ESIA of IEFCL-Train2. Total nine samples were collected, Seven (7) at different locations within the study area and two control sites outside the project area.

| ID | Sample Description/Location | Coordinates | |
|---|---|---|---|
| SS1 | SS1 (Aleto) ; Top and Bottom | E07°06’19.52” | N04°48’20.46” |
| SS2 | SS2 (Agbonchia); Top and Bottom | E07$^0$ 07'07.17" | N04$^0$ 47'46.94" |
| SS3 | SS3 (Flare Area); Top and Bottom | E07$^0$ 06'19.94" | N04$^0$ 50'02.66" |
| SS4 | SS4 (Agip Metering); Top and Bottom | E07$^0$ 06'19.93" | N04$^0$ 50'35.96" |
| SS5 | SS5 (IRC); Top and Bottom | E07$^0$ 05'25.98" | N04$^0$ 50'03.31" |
| SS6 | SS6 (Weigh Bridge); Top and Bottom | E07$^0$ 05'34.90" | N04$^0$ 49'53.97" |
| SS7 | SS7 (Akpajo); Top and Bottom | E07$^0$05'15.80" | N04$^0$49'37.92" |
| SSC1 | SSC1 Oyigbo Road; Top and Bottom | E07$^0$ 07'07.17" | N04$^0$ 47'46.90" |
| SSC2 | SSC2 Rumukrushi; Top and Bottom | E07$^0$ 03’38.40” | N04$^0$ 51’07.68’’ |

**Sampling Methodology**

Soil samples were randomly collected using the vegetation, slope and elevation as the factor determining the sampling point. The sampling stations were geo-referenced. Composite soil samples were collected at two depths: 0-15cm (Topsoil) and 15 – 30cm (Subsoil) with the aid of Dutch stainless steel hand auger. The soil samples were collected in duplicate; those for physical and chemical analysis were packed in Ziploc polythene bags, and those for microbial and oil & grease analysis wrapped in aluminum foil. The samples were neatly labeled, preserved and taken to FMEnv accredited laboratory for analysis. All in-situ observations were recorded in a field notebook.

**Morphological properties**

The soils of the study area is part of the coastal plain sands some times called Ogoni Sands of South Eastern Nigeria. The soils of the study area are coarse grained, gravelly, locally fine-grained, poorly sorted, subangular to well rounded (Assez,1975). Ojanuga et al (1981) stated that the genesis of these soils have resulted from cycles of soil formation which alternated with cycles of erosion in the mid tertiary to Holocene era in Nigeria. Soil consistency as observed during the field exercise were between wet (slightly sticky and non sticky) and moist (friable), while soil colour were between black (10YR2/1), Dark red (2.5/YR3/6), Brown (10YR5/3) and Strong brown (7.5YR4/6). The topography of the study area were relatively flat with some gentle slope as observsed around station one (SS1- Okulu Aleto).

Soils of the area with the exception of some localized variations are characterized as very good physical features, poor inherent fertility status, low degree of acidity, low cation exchange capacity (FAO, 1990) and predominant sandy texture.

**Soil Physico-chemical Characteristics**

The summary of results of the soil physico-chemical analysis is presented in Tables 3.9 and 3.10 for the topsoil (0 – 15 cm) and subsoil (15 – 30 cm) respectively. The textural classification of the two soil depths within the study area and control site was predominantly fine-grained fairly consolidated Loamy Sand, Sandy Loam and Sandy Clay Loam soil, with considerably low clay content. The sand, silt and clay contents of the topsoil ranged between 64.50 – 77.00%, 5.80 – 1.10% and 13.80 – 27.00% respectively, while the subsoil recorded 58.80 – 72.20% sand, 6.10-7.90% silt and 20.80 – 34.40% clay. The mean values obtained from the control sample locations were not significantly different from that of the project influence zone. The texture of a soil determines the water absorption /infiltration rate, the water holding capacity and migration of pollutant down the soil strata (Agede 2009).

The results obtained in this study revealed porosity range of 43.80 – 53.20% and bulk density 0.15 – 0.28 for topsoil, while the respective values for subsoil ranged from 44.00 – 56.08 % and 0.18 – 0.33 g/cm$^3$, with no significantly different ($p>0.05$) when compared to the control values. The low soil bulk density result revealed that no form of soil compaction is in progress within and outside the project influence zone (Nwachukwu 2016). The soil reaction falls within acidic pH range of 4.70 – 5.60 (5.22 ± 0.39) for topsoil and 4.30 – 6.80 (5.37 ± 1.03) for

subsoil indicating that the soil is slightly acidic, which is typical of a Niger Delta soil (Isirimah 1987). The soil moisture content ranged from 0.24 – 1.15% and 0.26 – 0.51% for topsoil and subsoil respectively. The Organic matter content of the soil ranged from 0.09 – 0.21% at the topsoil, while the subsoil ranged from 0.08 – 0.16% indicating low organic matter content of both topsoil and subsoil according to FAO (1990) classification, which also reflected in the Total Organic Carbon results recorded during this studied. Spatial variation in the measured TOM values across the sampling stations was not too high with coefficient of variation less than 25%. Soil organic matter contributes to soil aggregation and reduces susceptibility to erosion (Brady and Weil, 1996).

Table 3.9: Summary of Physiochemical properties of Soil (0-15cm)

| PARAMETERS | Min | Max | STD | Ave | CV % | Control 1 | Control 2 |
|---|---|---|---|---|---|---|---|
| **Sand (%)** | 64.50 | 77.00 | 4.32 | 69.05 | 6.25 | 76.50 | 66.70 |
| **Silt (%)** | 5.80 | 10.10 | 1.70 | 8.05 | 21.18 | 1.30 | 21.40 |
| **Clay (%)** | 13.80 | 27.00 | 4.75 | 22.90 | 20.75 | 22.20 | 11.9 |
| **Porosity (% Pore space)** | 43.80 | 53.20 | 3.38 | 50.07 | 6.75 | 42.80 | 50.90 |
| **Permeability (k-4cm/hr)** | 1.70 | 2.10 | 0.22 | 1.90 | 11.53 | 1.90 | 1.60 |
| **Bulk Density (g/cm)** | 0.15 | 0.28 | 0.05 | 0.23 | 20.39 | 0.22 | 0.20 |
| **Moisture Content (%)** | 0.24 | 1.15 | 0.31 | 0.60 | 51.60 | 0.72 | 0.42 |
| **pH** | 4.70 | 5.60 | 0.39 | 5.22 | 7.51 | 4.80 | 5.30 |
| **Electrical Conductivity (us/cm)** | 48.20 | 172.20 | 42.07 | 108.42 | 38.81 | 124.60 | 39.40 |
| **Phosphorous (%)** | 0.13 | 0.28 | 0.05 | 0.18 | 28.59 | 0.14 | 0.12 |
| **Total Nitrogen (%)** | 0.08 | 0.39 | 0.11 | 0.19 | 58.01 | 0.17 | 0.16 |
| **CEC (cmol/kg)** | 0.81 | 1.32 | 0.18 | 1.04 | 17.76 | 1.21 | 1.04 |
| **$SO_4^{2-}$ (mg/kg)** | 2.70 | 7.25 | 1.67 | 4.47 | 37.34 | 8.66 | 2.76 |
| **$NO_3$ - N (mg/kg)** | 0.05 | 0.18 | 0.06 | 0.12 | 48.78 | 0.07 | 0.05 |
| **$NH_4$ - N (mg/kg)** | 0.16 | 0.52 | 0.16 | 0.37 | 42.38 | 0.18 | 0.19 |
| **O & G (mg/kg)** | 1.28 | 6.16 | 1.93 | 2.22 | 86.93 | 2.31 | 0.68 |
| **TOC (%)** | 0.04 | 0.13 | 0.03 | 0.10 | 33.68 | 0.25 | 0.26 |
| **OM (%)** | 0.09 | 0.21 | 0.04 | 0.17 | 24.76 | 0.39 | 0.33 |
| **Exc. Acidity (meq/100g)** | 0.70 | 1.20 | 0.19 | 0.95 | 19.69 | 1.10 | 1.00 |
| **Base Saturation (%)** | 3.85 | 13.79 | 3.90 | 9.07 | 42.99 | 9.40 | 3.44 |
| **CATIONS** | | | | | | | |
| **Ca ($cmolkg^{-1}$)** | 0.63 | 1.30 | 0.25 | 0.90 | 28.27 | 0.86 | 0.72 |
| **Mg ($cmolkg^{-1}$)** | 0.36 | 3.61 | 1.36 | 1.97 | 68.89 | 1.63 | 0.12 |
| **Na ($cmolkg^{-1}$)** | 4.61 | 22.51 | 6.76 | 14.74 | 45.88 | 21.26 | 6.31 |
| **K ($cmolkg^{-1}$)** | 0.95 | 4.15 | 1.37 | 2.83 | 48.27 | 1.50 | 1.40 |

Table 3.10: Summary of Physiochemical properties of Soil (15-30cm)

| PARAMETERS | Min | Max | STD | Ave | CV % | Control 1 | Control 2 |
|---|---|---|---|---|---|---|---|
| **Sand (%)** | 58.80 | 72.20 | 5.43 | 65.15 | 8.34 | 71.1 | 75.9 |
| **Silt (%)** | 6.10 | 7.90 | 0.63 | 7.07 | 8.93 | 5.40 | 5.70 |
| **Clay (%)** | 20.80 | 34.40 | 5.18 | 27.78 | 18.63 | 23.5 | 18.4 |
| **Porosity (% Pore space)** | 44.00 | 56.08 | 4.35 | 50.70 | 8.58 | 52.30 | 57.40 |
| **Permeability (k-4cm/hr)** | 1.60 | 2.00 | 0.15 | 1.82 | 8.10 | 2.00 | 1.90 |
| **Bulk Density (g/cm)** | 0.18 | 0.33 | 0.07 | 0.25 | 27.08 | 0.28 | 0.26 |
| **Moisture Content (%)** | 0.26 | 0.51 | 0.09 | 0.41 | 22.31 | 0.16 | 0.15 |
| **pH** | 4.30 | 6.80 | 1.03 | 5.37 | 19.14 | 5.50 | 5.50 |
| **Electrical Conductivity (us/cm)** | 41.10 | 121.70 | 39.44 | 78.47 | 50.26 | 38.30 | 34.50 |
| **Phosphorous (%)** | 0.14 | 0.32 | 0.07 | 0.21 | 33.37 | 0.22 | 0.19 |
| **Total Nitrogen (%)** | 0.08 | 0.27 | 0.07 | 0.17 | 38.37 | 0.07 | 0.12 |
| **CEC (cmol/kg)** | 0.70 | 1.49 | 0.33 | 1.03 | 31.85 | 1.04 | 0.93 |
| **$SO_4^{2-}$ (mg/kg)** | 2.92 | 7.31 | 1.51 | 5.66 | 26.72 | 1.65 | 2.43 |
| **$NO_3$ - N (mg/kg)** | 0.04 | 0.22 | 0.06 | 0.10 | 64.98 | 0.06 | 0.09 |
| **$NH_4$ - N (mg/kg)** | 0.12 | 0.47 | 0.13 | 0.33 | 38.66 | 0.18 | 0.27 |
| **O & G (mg/kg)** | 0.92 | 1.52 | 0.33 | 1.14 | 28.99 | <0.01 | <0.01 |
| **TOC (%)** | 0.03 | 0.09 | 0.02 | 0.06 | 36.51 | 0.04 | 0.07 |
| **OM (%)** | 0.08 | 0.16 | 0.03 | 0.12 | 26.95 | 0.07 | 0.12 |
| **Exc. Acidity (meq/100g)** | 0.60 | 1.40 | 0.34 | 0.97 | 35.03 | 1.00 | 0.90 |
| **Base Saturation (%)** | 2.64 | 13.85 | 4.67 | 7.14 | 65.43 | 3.39 | 2.88 |
| **CATIONS** | | | | | | | |
| **Ca ($cmolkg^{-1}$)** | 0.50 | 1.21 | 0.25 | 0.72 | 35.44 | 0.88 | 0.53 |
| **Mg ($cmolkg^{-1}$)** | 0.34 | 2.27 | 0.76 | 1.13 | 66.77 | 0.59 | 0.17 |
| **Na ($cmolkg^{-1}$)** | 4.46 | 18.06 | 6.56 | 11.13 | 58.97 | 5.06 | 4.66 |
| **K ($cmolkg^{-1}$)** | 0.80 | 2.90 | 0.85 | 1.63 | 52.25 | 1.45 | 0.93 |

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**Soil microbiology**

Soil represents a very favorable habitat for microorganisms and is inhabited by a wide range of microorganisms, including bacteria, fungi, algae, viruses and protozoa. Microorganisms are found in large numbers in the soil (usually between one and ten million microorganisms are present per gram of soil) with bacteria and fungi being the most prevalent. However the availability of nutrients is often limiting for microbial growth in soil and may increase soil fertility and plant growth. Consequently, an investigation to determine existence of

heterotrophic as well as hydrocarbon Utilizing bacteria and fungi in the study area was carried out and presented in (Table 3.11).

Table 3.11: Summary of Soil microbes

| PARAMETERS | Min | Max | STD | Ave | CV % | Control 1 | Control 2 |
|---|---|---|---|---|---|---|---|
| **Topsoil** | | | | | | | |
| **THB (cfu/g X $10^4$)** | 0.52 | 4.50 | 1.47 | 2.64 | 55.77 | 1.00 | 1.61 |
| **THF (cfu/g X $10^4$)** | 0.15 | 1.59 | 0.55 | 0.86 | 64.25 | 0.45 | 0.23 |
| **HUB (cfu/g X $10^4$)** | 0.25 | 1.96 | 0.63 | 0.74 | 84.35 | 0.20 | 1.45 |
| **HUF (cfu/g X $10^4$)** | 0.64 | 3.00 | 0.84 | 1.50 | 55.96 | 2.00 | 0.38 |
| **T.Col. (cfu/g X $10^4$)** | 0.85 | 1.31 | 0.17 | 1.13 | 15.00 | 1.34 | 1.26 |
| **Subsoil** | | | | | | | |
| **THB (cfu/g X $10^4$)** | 1.50 | 3.95 | 1.09 | 2.65 | 41.29 | 2.03 | 0.85 |
| **THF (cfu/g X $10^4$)** | 0.45 | 2.00 | 0.56 | 0.99 | 55.87 | 0.94 | 0.12 |
| **HUB (cfu/g X $10^4$)** | 0.37 | 1.99 | 0.60 | 1.11 | 53.75 | 0.27 | NIL |
| **HUF (cfu/g X $10^4$)** | 0.22 | 3.50 | 1.29 | 1.62 | 79.66 | 1.21 | 0.5 |
| **T.Col. (cfu/g X $10^4$)** | 0.31 | 0.45 | 0.06 | 0.41 | 15.12 | 0.41 | 0.46 |

**Soil Fauna**

The soil macro-fauna identified through visual observation in the study area include various arthropods (*Myricarid striata*, *Dorylus fimbriatus, Glomens marginata*), Annelids (Earthworms) and Nematodes (*Acanthamoeba polyphaga, Acrobeloides sp, Porcellia scraber*). These organisms are primary consumers; decomposers, mixers and utilizers of energy stored in plants and plant residues, and contribute to the recycling of nutrients. They also help in soil particle aggregation to encourage soil stability. Others are secondary consumers such as centipedes and spiders. These animals consume smaller sized animals and they, also may serve as food for organisms occupying higher levels of the food chain. Soil fauna are notable and are critical in the biological turnover and nutrients release of plant residues by fragmenting the plant residues, resulting in enhanced microorganism activities.

