

Appendix - 4.2**METHODOLOGY****AMBIENT AIR/NOISE/METEOROLOGY AND MODELLING****Ambient Air Quality Study**

Field study for the proposed IEFCL-Train2 project was conducted in September 2017 for rainy season data collection. Secondary data from previous studies conducted in the area (IEPL & IEFCL, Jan/Feb/March' 2017) were used for the dry season analysis. The ambient air quality survey