**Heavy metals**

Heavy metals analysis in the soil samples revealed Iron (Fe) having the highest concentration (Mean 6847.25mg/kg topsoil and 6685.20mg/kg subsoil) which is peculiar to Niger Delta, while mercury (Hg) and Vanadium (v) recorded the lowest concentration <0.05mg/kg, Lead

concentration ranged from 38.14 to 51.16 topsoil and 31.03 to 48.74mg/kg in subsoil. Similar values were recorded at the control stations

Table 3.12: Summary of heavy metal composition in Soil

| PARAMETERS | Min | Max | STD | Ave | CV % | Control 1 | Control 2 |
|---|---|---|---|---|---|---|---|
| **Topsoil** | | | | | | | |
| **V (mg/kg)** | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **Ni (mg/kg)** | 7.81 | 17.32 | 3.19 | 13.27 | 24.00 | 13.57 | 13.38 |
| **Fe (mg/kg)** | 5931.95 | 8592.83 | 989.02 | 6847.25 | 14.44 | 3709.22 | 4468.47 |
| **Pb (mg/kg)** | 38.14 | 51.16 | 4.84 | 43.43 | 11.15 | 38.92 | 38.17 |
| **Cu (mg/kg)** | 7.06 | 11.31 | 1.52 | 8.84 | 17.23 | 5.91 | 5.81 |
| **Zn (mg/kg)** | 60.66 | 80.38 | 7.63 | 69.67 | 10.95 | 72.28 | 70.97 |
| **Cd (mg/kg)** | 5.31 | 8.90 | 1.37 | 7.88 | 17.37 | 8.93 | 2.68 |
| **Cr (mg/kg)** | 0.40 | 1.25 | 0.35 | 0.78 | 45.42 | 0.12 | 0.62 |
| **Hg (mg/kg)** | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **Subsoil** | | | | | | | |
| **V (mg/kg)** | <0.05 | <0.05 | 0.00 | 0.00 | 0.00 | <0.05 | <0.05 |
| **Ni (mg/kg)** | 10.92 | 17.27 | 2.07 | 14.01 | 14.80 | 17.28 | 15.62 |
| **Fe (mg/kg)** | 4003.32 | 8401.76 | 1583.27 | 6685.20 | 23.68 | 2915.96 | 2023.67 |
| **Pb (mg/kg)** | 31.03 | 48.74 | 7.70 | 41.31 | 18.65 | 40.59 | 38.28 |
| **Cu (mg/kg)** | 5.16 | 10.41 | 1.71 | 7.89 | 21.65 | 3.95 | 5.01 |
| **Zn (mg/kg)** | 52.96 | 78.58 | 9.23 | 64.02 | 14.43 | 52.25 | 62.77 |
| **Cd (mg/kg)** | 6.28 | 8.60 | 0.92 | 8.15 | 11.30 | 4.84 | 2.83 |
| **Cr (mg/kg)** | 0.12 | 3.78 | 1.32 | 1.41 | 93.51 | 0.19 | 0.56 |
| **Hg (mg/kg)** | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |

### 3.2.6 Land use

Land use within the study area is largely affected by large extent of human activities such as industrilisation, municipal and agricultural activities. High industrialization, which is at its peak within the area has resulted to visible reduction in agricutural activity of the study area. The notable landuse within the study area included Indorama complex (which is playing host to the proposed IEFCL-Train2 fertilizer project including FCU2 Unit), NNPC estate adjcent to

Indorama complex, Onura shrine, Port Harcourt Refinery, fuel stations and road infrastucture network. Comparatively, Port Harcourt Refinery, Indorama complex and NNPC Estate occupies prominent space in the land use of the study area.

### 3.2.7 Vegetation and Wildlife

The ecological study covered flora and fauna species compositions, in terms of species that are abundant, common, occasional and rare. The study area lies within the riparian lowland forest with a two-layer canopy characteristic and a low lying flat terrain that experiences seasonal flooding. The soil of the study area is wet and moist in the wet season but dry and friable during the dry season. However, the proposed development site had little vegetation components which are mainly herbaceous in nature as compared to the surroundings of the IEFCL-Train1 facility. No endangered and endemic species were encountered in the study area. Hence, the project will not affect any form of wildlife or plant in the project environs as well as in the study area. This study is extracted from ESIA of IEFCL-Train2 Project.

**Vegetation**

**Tree/Shrub species composition**

Within the study area, a total of thirteen tree/ shrub species occurred and out of which no specie (tree/shrub) was abundant but rather, one specie was found to be common and that specie was *Elaeis guinensis*. In the same vein, four species were occasional and they include; *Anthonota macrophylla, Alchornea cordifolia, Alstonia boonei and Harungana madascariensis*. However, eight species were found to be rare and they are; *Ficus exasperate, Psidium guajava, Anthocleista vogelii, Musanga cecropioides, Anacardium occidentalis, Bambusa vulgaris, Baphia nitida and Persea Americana.* The tree/shrub species composition of the study area is presented in table 3.13.

Table 3.13: Tree/Shrub Species Composition

| Sr. No. | Tree shrub composition | Common name | Family | A | C | O | R |
|---|---|---|---|---|---|---|---|
| **1** | *Ficus exasperate* | Forest sand paper | *Moraceae* | | | | X |
| **2** | *Elaeis guinensis* | Oil palm | *Arecaceae* | | x | | |
| **3** | *Psidium guajava* | guava | *Mytraceae* | | | | X |
| **4** | *Anthonota macrophylla* | African rose wood | *Mimosaceae* | | | x | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **5** | *Anthocleista vogelii* | English cabbage tree | *Potaliceae* | | | | X |
| **6** | *Musanga cecropioides* | Umbrella tree | *Urticaceae* | | | | X |
| **7** | *Alchornea cordifolia* | Christmas bush | *Apocynaceae* | | | x | |
| **8** | *Alstonia boonei* | African nut tree | *Apocynaceae* | | | x | |
| **9** | *Anarcadium occidentalis* | Cashew tree | *Anacardiaceae* | | | | X |
| **10** | *Harungana madascariensis* | Dragon blood tree | *Hypericaceae* | | | x | |
| **11** | *Bambusa vulgaris* | Bamboo | *Bambusae* | | | | X |
| **12** | *Baphia nitida* | Cam wood | *Fabaceae* | | | | X |
| **13** | *Persea Americana* | Avocado | *Lauraceae* | | | | X |

**Tree/Shrub family composition**

Twelve families were seen to occur within the thirteen tree/shrub species. From the occurrence, it was observed that a total of eleven families based on their ecological status were found to be rare and they include; *Moraceae, Arecaceae, Mytraceae, Mimosaceae, Potaliceae, Urticaceae, Anacardiaceae, Hypericaceae, Bambuseae, Fabaceae and Lauraceae* while *Apocynaceae* was the only occasionally occurring family. The tree/shrub family composition of the study area is presented in table 3.14.

Table 3.14: Tree/Shrub family composition

| Sr. No. | Family | Frequency | A | C | O | R |
|---|---|---|---|---|---|---|
| **1** | *Moraceae* | 1 | | | | X |
| **2** | *Arecaceae* | 1 | | | | X |
| **3** | *Mytraceae* | 1 | | | | X |
| **4** | *Mimosaceae* | 1 | | | | X |
| **5** | *Potaliceae* | 1 | | | | X |
| **6** | *Urticaceae* | 1 | | | | X |
| **7** | *Apocynaceae* | 2 | | | X | |
| **8** | *Anacardiaceae* | 1 | | | | X |
| **9** | *Hypericaceae* | 1 | | | | X |
| **10** | *Bambusae* | 1 | | | | X |
| **11** | *Fabaceae* | 1 | | | | X |
| **12** | *Lauraceae* | 1 | | | | X |
| | ***TOTAL*** | **13** | | | | |

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**Herbaceous species composition**

A total of eighteen (18) herbaceous species were found to occur within the study area and from the occurrences, it was observed that *Panicum maximum* was the only abundant occurring family while *Ipomoea involucrate* was the only common family. Occasionally speaking, six herbaceous species were found to be in that range and such species include; *chromoleana odorata, pennisetum purpureum, cyperus spp, costus afer, kyllinga erecta* and *sida acuta.* Moreover, nine (9) species were rare and they were; *Aspilia Africana, Elusine indica, Spermacoce venticullata, Mimosa pudica, Calopogonium mucunioides, Senna occidentalis, Amaranthus spinosus, Imperata cylindrical* and *Emilia sonchifolia.* The herbaceous species composition of the study area is presented in table 3.15.

Table 3.15: Herbaceous species composition

| Sr. No. | Herbaceous species | Common name | Family | A | C | O | R |
|---|---|---|---|---|---|---|---|
| **1** | *Panicum maximum* | Guinea grass | *Poaceae* | x | | | |
| **2** | *Aspilia africana* | Haemorrhage plant | *Asteraceae* | | | | X |
| **3** | *Elusine indica* | Wire grass | *Poaceae* | | | | X |
| **4** | *Centrosema pubescens* | Butterfly pea | *Fabaceae* | | x | | |
| **5** | *Spermacoce venticullata* | Shrubby false buttonweed | *Rubiaceae* | | | | X |
| **6** | *Mimosa pudiica* | Shame weed | *Fabaceae* | | | | X |
| **7** | *Chromoleana odorata* | Siam weed | *Asteraceae* | | | x | |
| **8** | *Calopogonium mucunoides* | Wild groundnut | *Fabaceae* | | | | X |
| **9** | *Senna occidentalis* | Coffee weed | *Fabaceae* | | | | X |
| **10** | *Amaranthus spinosus* | Spiny pigweed | *Amaranthaceae* | | | | X |
| **11** | *Pennisetum purpureum* | Elephant grass | *Poaceae* | | | x | |
| **12** | *Imperata cylindrical* | Cogon grass | *Poaceae* | | | | X |
| **13** | *Cyperus spp* | Nutsedges | *Cyperaceae* | | | x | |
| **14** | *Emilia sonchifolia* | Tassel flower | *Asteraceae* | | | | X |
| **15** | *Costus afer* | Spiral ginger | *Costaceae* | | | x | |
| **16** | *Ipomoea involucrate* | Morning glory | *Convolvulaceae* | | x | | |
| **17** | *Kyllinga erecta* | Spikesedges | *Cyperaceae* | | | x | |
| **18** | *Sida acuta* | Broomweed | *Malvaceae* | | | x | |

**Herbaceous family composition**

In consideration of the herbaceous family composition within the study area, it was observed that a total of nine families occurred within the eighteen (18) herbaceous species. Further, two families namely *Poaceae* and *Fabaceae* were in abundance while *Asteraceae* was the only commonly occurring family. In the same vein, *cyperaceae* was found to be the only occasionally occurring family. However, five species were found to be rare and they include *Rubiaceae, Amaranthaceae, Costaceae, Convolvulaceae* and *Malvaceae.* The herbaceous family composition of the study area is presented in table 3.16.

Table 3.16: Herbaceous Family

| Sr. No. | Family | Frequency | A | C | O | R |
|---|---|---|---|---|---|---|
| **1** | *Poaceae* | 4 | x | | | |
| **2** | *Asteraceae* | 3 | | x | | |
| **3** | *Fabaceae* | 4 | x | | | |
| **4** | *Rubiaceae* | 1 | | | | X |
| **5** | *Amaranthaceae* | 1 | | | | X |
| **6** | *Cyperaceae* | 2 | | | x | |
| **7** | *Costaceae* | 1 | | | | X |
| **8** | *Convolvulaceae* | 1 | | | | X |
| **9** | *Malvaceae* | 1 | | | | X |
| | ***TOTAL*** | **17** | | | | |

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**Wild Life species composition in the study area**

A total of twenty-one (21) wildlife species occurred within the study area and it was observed that no wildlife species was found to be abundant but however, three wildlife species were common namely *Rattus rattus, Streptopelia senegalensis* and *Corvus albus*. Occasionally, eleven (11) wildlife species were found in this range and they include *Cricetomys emini, Lemniscomys striatus, Dendroaspis viridis, Pycinonothus barbatus, Nectarinia chloropygia, Anthreptes gabonicus, Nectarinia fuliginosa, Streptopelia semitorqota, Milvus migrans, Ploceus cucullatus* and *Apus affinus*. Nevertheless, seven (7) wildlife species were found to be

rare and such species include; *Thryonomys swinderianus, Varanus niloticus, Python sabae, Agama agama, Vidua macroura, Ploceus nigerimus* and *Ploceus inelanocephala.*

Wildlife is important to the national economy both as a source of food and as a basis for tourism and recreation. The wildlife species associated with the study area are mainly vertebrate animals presented by mammals, amphibians, reptiles and birds. The wild life species occurred within the study area is presented in table 3.17. The study recorded similarity in terms of occurrence for species identified but observed variation in the distribution abundance. Black kite have been classified as endangered under the Nigerian Red List, while none of them are endangered species as per the list of International Union for Conservation of Nature (IUCN 2009).

Table 3.17: Wild Life Species

| Sr. No. | Common names | Scientific names | A | C | O | R |
|---|---|---|---|---|---|---|
| **1** | Greater cane rat | *Thryonomys swinderiamus* | | | | X |
| **2** | Emins giant rat | *Cricetomys emini* | | | X | |
| **3** | Black house rat | *Rattus rattus* | | x | | |
| **4** | Spotted grass mouse | *Lemniscomys striatus* | | | X | |
| **5** | Nile monitor lizard | *Varanus niloticus* | | | | X |
| **6** | Rock python | *Python sabae* | | | | X |
| **7** | Agama lizard | *Agama agama* | | | | X |
| **8** | Green mamba | *Dendroaspis viridis* | | | X | |
| **9** | Common garden bulbul | *Pycinonothus barbatus* | | | X | |
| **10** | Pintailed whydah | *Vidua macroura* | | | | X |
| **11** | Olive bellied sunbird | *Nectarinia chloropygia* | | | X | |
| **12** | Mouse brown sunbird | *Anthreptes gabonicus* | | | X | |
| **13** | Carmelite sumbird | *Nectarinia fuliginosa* | | | X | |
| **14** | Red eye dove | *Streptopelia semitorqota* | | | X | |
| **15** | Laughing dove | *Streptopelia senegalensis* | | x | | |
| **16** | Black kite | *Milvus nigrams* | | | X | |
| **17** | Pied crow | *Corvus albus* | | x | | |
| **18** | Village weaver | *Ploceus cucullatus* | | | X | |
| **19** | Viellot's black weaver | *Ploceus nigerimus* | | | | x |

| | | | | | | |
|---|---|---|---|---|---|---|
| **20** | Black-headed weaver | *Ploceus inelanocephala* | | | | x |
| **21** | Little African swift | *Apus affinis* | | | X | |

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**Plant Diseases Symptoms and Isolated Pathogens**

In the study area, plant disease symptoms and isolated pathogens of some plants were observed and asserted. Tissue analysis from the herbarium, showed that all four plants species which were sampled, namely *Chromoleana odorata, Costus afer,Anthocleista vogelii* and *Calapogonium mucunoides,* had one form of disease symptoms and so on. From the foregoing, it was observed *Chromoleana odorata* had common symptoms like leaf spot, mold and blight and necrotic lesions which were caused by *Botrylis linerea*, while *Costus afer* had dead streaks, black colorations and wilting of leafs which was believed to be caused by *Oedecephallum spp*. *Thielaviopsis mosaic/ Curvuleria Spp* was the pathogen that caused by yellow molting and wilting of leaves on *Anthocleista vogelii* and *Calapogonium mucunoides*. The identified plant species having disease symptoms and further isolated pathogens are presented in table 3.18. The observed disease and symptoms on plants species are common and have minor impact. The general plant health and conditions was in shape and the vegetation of the area was healthy.

Table 3.18: Plant diseases symptoms and isolated pathogens

| Sr. No. | Plant Species | Disease Symptoms | Isolated Pathogens |
|---|---|---|---|
| **1** | *Chromoleana odorata* | Leaf spot, mold and blight, necrotic lesions | *Botrylis linereae* |
| **2** | *Costus afer* | Dead streaks. Black colouration and wilting | *Oedecephallum spp* |
| **3** | *Anthocleista vogelii and Calapogonium mucunoides* | Soty molds, yellow wilting and molting | *Thieleviopsis mosaic/ Curvuleria Spp* |

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### 3.2.8 Hydrogeology

Geologically, the site is underlain by the coastal plain sands, which in this area is overlain by firm – stiff clay/sandy clay sediments belonging to the pleistocenic formation. The general geology of the area essentially reflects the influence of movements of rivers in the Niger Delta and their search for lines of flow to the sea with consequent deposition of transported

sediments. In broad terms, the area may be considered flat. The site is accessible from East-West Road – Onne – (from Eleme Junction to Alsea-Eleme Community) via Eleme refinery axis.

**Geomorphology**

The geomorphology of the study area Indorama Complex and Alesa Eleme corresponds with that of Niger Delta. The area forms part of Niger Delta, which extends from the Forcados in the West to Calabar River in the East and covers a distance of about 350km. The Delta has a narrow coastal strip varying in width from a few meters to about 16m, it makes up more than half of the Southern Nigeria basin, which includes all the sedimentary sequences, bounded by Benin hinge line in the West and the Calabar hinge line on the East. The Delta is tropical one, being composed mainly of fine grained deltaic sediments. The area is tectonically stable and is situated in the equatorial rain forest belt. The Niger Delta is characterized into five (5) major inter gradational geomorphologic units, these units occur from land to sea as.

- Dry flatland and plain
- Dry deltaic plain with rare fresh water swamps
- Extensive fresh water swamps and meander belts
- Saltwater mangrove swamps, estuaries, creeks and lagoons
- Abandoned and active coastal Islands and beaches

**Geology**

The literature reveals that the formation of the Niger Delta began in the early Palaeocene times and was as a result of the buildup of fine – grained sediment eroded and transported by the River Niger and its tributaries. The Niger Delta is composed of three subsurface lithostratigraphic units (Akata, Agbada and Benin formations overlain by various deposits of Quaternary Age. The Benin formation (2100m thick) is the most prolific aquifer in the region and constitutes over ninety percent (90%) massive, porous sands with localized clay/shale inter-beds. The quaternary deposits (40 – 150m thick) generally consist of rapidly alternating sequences of sand and silt/clay, with the latter becoming increasing more prominent seawards. The Agbada formation underlies the Benin formation and was deposited under transitional environment, with an almost equicom positional makeup of sands and shales. However increasing clay may occur with depth. Underlying the Agbada formation is the Akata

formation, which was deposited, in marine environment. It consists of marine clays, silts and shales with occasional turbidite sand lenses. The formation is rich in organic matter and is the source rock of oil in the Niger Delta. It has a relative thickness of 20,000ft (5882m).

**Local geology and Terrain**

The geology of the catchment area consists of alluvia and fluvia sediment deposits of peat, clay and sands within the depth probed.

The terrain within the local study area originally consists of mud flats with slight slope and swamps with dry sand ridges (sand fill) on which the facilities and settlements are found. A number of creeks and streams that empty into Okulu Stream that empties into Okirika Channel which empties into Bonny River also exist.

**Hydrology**

The hydrologic system in the catchment area can be conceptualized by series of flat and dipping topography towards Okulu Stream flow direction and other valleys (wetland). To assess the hydrology of ground water in area three (3) existing boreholes were considered borehole 1-3 in triangular array. This is to capture ground water flow direction and the heterogeneity of the subsurface across the area. The position and the slope of the water table (potentiometric surface in confined aquifer) is determined by measuring the position of the water level in wells from a fixed measuring point. The direction of slope of the water table is also important because it indicates the direction of ground water flow. The general groundwater flow direction is South-East. This is supported by the regional factors such as SSE trending pattern of Affluent River, topographic conditions as well as buried stream channels (surface outflow) in the study area.

**Groundwater quality of Boreholes**

The physiochemical properties of ground water are presented in Table 3.19. The result reveals that the ground water quality is slightly acidic to moderately alkaline which is typical to Niger Delta groundwater quality. Nutrient content result were very low across all stations indicating that the ground water is not under any form of organic stress, this is further justified by the low concentration of BOD result. Heavy metal were almost <0.001 except for iron with a maximum concentration below 5.0mg/l. Bacterial count were low and does not have any

influence to the ground water quality of the area. The seasonal variations of both seasons ground water quality within Indorama complex are very marginal and as such will not influence the process water quality to the plant.

Table 3.19: Physiochemical properties of Ground water

| PARAMETER | Wet season | | | Dry season | | |
|---|---|---|---|---|---|---|
| | BH1 | BH2 | BHC | BH1 | BH2 | BHC |
| | Flare Area | Water treatment plant | Akpajo | Flare Area | Water treatment plant | Akpajo |
| pH | 5.31 | 5.98 | 6.59 | 5.08 | 5.82 | 6.61 |
| Temperature | 28.7 | 28.2 | 26.9 | 26.4 | 24.2 | 27.2 |
| Color | Clear | Clear | Clear | Clear | Clear | Clear |
| Dissolved Oxygen | 1.52 | 2.96 | 2.92 | 1.28 | 3.22 | 2.43 |
| Turbidity (NTU) | 4.8 | 4.2 | 3.8 | 33.2 | 2.2 | 3.3 |
| Conductivity (µs/cm) | 19.9 | 24.6 | 182 | 22.2 | 36.8 | 393 |
| Total Dissolved Solids (mg/l) | 10.3 | 12.3 | 91.0 | 13.3 | 18.2 | 195 |
| Total Suspended Solids (mg/l) | 2.6 | 2.9 | 2.2 | 9.0 | 3.0 | 2.4 |
| Total Hardness (mg/l) | 4.0 | 14.0 | 24.0 | 5.0 | 24.0 | 40.1 |
| Biological Oxygen Demand(mg/l) | 1.20 | 1.40 | 2.80 | 1.98 | 0.98 | 1.98 |
| Chemical Oxygen Demand (mg/l) | 1.80 | 2.60 | 3.60 | 12.40 | 1.26 | 2.98 |
| Nitrate ($NO_3^-$) (mg/l) | 1.08 | 1.48 | 1.82 | 0.98 | 2.60 | 1.60 |
| Sulphate ($SO_4^{2-}$)(mg/l) | 8.4 | 13.6 | 19.8 | 11.4 | 18.0 | 13.0 |
| Phosphate $P04^{3-}$ (mg/l) | <0.10 | 0.11 | 0.13 | 0.12 | 0.16 | 0.24 |
| Oil and Grease (mg/l) | <1.00 | <1.00 | <1.00 | <1.00 | <1.00 | <1.00 |
| Cyanide (mg/l) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Mercury Hg (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper Cu (mg/l) | 0.029 | 0.018 | 0.046 | 0.025 | 0.011 | 0.085 |
| Lead Pb (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Zinc Zn (mg/l) | 0.096 | 0.082 | 0.078 | 0.071 | 0.129 | 0.120 |
| Iron Fe (mg/l) | 0.414 | 0.196 | 0.142 | 0.337 | 0.121 | 0.096 |
| Cadmium Cd (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Nickel Ni (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic (As) (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium Cr (mg/l) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.0001 |
| THB (cfu/ml) | $1.3x10^3$ | $1.0x10^3$ | $2.0x10^3$ | $1.2x10^3$ | $1.3x10^3$ | $2.4x10^3$ |
| HUB (cfu/ml) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| | | | | | | |
|---|---|---|---|---|---|---|
| THF (cfu/ml) | $1.2x10^2$ | $4.1x10^2$ | $1.2x10^2$ | $1.4x10^2$ | $1.7x10^2$ | $1.1x10^2$ |
| HUF (cfu/ml) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total coliform (MPN/100 ml) | <3.00 | 6.00 | 11.0 | <3.00 | 11.00 | 21.00 |

Fieldwork 2017 (wet) and 2015 (dry)

### 3.2.9 Surface Water System

The Okulu stream, approx 1.5Km at East direction from complex is only the fresh water body in the study area. Okulu stream takes its course form Ogale meandering through Agbonchia and serves as the Indorama complex treated effluent and rain water surface run-off discharge receiving water body. It flows from the East towards the West and changes direction South West towards the downstream. The Indorama complex treated effluent and rain water surface run-off is held in a retention pond and flows through a 1.5 km earth channel before emptying into the Okulu Aleto wetland.

**Physico-chemical properties of Surface water (Okulu Stream)**

The summary of the Physico-chemical characteristics of surface water collected during field work (wet season, 29 & 30th September'2017) are presented in Table 3.20 and the secondary data for dry season retrieved from IEFCL and IEFCL-compliance monitoring reports of January, February, March'2017 and average values are presented in table 3.21.

The water body is a fresh water body with pH slightly acidic at the upstream which is typical of the Niger delta surface water bodies. The pH during the rainy season fieldwork (2017) ranged from 6.80 to 6.95 and 6.55 – 6.60 at the Okulu River and control stations compared to 6.73 to 8.24 and 7.10 for control station for dry season sampling. The values recorded complied to regulatory limit of 6.50 to 8.50. The TDS concentrations range from 85.7 to 298.0mg/l and 270.3 mg/l at the control in dry season as against the wet season of 23.0 to 115.0 mg/l and 18.0 to 72.0 mg/l at the control stations. The TSS concentrations in dry season ranged from 8.9 to 11.5mg/l and 11.4 mg/l at control station as against the wet season (September 2017) concentration of 4.3 to 5.1 mg/l at sampling stations and 5.3 to 6.2 at control stations. The trend analysis indicated the TSS was higher during the dry season compared to the wet season probably due to less volume of water which resulted to higher presence of particles and muddiness of water body.

The dissolved oxygen level during the dry season was ranged from 6.22 to 6.36mg/l and 5.95 mg/l at the control station. The concentration recorded during fieldwork September 2017 was 5.31 to 6.93 mg/l, while at the control station it ranged from 4.56 to 5.68mg/l. This result clearly shows the intense anthropogenic activities at the control stations (car washings, storm run-off and waste disposal) which may have influence on the result recorded within these stations. This implies that the Okulu stream has more carrying capacity than the control stations located in Eleme and Obi-Akpor LGAs. The Chemical Oxygen Demand level for the study area in rainy season (September 2017) ranged from 26.40 to 37.60 mg/l and 25.20 to 28.80 mg/l at control stations against dry season results of 13.67 to 17.33 mg/l and 20.07 mg/l at the control station. BOD concentration recorded indicate that the water body is not in any form of organic stress, as such have sufficient oxygen to handle organic load intrusion into the water body.

The values of heavy metals determined were generally low and within their respective regulatory acceptable limits. The results showed concentration of the heavy metal such as Pb and Zn were moderately low, while vanadium, Chromium, Arsenic, Cadmium, Lead and Zinc were less than detectable limit of the instrument used. Some metal levels exhibited significant seasonal variation.

**Surface water microbiology**

Coliforms commonly referred to as indicators of recent contamination (bio monitors) of water were present in the surface water samples. The total coliforms ranged from 23 to 240 MPN/100ml for rainy season. The low prevalence of total coliforms, especially those of vegetative origins maybe attributed to the absence of several autochthonous species and supported by the prevailing environmental conditions and physicochemical characteristics of the surface water. Similarly, the total coliform counts in the control stations did not show any significant difference.

Table 3.20: Physico-chemical properties of Surface water (Okulu Stream) in Wet season

| Parameters | Up stream | Mid stream | Down Stream | Agbonchia River Control | Rumukrushi Control | FMEnv Limits Aquatic Life | IFC LIMITS |
|---|---|---|---|---|---|---|---|
| **pH** | 6.80 | 6.90 | 6.95 | 6.60 | 6.55 | **6.0-9.0** | **6-9** |
| **EC us/cm** | 42 | 226 | 63 | 35 | 140 | - | - |
| **Temperature $^oC$** | 26.1 | 25.8 | 25.8 | 24.8 | 28.0 | **20-33** | **-** |
| **TDS (mg/l)** | 23 | 115 | 32 | 18 | 72 | **-** | **-** |
| **Turbidity NTU** | 2 | 15 | 5 | 2 | 8 | - | |
| **D.O (mg/l)** | 5.8 | 5.31 | 6.93 | 5.68 | 4.56 | **6.8** | **-** |
| **TSS (mg/l)** | 5.1 | 4.3 | 4.8 | 5.3 | 6.2 | **NS** | - |
| **COD (mg/l)** | 28.80 | 37.60 | 26.40 | 28.80 | 25.20 | **40** | **150** |
| **$BOD_5$ (mg/l)** | 2.78 | 3.69 | 2.10 | 1.17 | 3.42 | **4.0** | **30** |
| **Total Hardness (mg/l)** | 10 | 12 | 10 | 12 | 12 | NS | |
| **Nitrate (mg/l)** | 1.31 | 1.29 | 0.96 | 2.16 | 1.58 | **NS** | **-** |
| **Sulphate (mg/l)** | 32.5 | 17.7 | 13.8 | 372.3 | 17.7 | **NS** | **-** |
| **Phosphate (mg/l)** | 0.08 | 0.06 | 0.19 | 0.20 | <0.01 | **NS** | **-** |
| **Ammonia (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | | **5.0** |
| **Chloride Cl- (mg/l)** | 30.0 | 12.0 | 15.0 | 6.0 | 10.0 | - | - |
| **Alkalinity(mg/l)** | 76.0 | 54.6 | 66.8 | 69.0 | 88.0 | - | - |
| **Cyanide (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | - | - |
| **Magnesium (mg/l)** | 0.26 | 0.18 | 0.13 | 0.14 | 0.12 | - | - |
| **Calcium (mg/l)** | 0.39 | 0.02 | 0.01 | 0.03 | 0.01 | - | - |
| **Nickel (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - | - |
| **Iron (mg/l)** | 0.43 | 0.26 | 0.12 | 0.22 | 0.01 | **1.0** | **-** |
| **Lead (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | **0.05** | **-** |
| **Zinc (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | **50** | **-** |
| **Cadmium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | **0.002** | **<0.1** |
| **Manganese (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | NA | |
| **Vanadium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.1 | |
| **Chromium, (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | **0.03** | **<0.1** |
| **Mercury (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | **0.001** | **-** |
| **Arsenic (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.5 | **-** |
| **Silver (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.1 | **-** |
| **Copper (mg/l)** | 0.013 | 0.11 | 0.09 | 0.12 | 0.06 | 1.0 | |
| **Oil and grease (mg/l)** | <1.0 | <1.0 | <1.0 | <1.0 | 2.5 | **NS** | **10** |
| **Total Coliform (MPN 100ml$^{-1}$)** | 93 | 240 | 23 | 75 | 1100 | 0 | 0 |
| **THB (x10$^4$cfu ml$^{-1}$)** | 2.4X10$^3$ | 6.2X10$^3$ | 1.7X10$^3$ | 2.1 X 10$^3$ | 4.2X 10$^4$ | N/A | **-** |
| **THF (x10$^3$cfu ml$^{-1}$)** | 1.0X10$^3$ | 3.0X10$^3$ | 1.0X10$^3$ | 1.0X10$^3$ | 2.6 X 10$^4$ | N/A | **-** |

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Table 3.21: Physico-chemical properties of Surface water (Okulu Stream) in Dry season

| Parameters | Up stream | Mid-stream | Down Stream | Agbonchia River Control (Mar'17) | FMEnv LIMITS Aquatic Life | IFC LIMITS |
|---|---|---|---|---|---|---|
| **pH** | 6.73 | 8.24 | 6.74 | 7.10 | **6.0-9.0** | **6-9** |
| **EC us/cm** | 592.0 | 298.1 | 171.7 | 538.7 | - | - |
| **Temperature $^{o}$C** | 25.7 | 25.7 | 25.6 | 24.3 | **20-33** | **-** |
| **TDS (mg/l)** | 298.0 | 149 | 85.7 | 270.3 | **-** | **-** |
| **Turbidity NTU** | 21.7 | 20.3 | 28.8 | 22.7 | - | - |
| **D.O (mg/l)** | 6.30 | 6.36 | 6.22 | 5.95 | **6.8** | **-** |
| **TSS (mg/l)** | 10.4 | 11.5 | 8.9 | 11.4 | **NS** | - |
| **COD (mg/l)** | 17.33 | 13.67 | 16.67 | 20.07 | **40** | **150** |
| **$BOD_5$ (mg/l)** | 2.40 | 2.23 | 2.30 | 2.47 | **4.0** | **30** |
| **Total Hardness (mg/l)** | 3.3 | 4.0 | 3.3 | 4.7 | NS | - |
| **Nitrate (mg/l)** | 0.46 | 1.43 | 3.14 | 0.91 | **NS** | **-** |
| **Sulphate (mg/l)** | 11.24 | 11.02 | 8.17 | 14.07 | **NS** | **-** |
| **Phosphate (mg/l)** | 0.68 | <0.001 | <0.001 | 0.59 | **NS** | **-** |
| **Ammonia (mg/l)** | <0.10 | <0.10 | <0.10 | 0.14 | **-** | **-** |
| **Chloride Cl- (mg/l)** | 24.71 | 19.07 | 18.97 | 21.10 | - | - |
| **Alkalinity (mg/l)** | 66.7 | 76.7 | 76.7 | 66.0 | - | - |
| **Calcium (mg/l)** | 10.47 | 8.11 | 12.05 | 8.82 | - | - |
| **Iron (mg/l)** | 1.20 | 1.21 | 1.89 | 1.07 | **1.0** | **-** |
| **Lead (mg/l)** | 0.054 | 0.053 | 0.757 | 0.057 | **0.05** | **-** |
| **Zinc (mg/l)** | 0.637 | 0.236 | 0.581 | 0.463 | **50** | **-** |
| **Cadmium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.002** | **<0.1** |
| **Manganese (mg/l)** | 0.036 | 0.010 | 0.035 | 0.080 | - | - |
| **Chromium, (mg/l)** | 0.147 | 0.041 | 0.080 | 0.123 | **0.03** | **<0.1** |
| **Mercury (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.001** | **-** |
| **Silver (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.1** | **-** |
| **Copper (mg/l)** | 0.008 | <0.001 | 0.012 | 0.011 | **1.0** | **-** |
| **Oil and grease (mg/l)** | <1.00 | <1.00 | <1.00 | <1.00 | **NS** | **10** |

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**Sediment**

The sediment samples collected from same location, from where surface water samples were collected. The analysis of sediments are presented in table no. 3.22 below.

Table 3.22: Physico-chemical properties of Sediment

| PARAMETERS | Up stream | Mid stream | Down Stream | Agbonchia River Control | Rumukrushi Control |
|---|---|---|---|---|---|
| **Sulphide, (mg/kg)** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Sulphate ($SO_4^{2-}$), mg/kg** | 434.10 | 51.83 | 483.46 | 362.73 | 185.73 |
| **Nitrate ($NO_3^-$), mg/kg** | 2.64 | 19.23 | 16.91 | 10.42 | 8.22 |
| **Phosphate ($PO_4^{3-}$), mg/kg** | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Total Organic Carbon (TOC),%** | 0.72 | 1.08 | 0.88 | 0.68 | 0.56 |
| **Total Petroleum Hydrocarbon (TPH),mg/kg** | 18.22 | 9.62 | 11.69 | 4.76 | 2.90 |
| **Total Coliform (MPN/100ml)** | >1100 | >1100 | 160 | 460 | >1100 |
| **Total Heterotrophic Fungi (cfu/ml)** | $5.10X10^4$ | $8.70X10^4$ | $4.60X10^4$ | $5.20X10^4$ | $1.47X10^5$ |
| **Total heterotrophic Bacteria (cfu/ml)** | $9.6X10^4$ | $1.01X10^5$ | $6.50X10^4$ | $8.40X10^4$ | $3.60X10^5$ |
| **Total Plate Count (cfu/ml)** | $1.17X10^5$ | $1.42X10^5$ | $1.00X10^5$ | $1.10X10^5$ | $4.40X10^5$ |
| **Total Iron, mg/l** | 5.01 | 4.02 | 2.07 | 4.22 | 3.90 |
| **Sodium (Na),mg/l** | 0.55 | 0.63 | 0.22 | 0.45 | 0.56 |
| **Calcium (Ca) mg/l** | 22.05 | 19.77 | 22.77 | 24.05 | 21.65 |
| **Magnesium (Mg), mg/l,** | 10.88 | 9.88 | 12.05 | 10.76 | 9.42 |
| **Zinc (Zn), mg/l** | 39.7 | 19.03 | 22.65 | 20.05 | 17.44 |
| **Copper (Cu) mg/l** | 7.03 | 5.03 | 6.03 | 2.05 | 3.76 |
| **Manganese (Mn) mg/l** | 2.90 | 42.03 | 1.04 | 0.44 | 1.43 |
| **Total Chromium (Cr) mg/l** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Nickel (Ni), mg/l** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Lead {Pb} mg/l** | 0.32 | 0.33 | 0.21 | <0.001 | <0.001 |
| **Mercury {Hg} mg/l** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cadmium {Cd} mg/l** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Arsenic (As),mg/kg** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Vanadium (V),mg/kg** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cobalt (Co),mg/kg** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Silver (Ag),mg/kg** | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

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**Sediment Physico-chemistry**

The color of the sediment samples ranged from black to dark grey coloration. The silt fraction was higher than the sand and clay content making the sediment Silty in texture. The concentrations of nutrients in sediment around the study area are indicated below; Sulphate concentrations varied from 51.8 to 483.5 mg/kg and 185.7 to 362.7 mg/kg for rainy season (September 2017) nitrate content ranged from 2.64 to 19.23 mg/kg and 8.22 to 10.42 mg/l at control stations for rainy season. The heavy metal concentrations are low in the sediment samples and there is no indication of their accumulation in the samples. Mercury and Arsenic were very low and below detection limit in the sediment samples.

**Sediment Microbiology**

The microbiological data obtained from the analysis of the sediment samples. The hydrocarbonoclastis (Hydrocarbon Utilizing Bacteria and Fungi) were not detected in the sediment, showing the low hydrocarbon burden and thus corroborating with the absence of hydrocarbon contamination in the sediment sample. The low hydrocarbonoclastic counts in the study area and control station further lends credence to the sediment physicochemical results as also described by Atlas (1981). Furthermore, the bacterial genera isolated in the sediment include *Pseudomonas, Klebsiella, Proteus, Bacillus, Staphylococcus, Serratia, Micrococcus, Flavobacterium, Enterobacter, Achromobacter* and *Arthrobacter.* The fungal isolate mainly belonged to the genera *Fusarium, Aspergillus, Candida, Mucor* and *Penicllium.*

**Treated Effluent Water Quality**

As a reference, the monthly treated effluent water sample collected from Indorama complex discharged point by third party and analysed by FMEnv approved laboratory, is presented in table 3.23 (dry season) and table 3.24 (wet season). The data revels that the treated effluent quality is in compliance with regulatory limits/IFC guidelines.

Table 3.23: Physico-chemical properties of Treated effluent water (Dry Season)

| Parameters | Jan'19 | Feb'19 | Mar'19 | Average | FMEnv LIMITS | IFC LIMITS |
|---|---|---|---|---|---|---|
| **pH** | 7.54 | 7.50 | 7.52 | 7.52 | **6.0-9.0** | **6.0-9.0** |
| **Temperature °C** | 28.5 | 28.5 | 28.5 | 28.5 | **<35** | - |
| **EC us/cm** | 300 | 280 | 513 | 364 | - | - |
| **TDS (mg/l)** | 150 | 140 | 247 | 179 | **2000** | - |
| **Turbidity NTU** | 16.5 | 13.2 | 19.3 | 16.3 | - | - |
| **TSS (mg/l)** | 15.7 | 12.1 | 18.1 | 15.3 | **30** | **30** |
| **Total Hardness (mg/l)** | 14.0 | 12.0 | 12.0 | 12.7 | - | |
| **Alkalinity (mg/l)** | 70.0 | 40.0 | 40.0 | 50.0 | - | - |
| **Chloride Cl- (mg/l)** | 15.4 | 19.7 | 20.7 | 18.6 | **600** | - |
| **Sulphate (mg/l)** | 28.7 | 25.8 | 28.8 | 27.8 | **500** | - |
| **Nitrate (mg/l)** | 2.89 | 2.31 | 3.31 | 2.84 | **20** | - |
| **Phosphate (mg/l)** | 1.22 | 0.75 | 1.75 | 1.24 | **5.0** | - |
| **Ammonia, (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | - | **5.0** |
| **Total Nitrogen (mg/l)** | 2.72 | 2.71 | 2.71 | 2.71 | - | **15.0** |
| **Urea (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | - | **1.0** |
| **Formaldehyde (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | - | - |
| **DO (mg/l)** | 5.82 | 5.15 | 5.20 | 5.39 | - | - |
| **$BOD_5$ (mg/l)** | 4.19 | 4.18 | 4.24 | 4.20 | **30** | **30** |
| **COD (mg/l)** | 37.40 | 54.95 | 38.20 | 43.52 | **40*** | **150** |
| **Oil and grease (mg/l)** | <1.00 | <1.00 | <1.00 | <1.00 | **10** | **10** |
| **Total Iron (mg/l)** | 0.23 | 0.21 | 0.29 | 0.24 | **5.0** | **3.0** |
| **Calcium (mg/l)** | 3.20 | 1.10 | 0.69 | 1.66 | **200** | - |
| **Magnesium (mg/l)** | 0.18 | 0.22 | 0.22 | 0.21 | **200** | - |
| **Zinc (mg/l)** | 0.24 | 0.21 | 0.26 | 0.24 | **1.0** | - |
| **Copper (mg/l)** | 0.03 | 0.05 | 0.03 | 0.04 | **1.0** | **0.5** |
| **Manganese ( mg/l)** | 0.01 | 0.02 | 0.02 | 0.02 | **5.0** | - |
| **Total Chromium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **1.0** | **0.5** |
| **Silver (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.1** | - |
| **Lead (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **1.0** | **0.1** |
| **Mercury (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.05** | **0.02** |
| **Cadmium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.1** | **0.1** |

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Table 3.24: Physico-chemical properties of Treated effluent water (Wet Season)

| Parameters | Jul'19 | Aug'19 | Sept'19 | Average | FMEnv LIMITS | IFC LIMITS |
|---|---|---|---|---|---|---|
| **pH** | 7.82 | 7.32 | 7.75 | 7.63 | **6.0-9.0** | **6.0-9.0** |
| **Temperature °C** | 28 | 27.1 | 26.6 | 27.23 | **<35** | **-** |
| **EC us/cm** | 410 | 570 | 163 | 381.00 | **-** | **-** |
| **TDS (mg/l)** | 205 | 370 | 82 | 219.00 | **2000** | **-** |
| **Turbidity NTU** | 12.3 | 15.4 | 15.6 | 14.43 | **-** | **-** |
| **TSS (mg/l)** | 11.2 | 13 | 14.9 | 13.03 | **30** | **30** |
| **Total Hardness (mg/l)** | 8.0 | 3.4 | 8.0 | 6.47 | **-** | |
| **Alkalinity (mg/l)** | 50 | 80 | 60 | 63.33 | **-** | **-** |
| **Chloride Cl- (mg/l)** | 21.7 | 29.1 | 39.9 | 30.23 | **600** | **-** |
| **Sulphate (mg/l)** | 43.9 | 36.6 | 52.2 | 44.23 | **500** | **-** |
| **Nitrate (mg/l)** | 3.82 | 2.52 | 2.38 | 2.91 | **20** | **-** |
| **Phosphate (mg/l)** | 1.31 | 1.16 | 0.94 | 1.14 | **5.0** | **-** |
| **Ammonia, (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | **-** | **5.0** |
| **Total Nitrogen (mg/l)** | 3.32 | 2.65 | 2.45 | 2.81 | **-** | **15.0** |
| **Urea (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | **-** | **1.0** |
| **Formaldehyde (mg/l)** | <0.10 | <0.10 | <0.10 | <0.10 | **-** | **-** |
| **DO (mg/l)** | 5.72 | 5.32 | 5.12 | 5.39 | **-** | **-** |
| **$BOD_5$ (mg/l)** | 8.12 | 6.6 | 4.1 | 6.27 | **30** | **30** |
| **COD (mg/l)** | 49.2 | 52.4 | 42 | 47.87 | **40*** | **150** |
| **Oil and grease (mg/l)** | <1.00 | <1.00 | <1.00 | <1.00 | **10** | **10** |
| **Total Iron (mg/l)** | 0.39 | 0.66 | 0.81 | 0.62 | **5.0** | **3.0** |
| **Calcium (mg/l)** | 2.1 | 0.84 | 3.92 | 2.29 | **200** | **-** |
| **Magnesium (mg/l)** | 0.31 | 0.51 | 1.23 | 0.68 | **200** | **-** |
| **Zinc (mg/l)** | 0.22 | <0.01 | <0.01 | 0.22 | **1.0** | **-** |
| **Copper (mg/l)** | 0.02 | <0.01 | <0.01 | 0.02 | **1.0** | **0.5** |
| **Manganese ( mg/l)** | 0.01 | <0.01 | <0.01 | 0.01 | **5.0** | **-** |
| **Total Chromium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **1.0** | **0.5** |
| **Silver (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.1** | **-** |
| **Lead (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **1.0** | **0.1** |
| **Mercury (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.05** | **0.02** |
| **Cadmium (mg/l)** | <0.001 | <0.001 | <0.001 | <0.001 | **0.1** | **0.1** |

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### 3.2.10 Hydrobiology

**Phytoplankton**

The composition and abundance of the phytoplankton taxa is presented in Table 3.25. A total of seven genera were recorded; comprising five diatom (bacillariophyceae) and one blue-green (cyanophyceae), and one green (chlorophyceae) algal genera. The bacillariophyceae were observed to be the most dominant in WS2 (68%), WS3 (65%) and WSC2 (88%), while chlorophyceae were dominant (65%) in WS1 and WSC1. *Nitzschia* spp and *Synedra* spp were the most common diatoms, being recorded in all the sampling stations; the blue green (*Spitulina* spp) and green algae *Spirogyra* spp) were represented by one genera each. The ranges of the indices of community structure are as follows: Margalef, 0.347 (WS2) to 0.604 (WS3); Shannon-Weiner, 0.825 (WS2) to 1.439 (WS3); Pielou, 0.513 (WSC2) to 0.894 (WS3); Simpson, 0.260 (WS3) to 0.524 (WS2).

Table 3.25: Composition and Abundance of Phytoplankton (Wet Season)

| TAXA | WS1 | WS2 | WS3 | WSC1 | WSC2 |
|---|---|---|---|---|---|
| **Bacillariophyceae** | | | | | |
| *Synedra* spp | 167 | 217 | 267 | 583 | 1567 |
| *Nitzschia* | 67 | 33 | 183 | 500 | 3233 |
| *Thalasiothrix* spp | 0 | 0 | 0 | 0 | 21633 |
| *Fragillaria* spp | 33 | 0 | 0 | 2833 | 83 |
| *Navicula* spp | 0 | 0 | 33 | 267 | 100 |
| ***Total*** | ***267*** | ***250*** | ***483*** | ***4183*** | ***26617*** |
| **Cyanophyceae** | | | | | |
| *Spirulina* spp | 0 | 67 | 83 | 0 | 0 |
| ***Total*** | ***0*** | ***67*** | ***83*** | ***0*** | ***0*** |
| **Cholorphyceae** | | | | | |
| *Spirogyra* spp | 500 | 0 | 183 | 7633 | 3583 |
| ***Total*** | ***500*** | ***0*** | ***183*** | ***7633*** | ***3583*** |
| **No of Species (S)** | 4 | 3 | 5 | 5 | 6 |
| **Abundance (N)** | 767 | 317 | 750 | 11817 | 30200 |
| **Margalef Richness (d)** | 0.452 | 0.347 | 0.604 | 0.427 | 0.485 |
| **Pielou Evenness (J')** | 0.692 | 0.751 | 0.894 | 0.617 | 0.513 |
| **Shannon (H')** | 0.959 | 0.825 | 1.439 | 0.993 | 0.920 |
| **Simpson (□)** | 0.482 | 0.524 | 0.260 | 0.480 | 0.541 |
| **Simpson (1-□)** | 0.519 | 0.478 | 0.741 | 0.521 | 0.459 |

Field study, 2018

**Zooplankton**

Seven genera, comprising five crustaceans (four copepoda and one cladocera) and one rotifera were recorded in the zooplankton samples (Table 3.26). The most common genera were *Eurytenora, Mesocyclos* and *Tartanus* while *Penilia and Bosmini, Brachious.* The relative abundance of the major taxonomic categories showed that the copepods were completely dominant at WS2 and contributed to a higher proportion in WS3. The cladocera were more dominant at WS1 and WSC1, while there was almost equal contribution at WSC2. Shannon-Weiner diversity index ranged from 0 (WS2) to 1.639 (WS3), Margalef index ranged from 0 (WS2) to 0.903 (WS3). The Pielou Evenness measure could not be determined in WS2 but the highest value was obtained in WSC1 (0.953).

Table 3.26: Composition & density (No/L) of Zooplankton (Wet Season)

| TAXA | WS1 | WS2 | WS3 | WS C1 | WS C2 |
|---|---|---|---|---|---|
| **Copepoda** | | | | | |
| *Eurytemora* spp | 50 | 0 | 250 | 83 | 33 |
| copepod nauplius | 67 | 0 | 17 | 50 | 67 |
| Mesocyclops spp | 50 | 33 | 167 | 0 | 0 |
| *Tortanus* spp | 33 | 0 | 50 | 100 | 0 |
| ***Subtotal*** | ***200*** | ***33*** | ***483*** | ***233*** | ***100*** |
| **Cladorcera** | 0 | 0 | 0 | 0 | 0 |
| *Penilia* spp | 117 | 0 | 167 | 167 | 117 |
| *Bosmina* spp | 183 | 0 | 100 | 83 | 50 |
| ***Subtotal*** | ***300*** | ***0*** | ***267*** | ***250*** | ***167*** |
| **Rotifera** | 0 | 0 | 0 | 0 | 0 |
| *Brachionus* spp | 0 | 0 | 17 | 0 | 0 |
| ***Subtotal*** | ***0*** | ***0*** | ***17*** | ***0*** | ***0*** |
| **No of Species (S)** | 6 | 1 | 7 | 5 | 4 |
| **Abundance (N)** | 500 | 33 | 767 | 483 | 267 |
| **Margalef Richness (d)** | 0.805 | 0 | 0.903 | 0.647 | 0.537 |
| **Pielou Evenness (J')** | 0.903 | | 0.842 | 0.953 | 0.925 |
| **Shannon (H')** | 1.617 | 0 | 1.639 | 1.534 | 1.282 |
| **Simpson (□)** | 0.231 | 1 | 0.223 | 0.232 | 0.305 |
| **Simpson (1-□)** | 0.770 | 0 | 0.778 | 0.770 | 0.698 |

Field study, 2018

**Benthos**

The benthos consisted of two families of oligochaete (niaididae, lumbricidae and echitridae) and three insect families (chironomidae, aeschnidae) (Table 3.27). Niaididae was the most widely distributed being found in all the stations, and was dominant in WS2 (100%), WSC2 (65%) and WS1 (55%). The chironomids were the most dominant in WSC1 accounting for over 80% of the benthos, and were 50:50 with the niadidae in WS3. *Uncinais Uncinata* was recorded in all stations with mean abundance ranging from 17/$m^2$ at WS2 to 58317/$m^2$ at WSC2. *Eiseniella tetrahidra* (lumbricidae) was observed only at WS1 while *Eiseniella tetrahidra* (echitridae) was found only at WSC2. The mean abundance of the chironomid *Chironomus ablabiesmia* ranged from 0/$m^2$ at WS2 to 2963/$m^2$ in WSC2. Shannon-Weiner diversity index ranged from 0 (WS2) to 1.030 (WS3), Margalef index ranged from 0 (WS2) to 361 (WS3). The Pielou Evenness measure could not be determined in WS2 but the highest value was obtained in WS3 (0.937).

Table 3.27: Composition and Abundance (number/$m^2$) of Benthic Organisms- (Wet Season)

| TAXA | WS1 | WS2 | WS3 | WSC1 | WSC2 |
|---|---|---|---|---|---|
| **OLIGOCHAETA** | | | | | |
| **Naididae** | | | | | |
| *Ophidonais serpentina* | 17 | 0 | 50 | 417 | 5917 |
| *Uncinais Uncinata* | 67 | 17 | 33 | 83 | 583 |
| ***Subtotal*** | ***83*** | ***17*** | ***83*** | ***500*** | ***6500*** |
| **Lumbricidae** | 0 | 0 | 0 | 0 | 0 |
| *Eiseniella tetrahidra* | 33 | 0 | 0 | 0 | 0 |
| ***Subtotal*** | ***33*** | ***0*** | ***0*** | ***0*** | ***0*** |
| **Echitridae** | 0 | 0 | 0 | 0 | 0 |
| *Lumbricillus* sp | 0 | 0 | 0 | 0 | 517 |
| ***Subtotal*** | ***0*** | ***0*** | ***0*** | ***0*** | ***517*** |
| **INSECTA** | 0 | 0 | 0 | 0 | 0 |
| **Chironomidae** | 0 | 0 | 0 | 0 | 0 |
| *Chironomus ablabiesmia* | 33 | 0 | 83 | 2617 | 2983 |
| ***Subtotal*** | ***33*** | ***0*** | ***83*** | ***2617*** | ***2983*** |
| **Aeschnidae [Odonata]** | 0 | 0 | 0 | 0 | 0 |
| *Aeschna* sp | 0 | 0 | 0 | 17 | 0 |
| ***Subtotal*** | ***0*** | ***0*** | ***0*** | ***17*** | ***0*** |
| **No of Species (S)** | 4 | 1 | 3 | 4 | 4 |
| **Abundance (N)** | 150 | 17 | 167 | 3133 | 10000 |
| **Margalef Richness (d)** | 0.599 | 0 | 0.391 | 0.373 | 0.326 |
| **Pielou Evenness (J')** | 0.918 | | 0.937 | 0.392 | 0.714 |
| **Shannon (H')** | 1.273 | 0 | 1.030 | 0.543 | 0.990 |
| **Simpson (□)** | 0.309 | 1 | 0.380 | 0.716 | 0.445 |
| **Simpson (1-□)** | 0.696 | 0 | 0.624 | 0.284 | 0.555 |

### 3.2.11 Fisheries

Fishing activities in the surface water bodies around the project area are generally subsistent and nearly absent in the last few years. The fishery resources in these lentic systems have been severely threatened with increasing manual and mechanical sand-mining activities. During the field data gathering exercise, there was no presence of artisanal fishing activities in the Okulu stream.

The analytical result of the aquatic ecosystem in both climatic regimes (Surface water quality, Sediment quality and Hydrobiology) which are far below threshold limits set by regulatory agency indicate sufficient carrying capacity of the Okulu stream.

## 3.3 SOCIO – ECONOMIC ASSESSMENT

### 3.3.1 Study Settlements

The area considered for the Socio Economic Impact Assessment (SEIA) covers a radius of 5km from the Indorama Complex. In the area under consideration, there are four (4) main settlements namely Agbonchia, Aleto, Akpajo, in the Eleme Local Government Area and Elelenwo in Obio/Akpor. Elelenwo is of Ikwerre origin. Among Aleto and Agbonchia settlements, there are three family units, respectively Okerewa, Njuru and Akpankpan, whose creations were to ensure adequate community welfare packages to the host communities by the Indorama management. Okerewa is studied under Aleto, while Njuru and Akpakpan are covered under Agbonchia.

These settlements have been considered for the study because of their proximity to the complex, in which the major social impacts related to the project are expected. The people of Eleme claim a common ancestry, language and ethnicity while the Elelenwo community is of the Ikwerre ethnic group.

### 3.3.2 The Eleme Communities

Eleme is a kingdom and the current traditional head king Oluka Ejire, the Onne-eh Eleme is a government recognized 1st class chief. Although Ogale is the traditional headquarters of Eleme kingdom, the present ruler hails from Agbonchia. Eleme shares boundary with other ethnic groups in Rivers State like Ikwerre, Okrika, Oyigbo and Ogonis. The language of Eleme also borrows from these neighbours and shares strong similarities with Ogoni. There are two clans in Eleme: Odido and Nchia; the study communities belong to the Nchia clan.

There is a hierarchical order of leadership whereby the paramount ruler is at the apex and the ordinary citizen is at the bottom. In-between the hierarchy are family heads or chiefs who usually sit with Emere Eleme in Council. Within the leadership structure are influential groups such as the Community Development Committee (CDC) and the youths. The CDC comprises representatives from the various units that make up the community. Notable individuals are co-opted as members if they feel that they could be resourceful in contributing to the progress of the community even if they are not initially proposed from their units.

Rise in the proportion of young people who become exposed to modern lifestyle, education and attitudes has brought youthful exuberance to the fore. The Youths Council in Eleme are active in conversing issues such as employment, scholarship, industrial relations and culture. Accordingly, sub committees of the Youth's Council are formed to address the various challenges they face. Another group with influence in Eleme is the women head chiefs in the various sub-clans. Other groups in the community are peer groups, age grade, trade groups and social clubs.

### 3.3.3 Elelenwo Community

The people of Elelenwo are descended from Obio after whom Obio/Akpor local government area of Rivers state is named. Obio had two sons namely Evo and Apara. Under Evo, there are three clans EvoKpotoma and Esara. Kpotoma has six communities namely Rumuluku, Rumuenyeron, Rumueziolu, Rumuoduwere, Rumueheleze and Rumuodani. Elelenwo comprises sections of the last three communities. Rumuodani is the community whose land is part of the territory that was acquired by the Federal government to build the then Eleme Petrochemical complex. Elelenwo traditional leadership has a committee of the three clans whose chairman is the paramount ruler of Elelenwo. The headship is rotated so that every clan at some time have the chance of leading the community. For Elelenwo as a whole, there is a community development committee, youth council, women group and Owhor holders (Ikwerre traditional priesthood). These various groups are like arms that govern Elelenwo community.

### 3.3.4 Socio-economic Survey

This survey was conducted in September'2017 by consulting team of M/s Environmental & Chemical Services, Port Harcourt. To complete the survey the SIA questionnaire were also administered in November'2017 for the purpose of groundtruthing the socio-economic status of study area. In community governance; chiefs were rated highest, followed by the youths, elders, women and age grade.

**Settlement Pattern**

Settlement pattern in the study area is nucleated. All the settlement layouts are densely built and occupied with streets and lengthy roads. It is likely that they all began as linear settlements along the old Bori road, but the evidence now is of settlements with internal structures that spread deep from the main thoroughfare. The internal structures of the settlements have not matured to a point where they acquire distinctive functional properties like commercial, residential or public uses. These settlements are all struggling to integrate with the sprawl at the fringe of Port Harcourt; therefore they may take some time to develop unique identities.

**Demography**

The total population of the four settlements surveyed in this study was 66,614 in 2010. The data was generated by tabulating their respective 1991 census and the projections for 1996 as published by the National Population Commission (1996) at settlement level. The Federal Government of Nigeria (2007) estimates the growth rate of population in Rivers State as 3.4% annually, although Nigeria grows at 3.2%. The growth rate for Rivers State is used to project the population of the study settlements from the 2010 to the present. By the estimate, Agbonchia has 25,876 people, Elelenwo 24,491, Akpajo 14,404 and Aleto 17,678 people in 2017. There are more male population (57%) than female (43%) among the households surveyed in this study. The study settlements are in the outskirts of Port Harcourt and influenced by companies operating outside Indorama complex but within the thematic region of the study area.

**Occupation, Employment and Income**

The distribution of occupation among the respondents is 48% for the self-employed, 21% for those who work in government offices, 12% for company workers and 19% unemployed. The self-employed are more in Agbonchia and Elelenwo than in Aleto and Akpajo. Likewise too, Aleto and Akpajo have more government and company employees than the other settlements. The highest rate of unemployment was reported in Agbonchia and the least in Akpajo. The occupation of the self-employed are business (small scale business and contractors to EPC) (56%), farming (29%), trading (12%) other (3%). Those categorised as other include, clergy and church workers, artisans, transport workers, etc. Majority of the businessmen are suppliers to the large companies in the area. Only 2% of the respondents claim they fish.

The mean daily income of people in the study area is ₦1000. This is slightly above the national minimum wage of ₦18, 000/month. It should be noted that the national minimum wage is paid to individuals who may be heads of households and its overall impact will be significantly below what a household require for its sustenance.

**Commerce and Industry**

In the Port Harcourt Master Plan 75, the settlements surveyed in this study are located in the North Eastern axis designated for heavy duty industries. The state-of-affairs is that the large industrial complexes have not attracted medium manufacturing industries to utilize their products. This lack of backward integration permeates to the low level of small aspiring entrepreneurs. There are no signs of industrial activities at the community level in the study settlements. As reflected in the occupation structure, people either farm, work for government or they are businessmen. Being a businessman simply means as a vendor to many of the large industrial complexes in the area. What remains of industries that community members can relate to are small time welding and fabrication, sand mining in all the rivers in the area, traditional food processing like fish smoking and cassava flour production.

The presence of the large industries, the local government headquarters of Eleme and a large population means that there are commercial activities. In the formal sectors are many commercial bank branches, retail outlets, small hotels, and asphalt plants. In the informal

sector, there are many small trading activities, automobile mechanics, local transport business, eateries and building construction. The informal commercial sector is the most numerous business activities in the area. Every community own a market; some are periodic while others are daily. The Nchia market is the largest of the daily markets. Two periodic markets are famous in the area: the Nim market (also called Ikwurugba) trades every fifth day in Elelenwo and the Echietaejie market of Agbonchia which trades only on Sunday. These two markets have patrons from across Rivers State and beyond.

**Agriculture and Land Practices**

Land ownership and the rules of transfer are strict and contentions in the settlements. Distant lands from the community are devoted to subsistent farming. The crops cultivated in their order of importance are cassava, maize, yam, plantain, green vegetables, cocoyam and fruits. The farming system is a limited form of shifting cultivation whereby land is cleared and cultivated for several years until productivity diminishes; it is then abandoned until natural processes regenerate the soil. The fallow period was up to 7 years about 30 years ago. Presently fallow period is reduced to a year or two. Consequently agriculture in the study area as a main stay of the people's income has reduced to very low level of subsistence farming.

**Water Supply and Sanitation**

The sole source of domestic water supply is shallow boreholes. The water tables in the study areas are close to the surface and water can be tapped at 10m in most cases from the first aquifer. All domestic water supplies in the study area rely on this ubiquitous method. It is augmented by rainfall during the peak of the rainy season when the harvest is cleaner. Settlements around industrial Complexes however complain that sometimes their rainwater is polluted by emissions washed out from the various plants nearby.

A more comprehensive study of domestic water supply in the study areas by NDDC (2008) shows that majority of households in the study area rely on outdoor taps (usually boreholes) for their water supply. Another proportion sinks the boreholes in their premises, and then pipes the water to their houses. Others use land dug wells and streams as their source of water supply.

The study settlements are covered by the activities of the state sanitation authority, responsible for the evacuation of refuse in Port Harcourt and its immediate neighborhoods. Most respondents, especially in Akpajo and Elelenwo attribute the management of waste in their domain to the sanitation authority. They however complain about paucity of collection sites which prompt people to also use nearby bushes, vacant plots and their backyard as dumping grounds. These methods of disposal are common in the host communities. Dumps of waste can be seen in communities and it indicate the inadequacy of waste segregation, storage, collection and disposal. Depending on the type of refuse and the season, burning is used by the citizenry to minimize the nuisance and unhealthy situation rounding waste management in the area.

The flushing of toilets into septic tanks and soak away are the commonest means of excreta management. Ideally, the septic tank should be evacuated when due but not later than six months; however that is not the case in the study area. Another observation with the use of septic tank as retainer for sewage is that the owners are oblivious of the fact that boreholes for domestic water supply are often sited close to these septic tanks. There are no clear cut regulations on this in Nigeria but, the practice elsewhere is that boreholes cannot be sited less than 200m from a septic tank (Ede and Edokpa, 2010). This calls to question the quality of water sourced from boreholes as practiced in the study area. The other important means of excreta disposal in the study area is covered pit latrine and it is nearly as prevalent as the water closet system. People also use surrounding bushes, water channels and the pail system to manage their excreta in the study area.

**Transportation**

The four settlements in the study area are traversed by two major highways: the East-West Road that begins from Warri and end in Eket and the Port-Harcourt-Aba Expressway. The two roads are in fairly good condition and are always busy. It is from these major roads that the internal road arteries emanate. Most of the internal roads are not paved. In Aleto and Agbonchia, NDDC paved some roads, but most of them have failed and are un-useable at some points. The problems with the NDDC roads are that they have very poor foundation and no proper base before the asphalts were laid. Sometimes they do not have drainages and where drainage exists, they channel water to nowhere, which contributes to the road failure.

Movement from one place to another is by road in the study settlements. All the study settlements are big enough to require some sort of transport and it is met through the use of tricycles and motorcycles.

**Education**

Every community in this study has a model primary school. All the settlements except Akpajo also have a secondary school owned by the government. All the communities have benefited from the new primary schools project by the state government, who have vowed to equip them with modern facilities like computers, laboratories and well trained teachers. Privately run schools from primary to secondary levels are present in all the settlements. These private schools sometimes may offer teaching standard that are higher than those in government schools, but their fees are usually exorbitant. They nevertheless provide opportunity and choices to parents and pupils.

**Energy and Electricity**

Energy demand in the study area is for lighting, cooking, maintenance workshop and driving machines, (including automobile). Vehicles are driven with gasoline and diesel, electricity and kerosene are used in lighting, while wood, kerosene and liquefied petroleum gas (LPG) are used in cooking. Our experience during the field work is that all these energy types are in short supply. Electric light is epileptic and there are occasions when they receive only a few hours of power in a week. The petroleum based types are scarce and expensive, for instance, one liter of kerosene costs ₦350 as against the advertised and regulated price of ₦50. A modest bundle of wood cost ₦1,200 because the bushes from where they are sourced have been significantly depleted. It is true to say that residents of host communities are facing difficulties in acquiring adequate energy for various household uses (fuel for generator; fuel for motorbikes; kerosene for house lamps, cooking and house lighting, and wood).

**Housing and Household Possessions**

Most respondents live in owner occupier houses. Majority of the houses are constructed with concrete blocks and roofed with corrugated iron sheets, few are earth block and iron sheets

and the traditional wattle and mud houses roofed with thatch or iron sheets are negligible. The crowding index is 1.2, that is, a room is available to every 1.2 persons in the study area. Household assets indicated by the respondents include bicycles, motor car, van, television, power generator, motor cycle, radio refrigerator and air conditioner. The most widely owned household possessions are television, generators, and radio sets. Half of the households surveyed in this study owned refrigerators and a third owned car and motor cycle.

**Cultural Calendar and Social Affiliations**

Four activities dominate the cultural calendar of communities in the study area namely; wrestling, traditional marriages, new yam festival and dances. Wrestling takes place during and after harvest, usually in the months of September, October and November. Wrestling is invitational that is one community goes to another community, showcases their prowess and engages their host wrestlers in a duel. A winner emerges between two wrestlers when an opponent is dusted on the ground. A visiting community becomes a host to their previous host another.

Marriage is like a rite of passage in the communities. Every adult (males in particular) must marry sometime in their life to signify that they are now men. Marriage ceremonies are however conducted according to the woman's (bride's) culture. Traditional marriages in Eleme and Ikwerre are elaborate systems that include hosting the family and community in feasts. As a result, the drinks and foods are the key expenditures the groom has to prepare for. Marriage in these cultures is also not a onetime event among the Ikwerres, this may include a minimum of four occasions and each of those occasions is embellished with food and drinks. In Eleme a woman may be sponsored in what is called Mgbete that takes a year of preparation before her outing to the public and suitors.

The decline in yam production in the area has affected new yam festivals also. New yam festival used to hold in August and it is practiced in all the study settlements. The principle is that nobody in a community eats of their yam harvest unless it is first offered to the gods and ancestors, whom it is believed made the harvest possible. Some respondents who do not grow yam of their own even purchase newly harvested yam in order to partake in the ceremony. Again the new yam festival which was highly regarded as Christmas today is fading into obscurity due to urbanization and modernity.

Traditional dances are found in every African culture. The dances may be for members' only, free and open participation with or without masquerades. The dances may be mixed or gender restrictive sometimes too; Esomba dance in Aleto is for women only. Similarly, Ndudu is a form of dance for women in Ikwerre culture.

Social Affiliation in the societies involves being a member of groups where people share things in common. The categories posed to the respondents include politics, co-operatives, social clubs, education, religion and cultural associations. Across the study communities, affiliation to a religious body was the greatest indicated by the respondents. The implication is that almost all the respondents are religious, usually of the Christian faiths. Affiliation to one or more (mainly foreign) football clubs came second. There is no doubt that most adolescents and young adults in the community have their favourite football clubs, and that watching their club play on television is perhaps their preferred pastime. Other social affiliations include membership of political parties, social clubs, educational associations, co-operatives and cultural clubs. We observed a tendency among respondents to see specialized training in trades like fitting, iron bending, welding and mechanics which are required in striving petroleum industries around the area. Some even enroll for higher education as reasons for citing education as a social affiliation.

**Taboos and Sacred Places**

All human activities in traditional Eleme or Ikwerre setting has a spiritual side to it that is effected through rituals and sacrifices and the places designated to perform these rituals are sacred places. The basic structure of traditional religion in the study areas begins with the family alters. In Agbonchia the study team were shown spots where the family alters are. The Elelenwo people also have their rukannis that approximates the same thing in Ikwerre land.
At the community level there are shrines dedicated to so many causes. Adooka and Onura shrine in Aleto protects the community and in Elelenwo Mini Achara will be the equivalent. Seseiokulu in Agbonchia is a shrine to which sacrifices are made before planting, soil fertility and harvest. When things considered abomination (e.g., the death of a woman under pregnancy, drowning) occur, the chief priest Onnenkike in Eleme is invited to cleanse the land through sacrifice, so that such bad event do not happen again. In Elelenwo, an infant who is

afflicted may be taken to the shrine of Mini Achara vows made to the deity. If reprieve is granted the parents are expected to redeem their pledge through sacrifice. In Ikwerre calendar as used in Elelenwo there are five days in a week namely Riabo, Sarabo, Namake, Okwa and Nim. Riabo is the sacred day in which most traditional religious rites are performed and Nim is the market day. In Eleme there are five (5) days a week namely Obo (big market day), Nma, Ojua, Ochun (small market day), Okor. Obon is the traditional market day that no farming is allowed.

**Religion**

In spite of the traditional observances in the study communities most respondents profess themselves to be Christians. The religious learning of the people include all possible denomination, whether Orthodox or unorthodox. Among the orthodox churches cited are Anglican, Catholic, Lutheran, Baptist, Jehovah's Witness, and Cherubim. The Anglican Church was however described as the community church. It is usually the oldest Christian denomination in the communities, built through community effort and it will have a mission school attached which is to the congregations' commitment. Every community surveyed in this study had several Anglican churches for instance Agbonchia had 4, Aleto 3 and Elelenwo 4. The new (Pentecostals) churches are also gaining acceptance in the communities and their membership is growing even more rapidly. Some of the Pentecostals in the communities include Redeemed, Deeper life, Assemblies, Church of God, Commonwealth and Greater. The attraction of the Pentecostals is in their use of music and rigorous preaching. The congregations are often smaller and the pastors appear to be more likely to be rigid in the interpretation of the doctrines as with Deeper Life, but some are also lax in the area of dressing by not requiring women to cover their head like Winners.90% of the population are Christians, 6% traditional worshiper and 4% Muslims.

**Conflict Resolution in Communities**

Dispute over land boundary and ownership is the primary cause of intra and inter communal conflicts in the study settlements. The respondents affirm that there is a rise in conflict over land and who benefits from the proceeds of land in all the study settlements. Settlements like Akpajo with large water front also have disputes over the ownership of water bodies. Politics have become an important source of dispute in the study area. Who represents the

people at the various levels of government and legislative bodies are becoming contentious because there appear to be a lot to be gained in holding political office. Traditional dispute resolution takes the form arbitration of chiefs acting individually or in a group (in-council). Resort to courts is very popular and was rated by respondents as the principal mode of dispute resolution. The opening of courts at local government levels has made this option attractive among litigants. In the past, it was also usual for people to be summoned before shrines.

### 3.3.5 Health Impact Assessment

The baseline health data presented are based on information generated from sampled groups in the study communities. The data relies on self-reporting, presumptions by respondents in the survey and data from the health centers in the area. Data obtained from these facilities were subsequently compared with state and National data and averages that are available.

**Health services**

The analysis of questionnaire responses, focus group discussion, interviews and personal observations, indicate that the primary health care delivery service in these communities was inadequate. Healthcare delivery services lack infrastructural facilities, adequate funding for drug procurement, adequate health personnel and financial resources to sustain and upgrade the entire health system.

The communities of Agbonchia, Aleto, Akpajo and Elelenwo are blessed with primary Healthcare Service Centers. There are also a lot of private clinics, maternities, medical laboratories and pharmaceutical/chemist shops are there in communities. The medical team also identified many traditional medicine practitioners, few Traditional Birth attendants who in their limited capacity still assist and compliment orthodox Healthcare delivery. These people lack adequate training in Hygienic procedures. Facilities for prompt/emergency responses is only available in few of the hospitals such as the General hospital Eleme etc. Poor economic and financial resources, problem of trained personnel, lack of infrastructural facilities limiting the quality and type of Healthcare delivery in these private Health institutions. The study showed that about 55% used hospitals/health centers; chemists/pharmacy by 20%; traditional/herbal home by 10% and 15% used healing

home/church for treatment. For birth delivery, patients used clinics and traditional medical practitioners, churches and untrained traditional birth attendants too.

**Nutritional Status**

The nutritional status was good because of the availability of fish, fish products, and other sea foods which supplied proteins, vitamins and other mineral salts. The people engage in farming and rich calorie foods like yams, garri, rice, corn; are produced from their farms. In this study anthropometric assessment was done on children from the different communities i.e. Height, Weight and Mid arm circumference measurements were taken in addition to physical examination, appearance of skin, eyes and tongue were done. The result of these assessments indicates that the nutritional status was good. There were a few of the children in some of the communities and pregnant women that showed slight evidence of malnutrition, the rest were nutritionally healthy.

**Sanitation of the Living Environment**

The general sanitary status of the living environments in the communities were rated as good based on a set of WHO criteria. Majority of the communities had good sanitary status of the living environments. Housing is a key component in the protection and promotion of health which carries equal priority with nutrition, water supply, sanitation and health care. House needs to be sited properly and constructed in such a way as to provide the physical and social needs of those housed. House needs to protect people from adverse effects of the climate as well as provide fresh air, security and privacy to ensure, dignity, health and wellbeing. All these qualities and attributes depict a good housing in most of these communities.

**Reproductive Health**

Reproduction and sexual health as a concept encompasses a set of health problems or diseases associated with the physical and social risks of human sexuality and reproduction. Common Reproductive and Sexual Health problems in the Communities includes, lack of access to good quality contraceptive family planning; Infertility; maternal and child malnutrition and infection and human immune deficiency syndrome (HIV) & sexually transmitted diseases (STIs).

During the sampling, it was found that these health problems exert an enormously heavy illness burden on adults, young people and children, often with long term physical and social consequences. About 50-100 pregnancy related deaths cases occurs each year and each of these perhaps one-quarter to one-third are due to lack of access to safe abortion services. This information cannot be authenticated, because the source could not back it with records. It is estimated that for every pregnancy related death, some may have suffered significant complications. In other words, many women suffer serious morbidity each year. Of the prenatal deaths among children in the community, about half are associated with low birth weight (under 2500gm) due predominantly to maternal protein-calorie malnutrition and anemia and in some cases STIs.

HIV and STIs constitute another major cluster of reproductive health problem, which cannot be statistically reported because of lack of records in the area. Again the State Governments policy/programme in health care may bring succor to this important global issue when the health centers become functional and operational.

**Disease Prevalence**

The information provided in these sections is based on hospital records and responses from questionnaires, focus group discussion, on the spot observation and key informants on the nature and pattern of diseases in the communities in the study area in the last 12 months. There were a few fragmented data from hospital records in the area.

The prevalence rate (i.e. the number of cases of the condition at a particular time or period divided by the size of the population exposed) has been used in the assessment of disease prevalence. It has enabled a fair interpretation of data about the disease prevalence in the community and its comparison with the ill health in other areas in subsequent studies. A reliable prevalence rate could not be determined because of insufficient data In addition a lot of people carried out self-medication while some are treated by traditional medical practitioners and traditional birth attendants without records. Some of the prevalence diseases in studied communities are malaria, diarrhea, food poisoning, upper respiratory tract infections, skin rashes and sexually Transmitted Infections (STIs).

**Environmental Health Conditions**

The entries in this section were compiled from field observation, questionnaire and interviews. The noise and vibration levels from trucks traffics and aerial one are still within acceptable limits. Treated municipal water was not observed in the communities. Water for drinking and domestic services are from streams, hand dug wells, mono pumps, rain harvesting, small pools and ponds. For waste management in communities, each household provides containers to collect the wastes mainly household/organic wastes which is taken care by local government and disposed at dump sites. Commercial wastes (papers, cartons, nylon bags) and canteen wastes (left-over foods, yams and cassava peelings, cans, plastic containers) are collected and taken to waste dumps sites, where the useful material segregated for reuse/recycle. The waste scattered all over the place in Agbonchia, Aleto, Akpajo and Elelenwo can also be seen.

**Sewage Disposal**

In the communities, there are generally little control over the disposal of both liquid and solid waste from industrial, dwellings, villages, factories, towns and cities. The control of the disposal of wastes of all kinds is necessary in order to improve and safeguard public health and to protect water resources.

**Water Supply**

There is no functional Municipal treatment scheme sighted anywhere in the study area. Source of water supply included shallow hand-dug well, rivers, streams, ponds, rain harvesting, and a few sometimes non-functional bore holes. Some of these non-functional boreholes were provided by SPDC and Indorama and others by families/personal efforts. They are used for all domestic purposes including drinking and bathing, the water is not usually treated before use. Analysis of water indicate the presence of coliform. The settlements sometimes face water–borne diseases. Majority of households in the study area rely on outdoor taps (usually from boreholes) for their water supply. Another proportion sinks the boreholes in their premises, and then pipes the water to their houses. Others use hand dug wells and rain harvesting as their source of water supply.

**Cooking Practices**

The most commonly used fuels for cooking in the area are firewood and kerosene. Wood is the most common fuel used for cooking, reported by 66 % of households. Indoor cooking is also commonly practiced. Indoor cooking is prevalent in most of the locations. About, 45% and 43% in Eleme and Akpajo respectively all cook indoors. Cooking with firewood indoors exposes individuals to air pollutants and can be a cause of respiratory infections, asthma, chronic bronchitis, and other health problems. The indoor cooking practice is common across Nigeria. According to the National Demographic and Health Survey (2008) about 40% of household cook inside their houses, while about one-quarter (25%) cook outdoors.

**Social issues affecting Health**

The WHO (2011) reports that the harmful use of alcohol is a worldwide problem resulting in millions of deaths, including hundreds of thousands of young lives lost. It is not only a causal factor in many diseases, but also a precursor to injury and violence. Furthermore, its negative impacts can spread throughout a community or a country, and beyond, by influencing levels and patterns of alcohol consumption across borders. Indeed, people who drink alcohol excessively (over two drinks per day) have a one and a half to two times increase in the prevalence of hypertension. The association between alcohol and high blood pressure is particularly noticeable when the alcohol intake exceeds 5 drinks per day. Moreover, the connection is a dose-related phenomenon (WHO, 2010).

Smoking on the other hand increases the risk of vascular complications (for example, heart disease and stroke) in people who already have hypertension, it is not associated with an increase in the development of hypertension (CDC 2006).

The health surveys in the host communities suggests that more than a tenth (12%) of the households have someone who smokes, while more than a quarter (29.8%) of the households have one or more persons who drinks alcohol. Beer is the most commonly consumed, followed by gins. Other forms of alcohol reported to be consumed are spirits and other wines. Marijuana use was reported in less than 1% of households, and no other drug substance use was reported

## 3.4 STAKEHOLDER ENGAGEMENT / PUBLIC CONSULTATION

Meaningful public and stakeholder participation and engagement is the cornerstone of any successful environmental assessment of a project. Not only the public and stakeholder consultation required as part of Nigerian environmental regulations and IFC Environmental Guideline, an open and meaningful public engagement program undertaken for a project contributes to building positive community relations, and generally assists in the acceptance of, or co-existence with, a development proposal.

The project team held series of stakeholder consultation sessions. Initial discussions and consultation were initiated with the stakeholders, including the business community, government, community groups and neighbours, to obtain information on any initial concerns that these and other stakeholders may have about the Project. The consultation sessions culminated in a scoping workshop. The stakeholders identified for the project and who participated in the various consultation sessions included communities within the project area and the regulators, and where adequately engaged through scoping workshop, baseline data gathering, focal group discussion, questionnaire administration and Public forum etc.

The consultation sessions with FMEnv officials were held on 25th August'2017; 06th September and 29th Septemeb'2017. Likewise first consulting session with RSMEnv officials was held on 29th August'2017. The RSMENV officials were the part of team with FMEnv officials during subsequent two consulting sessions.

The consultation sessions with communities were held on 29 & 30th September; 14 to 17th October'2017 by consulting team of M/s Environmental & Chemical services Limited. The stakeholder engagement/consultation program was conducted on 17th November'2017 in which regulators were also present as observers. The consultation sessions/meetings with project advisory committee (PAC) and community representative is ongoing event.
Communities concerns and expectations that were apparent in the community stakeholder engagement were recoded and incorporated in ESIA report, ESMS and ESMPs.

### 3.5 CORPORATE HEALTH AND SOCIAL RESPONSIVENESS

The present report also reviewed how the proponent had responded to the social and health needs of the host communities.

**The Company's Philosophy of Corporate Social Responsibility (CSR)**

- Indorama-Nigeria Group strongly believes in being socially responsible and responsive, especially as it related to health, safety and environment, as well as community development and empowerment.
- The Company firmly believes in the concept of Corporate Social Responsibility (CSR) or Corporate Social Investment (CSI) as a major integral part of business operations.
- In this regard, the company makes conscious or deliberate effort to protect peoples and environment from the potential impacts of the project as well as includes public interest and sustainability in corporate decisions involving people, plant and profit.
- Consequently, the Company considers the welfare, wellbeing, healthcare and socio-cultural issues of the host communities, surrounding or neighboring communities and the larger society.
- The Company firmly believes in giving back to society part of its fortunes in appreciation of good neighborliness and good corporate citizenship.
- Areas of community interventions include providing employment opportunities, youth empowerment programs, micro-credit for vulnerable groups such as widows, construction of roads, and providing social amenities such as building of schools, rural electrification, water supply, healthcare; etc.
- The Company strongly believes in the sustainability of its CSR programmes through needs analysis and community participation in all corporate interventions and executions.

**Sustainable CSR Programmes for Host Communities**

In the past ten years, the INDORAMA have executed many community development programmes such as building of schools, construction of roads and drainages, rehabilitation of hospitals and supply of medical equipment and electrification projects.

Others includes award of scholarships to indigent undergraduates from Eleme and Elelenwo, employment opportunities for indigenes, sponsorship of worthy events, donation of drugs and food items to some charity organizations in the area and youth empowerment programmes.

In specific terms, the companies have achieved the following CSR millstones in the following areas:

**Socio-economic Financial Empowerment**

- The biggest of Indorama's CSR programmes is the allotment of 7.5% shares of the company to six host communities of Akpajo, Aleto, Agbonchia, Elelenwo, Njuru and Okerewa as a successful example of private - public partnership.
- This has created tremendous value and engendered significant economic activities in the communities. More than N20 Billion has accrued to the host communities through this intervention since 2012.
- The company has created over 3,500 direct and indirect employment opportunities to indigenes of the six host communities, the pipeline communities and neighboring communities. This has significantly increased their socio-economic wellbeing of the workers and their families and other dependents.
- The company's micro-credit scheme has been able to empower many widows and other vulnerable groups in the six host communities who are into micro businesses.
- Indorama has created a pool of entrepreneurs from the host communities. Capacity of a people to earn income and generate employment has been developed.
- Lots of contract jobs have been given to host community contractors ranging from civil, electrical, logistics, labour supplies, car hire, equipment leasing, asphalting of roads in the complex, security on the company pipelines, etc.

**Education:**

- Building of a massive secondary school complex (boys and girls) for Aleto community (one of the host communities). The school comprising 12 classrooms, Principal's office, staff offices, science laboratories, sick bay, etc. was commissioned and handed over to the community leaders on 11$^{th}$ January 2017.
- Donation of 79 sets of solid high quality seat-fitted tables to the Nigerian Navy Basic Training School, Onne, Rivers State;

- Has awarded scholarships to 30 indigent students of Eleme/Elelenwo extraction doing engineering and other science related courses in universities and polytechnics. For Engineering Courses are for five years while others are for four 4 years.
- In 2008, the company organized a graduate training program for host community engineering students with zero experience and later absorbed them as staff. The company shall consider it again as personnel requirement improves.
- Purchased a plot of land in Aleto community and constructed ICT and Skill Acquisition Center, which is operational and functional now.
- Indorama donated N10 million to the University of Port Harcourt Centre of Gas, Refining & Petrochemicals to sponsor an international conference to add value to the education and knowledge sharing for national development.

**Healthcare:**

- Indorama carried out a full renovation of the Nchia General Hospital Eleme and donated drugs and medical equipment worth Eighty Million Naira (N80,000,000) to the hospital.
- To make the hospital fully functional, Indorama embarked on building of doctors' and nurses' quarters, and building of a major emergency entrance/exit road in the hospital. All these have been commissioned.
- As a follow up to the hospital renovation, Indorama organized a two-day Free Eye Camp in which about 500 persons with eye diseases were diagnosed and treated free of charge.
- At various times, Indorama has donated drugs and food items to Daughters of Charity, a Catholic charity organization, which takes care of the poor and needy in the Eleme and environs.
- Indorama healthcare interventions also are extended to the larger society. In March 2013, the company donated various sets of medical equipment to the University of Port Harcourt Teaching Hospital.
- Another donation of medical equipment worth millions of naira was also made to the Braithwaite Specialists Memorial Hospital (BSMH), Port Harcourt (owned by the Rivers state Government) in August 2017.

**Infrastructure**

- In July 2015, Indorama donated N530 million in an initiative of the Rivers state Government to rehabilitate the Eleme – Onne axis of the Federal highway which had become impassable and causing terrible hardship for motorists and workers.
- The company has done quite enormous number of developmental projects in the host communities including
  (a) Building of roads in Elelenwo and Agbonchia communities,
  (b) Electrification project in Njuru and Akpajo communities,
  (c) Building of modern secondary school in Aleto community.
  (d) In each Community the company has expended N26M (N52M for 2 Communities).
  (e) Each community has 600 MTR road and Electrification project consisting of erection of 36 High Tension Poles, 22 Low Tension Poles to cover 1KM, Installation of 1KM long HT and LT Cables and procurement & installation of 500KVA Transformer to power the HT/LT Cables.
- Indorama Eleme Petrochemicals Ltd and its sister companies have made lives better to its host and transit community as well as the larger society through its numerous corporate social responsibility (CRS) initiatives.

Conclusively, Indorama, Nigeria is committed to inclusive development and CSR activities as a part of IEFCL-Train2, IEFCL has already initiated the process with due discussion with community representatives and project advisory committee.

# CHAPTER FOUR

# ENVIRONEMNTAL ASPECTS, POTENTIAL IMPACTS AND MITIGATION MEASURES

## 4.0 IMPACTS ASSESSMENT AND MITIGATION MEASURES

The identification of environmental aspects and impacts is important for the selection of environmental safeguards and work methods for the proposed unit activities such as construction, operation and maintenance. The methodology adopted for assessment and the outcome are described below.

## 4.1 Impact Characterization

In order to describe the nature and duration of the various activities on the biophysical and socio-economic environment, the identified impacts were characterised as follows.

- Beneficial Impacts: Impacts that would produce positive effect on the biophysical or socio-economic environment.
- Adverse Impacts: Impacts that may result in:
    - Irreversible and Undesirable change(s) in the social and/or biophysical environment;
    - Decrease in the quality of the biophysical or social environment;
    - Limitation, restriction or denial of access to or use of any component of the environment to major stakeholders and other interested parties.
- Direct Impacts: Impacts resulting directly (direct cause-effect consequence) from the developmental activity.
- Indirect Impacts: Impacts that are at least one step removed from a project activity. They do not follow directly from a project activity.
- Short-term Impacts: Impacts that will last only within the period of a specific project activity.
- Long-term Impacts: Impacts whose effects remain even after a specific project activity.
- Irreversible Impacts: Impacts whose effects are such that the subject (impacted component) cannot be returned to its original state even after adequate mitigation measures are applied.
- Cumulative Impacts: Impacts resulting from interaction between ongoing project activities with other activities, taking place simultaneously.
- Incremental Impacts: impacts that progress with time or as the project activity proceeds.
- Residual Impacts: Impacts that would still remain after mitigation measures have been applied.

### 4.2 Characterization of Potential/Associate Impacts and Mitigation measures

The anticipated impacts that arise from actualization of the FCU2 unit and proposed mitigation efforts are described in the Table 4.1 below.

**Table 4.1: Aspect/Impact and Mitigation measures**

| Project Phase | Project Activities & Environmental Aspects | Potential and Associated Impacts | Character of Impact | Monitoring / Mitigation measures | Responsibility |
|---|---|---|---|---|---|
| **Pre-construction** | Mobilization of personnel, materials and equipment to site | Risk of road accidents from movement of workers and heavy construction equipment to the site. | Adverse, direct, short-term | Contractor shall mobilize heavy duty trucks carrying equipment in the night to avoid traffic. Workers will be moved by busses. Setup traffic warden and road sign at strategically position, where necessary. | IEFCL/ Contractor |
| | | Air/noise pollution from vehicular movement. | Adverse, direct, short term | Use of road worthy vehicles, movement restricted to lean period | IEFCL/ Contractor |
| | | Conflicts due to belief that some communities are short changed in employment | Adverse, direct, short-term | The FCU2 Unit as part of IEFCL-Train2 project will benefits from Indorama's Stakeholder Management Plan. | IEFCL/ Contractor |
| **Construction** | Transportation of workers, materials and equipment to site | Air/noise pollution from vehicular movement and construction equipment. | Adverse, direct, short term | Contractor shall use healthy vehicles. Installation of Noise insulators on heavy equipment. Carryout regular ambient air and Noise monitoring of facility | IEFCL/ Contractor |
| | | Moderate Increase in business opportunity to the host community | Beneficial, some long-term, | IEFCL will patronize local vendors, as much as possible | IEFCL |
| | | Skills acquisition | Beneficial, some long-term, mostly short-term | Encouragement of workers to take work as an opportunity for skill development. | IEFCL |

| Project Phase | Project Activities & Environmental Aspects | Potential and Associated Impacts | Character of Impact | Monitoring / Mitigation measures | Responsibility |
|---|---|---|---|---|---|
| | Civil, Mechanical construction, erections and installation | Reduction in air quality | Adverse, direct, short-term | Regular maintenance of equipment and machineries | Contractor |
| | | Employment of unskilled labour | Beneficial, some long-term, mostly short-term | Contractors will strictly follow the local content rules, and Indorama policies in employment of labour from Host communities. | IEFCL/Contractor |
| | | Injury to workers | Adverse, direct, short-term | Implement and enforce policies on use of PPEs | IEFCL/Contractor |
| | | Generation of various waste materials; scrap materials on site, etc. | Adverse, direct, short-term, | Construction and packaging materials, wooden and metal scraps shall be managed and disposed of in accordance with Waste Management Plan and IEFCL waste management policy | IEFCL/ Contractor |
| | | Noise and vibration from, Erection and construction equipment | Adverse, direct, short-term | Adequate use of PPEs<br>Insulate Noise generating machine | IEFCL/Contractor |
| | | Respiratory tract symptoms due to inhalation of dust and toxic fumes. | Adverse, direct, short-term | Regular maintenance of machinery and equipment; wet construction site during dry season; Enforce use of PPEs by construction workers | IEFCL/ Contractor |
| | | Youths/community restiveness especially during recruitment of unskilled labour | Adverse, direct, abnormal, short-term, reversible | Regular meetings with Project Advisory Committee (PAC). | IEFCL/ Contractor |

| Project Phase | Project Activities & Environmental Aspects | Potential and Associated Impacts | Character of Impact | Monitoring / Mitigation measures | Responsibility |
|---|---|---|---|---|---|
| | | Improper disposal of solid waste by construction contractors. | Moderate | Generated solid waste shall be segregated at source by the provision of color coded bin and disposed-off according to IEFCL waste management guidelines<br>The generated paper waste shall be shredded and sold to any approved paper recycling company or send for composting<br>De-contaminated scrap metals/drums shall be collected and taken by an accredited waste recycler or vendor.<br>Oily waste materials shall be collected and taken to approved incinerator for incineration.<br>Kitchen waste shall be collected and handled by approved contractor and dispose at approved dump site. | IEFCL/Contractor |
| | | Emission of noxious substances (emissions) to atmosphere could affect air quality. | Adverse, direct, long-term, residual | Regular maintenance of machineries.<br>Ambient air quality shall be monitored in line with regulatory requirements (NOx, CO, SOx, SPM, PM10, PM2.5 etc) | Emission of noxious substances (emissions) to atmosphere could affect air quality. |

| Project Phase | Project Activities & Environmental Aspects | Potential and Associated Impacts | Character of Impact | Monitoring / Mitigation measures | Responsibility |
|---|---|---|---|---|---|
| | | Nuisance (noise, emissions, vibrations) from heavy machinery could impact human hearing | Adverse, direct, long-term, residual | Machinery with noise levels within acceptable limits (90 dB (A)) shall be used<br>Site construction shall be done within the shortest possible time<br>Acoustic mufflers shall be provided for heavy engines with noise level above acceptable limits<br>IEFCL EHS policy of wearing ear muffs/ plugs shall be applied in all construction sites<br>Workers with existing hearing impairment shall not be deployed to site<br>Construction equipment shall be maintained regularly<br>Regular monitoring of Noise level at Construction site | IEFCL/Contractor |
| **Operation** | Processing of Natural, maintenance and house cleaning activities | Increase in noise levels | Adverse, direct, short-term, | Regular use of PPEs. Periodical monitoring of noise level | IEFCL |
| | | Reduction in air quality due to emissions released from regeneration heater. | Adverse, direct, local, short-term, | Regular maintenance of equipment and regular established monitoring | IEFCL |
| | | Generation of waste especially from maintenance workshops | Adverse, direct, short-term, | Ensure only approved waste contractors are engaged | IEFCL |

| Project Phase | Project Activities & Environmental Aspects | Potential and Associated Impacts | Character of Impact | Monitoring / Mitigation measures | Responsibility |
|---|---|---|---|---|---|
| | | Reduction in greenhouse gas emissions, due to use of recovered CO2 from NG in urea synthesis, before used as fuel/feed | Beneficial, direct, long-term | Regular monitoring of recovered carbon dioxide | IEFCL |
| | | Injury to workers due to non-usage of PPEs | Adverse, direct, long-term, irreversible | Regular use of PPEs | IEFCL/ Contractor |
| | | Engagement of indigenous Persons as Workers and Service Providers. | Beneficial, direct, short-term | The FCU2 Unit as part of IEFCL-Train2 project will benefits from Indorama's Stakeholder Management Plan. | IEFCL/ Contractor |
| **Decommissioning** | Site Restoration activities | Generation of wastes including abandoned equipment, oil, scrap metal | Adverse, direct, long-term, residual | Develop decommissioning plan and shall be approved by the Regulators prior to demolition | IEFCL/ Contractor |
| | | Unsafe area accessible to the public | Adverse, direct, long-term | Cordon unsafe area from been accessed by the public | IEFCL/ Contactor |

### 4.3 Complementary Initiatives

The current ESMP already covers all the complementary initiatives as explained in above Table. Since, the project has key element focus (Environment & Social), it is imperative that all the stakeholders associated with these aspects shall compliment the actions thereof. The monitoring & Mitigation plan explains the stakeholder engagement apart from SEP.

The other elements such as identification and assigning of responsibilities, institutional arrangements, cost estimates and implementation schedule has been explained at various stages in other chapters.

# CHAPTER FIVE

# ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

## 5.0 ESMP GUIDELINES FOR PROPOSED FCU2 UNIT

The proposed FCU2 unit will be a part of IEFCL-Train2 Project, which is under construction. The Environmental and Social Management System (ESMS) and Plans (ESMP) proffered in IEFCL-Train2 approved ESIA, shall be followed strictly during construction and operation of FCU2 unit, this being part of IEFCL-Train2 project. The following Environmental and Social Management plans shall be complied for FCU2 ALSO:

- Environmental Capacity Building Program
- Monitoring Program and Reporting System
- Environmental Audit Program
- Traffic Management Plan
- Energy Conservation Program
- Leak Detection and Repair program
- Risk Management Plan for Contaminated Land
- Hazardous Materials Management plan
- Decommissioning and Closure Plan
- Waste Management Program
- Occupational Health and Safety Management Plan
- Hazardous Materials Risk Management plan
- Security Management Plan
- Human Resources management Plan
- Social management / Stakeholder Engagement Plan

In addition, the construction contractor shall develop EHS & S management plans and procedure and shall submit to IEFCL for approval. During construction, the contractors either follow the approved plans and procedures or shall follow the IEFCL's EHS & S plans and procedures.

The summary of Environmental and Social Management Plans (ESMP), extracted from approved ESIA of IEFCL-Train2 is presented below.

## 5.1 Environmental Capacity Building Program

The essence of the environmental capacity building program is sustained training and awareness to be imparted to all the stakeholders as part of project execution. Hence, training and awareness are the key aspects to be considered in the establishment of a capacity building program. The training program will be implemented by IEFCL and Construction contractor through technical assistance with project management training specialists. The IEFCL's project team members & the personnel of the Construction Contractor shall be trained on environmental issues by project management training specialists. Training needs of target groups shall be prepared in advance to ensure the success of the training program. The training to the line managers, construction staff and supervisors shall be provided based on responsibilities and training needs.

## 5.2 Environmental Monitoring Program and Reporting System

The environmental monitoring plan is designed to confirm that the applicable international and national environmental regulatory standards and guidelines shall be complied with. IEFCL shall comply with National regulatory controls as well as internationally agreed requirements (i.e. IFC PS; AfDB OS) by establishing an ecological, environmental, health and safety monitoring program that shall cover the entire project development phases (i.e. pre-Construction through operation phases including decommissioning phase).

It is important to mention here that the IEFCL Train-1 operations, IEFCL-Train2 project and FCU2 unit all exist synergistically in one single complex (share same geographical area). Already, IEFCL-Train1 ESMP for operations is in force and has been ratified by all the federal agencies. IEFCL-Train2 has an approved ESMP that guides the environmental monitoring program. The philosophy of implementation of IEFCL-Train2 is same as IEFCL-Train1 as part of environmental monitoring. Since FCU2 is also a part of IEFCL-Train2, the same philosophy of monitoring shall be implemented.

The reporting system will operate linearly with the Contractor (which is at the lowest rung of the implementation system) reporting to the Project Manager, which reviews the reports with the Project EHS Lead that finally reports to the Project Director. The environmental compliance monitoring performed by IEFCL Environmental Consultants and by in-house EHS

team and the progress reports on environmental components will be clubbed together and submitted to the FMEnv/RSMEnv quarterly during the implementation period. In addition, during construction, IEFCL will submit quarterly E&S monitoring reports to IFC. After construction, will submit E&S monitoring report twice a year during first year of operation and their after annually.

Table 5.1: Environmental Monitoring Plan

| S/N | Environmental Components | Indicator Parameters | Frequency | Location | Responsibility | Time Frame |
|---|---|---|---|---|---|---|
| 1 | Noise | Sound Pressure | Monthly – Day and Night hours | Project Site | IEFCL Environment Department | Construction; Operations and Decommissioning |
| 2 | Waste management | Generated waste quantity | Regular evacuation schedule | Project Site | IEFCL Environment Department | Construction; Operations and Decommissioning |
| 3 | Ambient Air* | SPM; NOx, CO, O3, VOC, SOx, CxHy, PM10, PM2.5 | Monthly | Plant Site & selected community based stations | IEFCL Environment Department and Third Party (Environment Consultant) | Construction; Operations; and Decommissioning |
| 4 | Surface Water* | pH, Alkalinity, Conductivity, Ammonia, Turbidity, DO, COD, BOD, PO4, Total Nitrogen, TSS, TDS, Metals etc. | Monthly | Sluice gate, Outfall, Upstream and Downstream of receiving water body | Third Party (Environment Consultant) | Operations |
| 5 | Treated effluent streams* | pH, Alkalinity, Conductivity, Ammonia, Turbidity, DO, COD, BOD, PO4, Total Nitrogen, TSS, TDS, Metals etc. | Monthly | Sluice gate, Outfall, Upstream and Downstream of receiving water body | IEFCL Environment/QAQC Department and Third Party (Environment Consultant) | Operations |

- The monitoring of these components is the part of holistic monitoring of IEFCL (mother plant).

The sponsor estimates that it will cost about USD 8million (0.57% of the overall project cost) to implement and monitor actions to mitigate E&S risks. A detailed cost plan has been presented in Table below:

Further the ESMP allocation for Line 2 will also cover ESMP for FCU 2 as both the projects are being constructed under IEFCL. We have added some additional cost to the ESMP allocation for Line 2.

**ESMP-Budgetary Allocation**

| | **Host Community Welfare (2018-2021)** | **Amount in Naira** | **Amount in US$** |
|---|---|---|---|
| 1 | Community Welfare Projects to be nominated by each community | 450,000,000 | 1,475,410 |
| 2 | Micro Credit (Grant) Scheme for women | 18,750,000 | 61,475 |
| 3 | Scholarship Programmed | 11,250,000 | 36,885 |
| 4 | Support for Traditional Institutions | 69,000,000 | 226,230 |
| **Sub Total 549,000,000** | **1,800,000** | | |
| **Skill Acquisition Program for Eleme (period - 2018 - 2021)** | | | |
| 1 | Renovation of Eleme Local Government Vocational Training Center | 12,200,000 | 40,000 |
| 2 | Masonry, Welding & Fabrication, Grinding, Insulation, Iron bending, Fitter training for youth | 30,500,000 | 100,000 |
| 3 | Hair Dressing for women ( startup package) | 15,250,000 | 50,000 |
| 4 | Special empowerment for Physically challenged | 9,150,000 | 30,000 |
| **Sub Total 67,100,000** | **220,000** | | |
| **CSR Project for Pipeline Communities** | | | |
| 1 | Empower Programmed for land owning families along the Right of | 12,200,000 | 40,000 |
| 2 | CSR Projects | 56,120,000 | 184,000 |
| 3 | Skill Acquisition Training Programmed & Start Package | 7,015,000 | 23,000 |
| 4 | University Scholarship | 8,540,000 | 28,000 |
| **Sub Total 83,875,000** | **275,000** | | |
| **Others** | | | |
| 1 | Manpower Engagement Service Fees (Depends on Project timeline) | $2.5mn to $3.5mn | |
| 2 | Indorama General Hospital & Dialysis Centre (50% of the Amount allocated to IEFCL) | 610,000,000 | 2,000,000 |
| 3 | Other Projects/CSR Activates | 152,500,000 | 500,000 |
| 4 | ESMP FCU 2 | 10,000,000 | 25,000 |
| **Total ESMP Budgetary Allocation** | **$7.3 MN to $8.3 MN** | | |
| **Project Cost $1.285 bn** | | | |
| **% of ESMP to Project Cost** | **0.57** | | |

### 5.3 Environmental Audit Program

As the FCU2 is a part of IEFCL-Train2 project, the Environmental audit will be conducted as per regulatory requirement. This audit process shall be used to check the prediction in the ESIA/ESMP and also to assess the environmental performance during the operational phase. This will ensure that environmental protection and management procedures are reinforced. Indorama Eleme Fertilizer & Chemicals Limited shall produce an Environmental Audit Report (EAR), which shall be submitted to FMEnv and State Environmental Authorities.

### 5.4 Traffic Management Plan

Measures on transportation/traffic will be adopted to minimize the impact due to the mobilization of trucks and other vehicles for the construction and operation phases. A comprehensive traffic management plan for construction and operation phase has been developed. The following mitigation measures shall be taken into account for transportation management of heavy equipment, construction materials, products and personnel:

- Schedule large and slow moving vehicles during off peak periods;
- Raise community awareness in case of transportation of equipment having over dimensional crate (ODC);
- Strictly enforce vehicle speed limits;
- Provide safety and environmental awareness training to Contractors/Company Drivers and conduct periodic assessments and monitoring;
- Implement systems at place to restrict movement of construction vehicles at designated and earmarked roads;
- Maintain vehicles to minimize emissions and fuel consumption;
- Place warning signs at road crossings and other appropriate locations as required;
- Establish temporary traffic control where necessary at road crossings and junctions;
- Establish Traffic wardens for monitoring and controlling of vehicle speed.

### 5.5 Energy Conservation Program

Energy conservation shall be the basis for project engineering. Energy conservation as part of design criteria shall be considered to effectively operate the plant. This has tangible benefits in the long run. An energy conservation program shall be adopted for the facilities (process and auxiliary) that consume energy in process, heating and cooling during operational phase. Common techniques/measures/procedures may be applied in accordance with the IFC general EHS Guidelines (April 30, 2007). Specifically, on energy conservation in process heating, cooling and compressed air system.

### 5.6 Leak Detection and Repair program

Referring to the possible fugitive emission during the operations phase, IEFCL shall implement a leak detection and repair (LDAR) program. This proactive approach controls fugitive emission by quarterly monitoring by operations engineers to detect leaks and respective engineering section to implement repairs when need arises. Established leak detection and repair (LDAR) program existing in IEFCL-Train1 will be adopted in IEFCL-Train2.

### 5.7 Risk Management Plan for Contaminated Land

IEFCL shall define the contents/indications to be developed/followed in case of land contamination due to anthropogenic releases of hazardous materials, wastes or oil, including naturally occurring substances during both, construction and operation phases. In such areas where oil is dispensed and where mechanical equipment repairs will take place, dedicated catchment/secondary containments will be supplied and regularly collected in remarketed receptacles for reuse/recycling. To prevent land contamination, the secondary containments shall be made available at oil and chemical storage area. Secondly during transportation suitable containers shall be provided to prevent land contamination in case of any incident lead to spillage. During construction, the contractor shall have his own spill management plan for spill collection and disposal. Subsequently, during the operations IEFCL shall extend the current spill management plan for IEPL & IEFCL-Train1 to IEFCL-Train2 with necessary changes to include locational areas.

### 5.8 Hazardous Materials Management plan

The Hazardous Materials Management Plan shall be consistent with the Occupational Health and Safety Management plan, including written process safety parameters (i.e., hazards of the chemical substances, safety equipment specifications, safe operation ranges and other applicable parameters, evaluation of the consequences of deviations, etc.); written operating procedures; and Compliance audit procedures.

Hazardous materials shall be stored within designated storage areas and using appropriate procedures (e.g. containment and bounding, impermeable surfaces, secure drainage, limited access, labeling). A record shall be kept of all hazardous materials on-site. The Material Safety Data Sheets (MSDS) shall be maintained by relevant departments and also safety precautions shall be displayed at storage site. The hazardous material shall be stored as per compatibility and potentially reactivity of the materials. Personnel shall be trained in safe use & handling of hazardous materials. Spill response equipment (absorbents, etc.) will be available and emergency response training provided.

### 5.9 Decommissioning and Closure Plan

The activities shall involve demolition and site clean-up, disposal of wastes, worker's exposure to workplace agents. Decommissioning activities and closure plan will commence only after the plan has been reviewed and approved by FMEnv & State Environmental Authorities. Any possible measure shall be taken to avoid negative impacts during decommissioning. IEFCL commits itself to restore the site back to as much as possible to the environmental conditions existing before the realization of the unit. A detailed decommissioning and closure plan will be developed and be ready to be implemented prior to the commencement of this activity.

### 5.10 Waste Management Program

Waste management programs shall be implemented to address all activities that have been identified to have potential significant impacts on the environment with respect to waste generation and disposal during construction, operation and decommissioning. Consequently, waste type to be generated during the construction, operation and decommissioning of this project has been classified into non-hazardous and hazardous waste. The existing operational waste management program and procedures shall be extended to FCU2 and waste materials shall be managed by following the procedures and in compliance with National regulations.

### 5.11 Occupational Health and Safety Management Plan

IEFCL will adopt an Occupational Health and Safety (H&S) management plan which provides workers and contractors a safe and healthy work environment by establishing measures to prevent the likelihood of workers accidents/incidents, provisioning adequate personnel protective equipment, conducted sound H&S training, provisioning first aid facilities and clinic, ensuring appropriate welfare workplace accommodations (canteen, appropriate number of toilets and change rooms (conveniences) , hydration stations, etc.), good lighting, potable water supply, integrity (well insulated structures) of workplace structures, etc. The Construction contractor shall subscribe to the occupational H&S management plan and in addition, the contractor will be required to present to project team, its specific occupational H&S plan and procedures. IEFCL will also develop a corresponding Occupational HSE Plan for the operation phase.

A Communication and Training Programme to ensure that all the employees involved in the project receive training about Occupational Health and Safety (OHS) aspects, will be put in place. The existing IEFCL-Train1 Emergency plan to ensure that all employees are capable of acting in an emergency so as to protect human life and property will be reviewed to accommodate the activities of IEFCL-Train2 prior to commencement of construction. Safety and emergency procedures shall cover handling of chemical that will be used in IEFCL- Train2, most importantly the management of such chemicals in addition to company's policy will follow the guideline specified by manufacturers of such chemicals as contained in the Material Safety Data Sheet (MSDS).

Upon completion of IEFCL-Train2 and FCU2, the current operational emergency plan shall be revised to include the aforementioned units.

#### 5.11.1 Hazardous Materials Risk Management Plan

IEFCL shall implement a Hazardous Materials Risk Management Plan containing the elements: handling, storage and use of hazardous materials; Management actions to be addressed; Use

of appropriate PPEs; MSDS of each chemical; Proper house-keeping; Preventive Measures to be taken; Emergency Preparedness and Response to be developed; Community involvement and Awareness in relation to potential hazards etc.

### 5.12 Security Management Plan

The security will be assured by the existing security infrastructure laid out by the Proponent. The construction contractor shall have its own security team and work and perform within the IEFCL security framework. Their action will be monitored by the Proponent to assure that the possible use of force will be adopted according to the Voluntary Principles as stated in IFC Performance Standard 4. The detailed security management plan was developed and implemented.

### 5.13 Human Resources Management Plan

IEFCL operates a human resource department which also includes the community relations and development. IEFCL has developed a high ethical standard for work conditions and relationship between management, staff and labor in strict compliance with IFC Performance Standard 2 and AfDB OS5. A detailed employee handbook covering all areas of labor relationship developed and implemented for IEFCL-Train1 shall be adopted for IEFCL-Train2. The Labour and Working conditions shall be in compliance with IFC Performance Standard 2 and AfDB Operational Safeguard 5. Development of a code of conduct for construction workers, and disciplinary procedures is expected to guide the activities of construction workers.

### 5.14 Social Management / Stakeholder Management Plan (SMP)

IEFCL has adopted a Social Management plan according to the Equator principles and the IFC EHS guidelines / AfDB OSs. According to the Equator Principle n. 5, the Proponent will assure the consultation and participation of affected parties in the implementation of the Project.

IEFCL has developed a Stakeholder Engagement Plan and implemented the same. The implementation of Stakeholder Engagement Plan has encourage the participation of relevant Stakeholders in various project phases with ensuring the equally socio-economic development of communities. Where applicable, the Stakeholder Engagement Plan include

differentiated measures to allow the effective participation of those identified as disadvantaged or vulnerable.

The Proponent shall provide Affected Communities with access to relevant information on: (i) the purpose, nature and scale of the project; (ii) the duration of proposed project activities; (iii) any risks and potential impacts on such communities and relevant mitigation measures; (iv) the envisaged stakeholder engagement process and (v) the grievance mechanism to express their concern with respect to the project. Social conditions of the host communities shall be monitored during Environmental Audit. SMP shall be fully implemented and establishment of community liaison team enforced to facilitate relationships with communities during the construction, operation and decommissioning phases.

# CHAPTER SIX

# CONCLUSION

## 6.0 CONCLUSION

The ESMP describes the summarized impacts both negative and positive applicable for the construction and operation of FCU2 unit. Adequate management guideline and mitigation measures have been proffered for negative impacts identified to reduce them to barest minimum. With the effective implementation of the guidelines, mitigation measures and monitoring programs defined in the approved ESIA of IEFCL-Train2 and listed in this ESMP, IEFCL can indeed limit the negative impacts associated with the construction and operation activities. These will be fulfilled by EHS & S unit, who will drive this ESMP in IEFCL activities.

**REFERENCE**


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- Final ESIA Report – IEFCL-Train1 Project, 2013
- Final ESIA Report – IEFCL-Train2 Project, 2018.
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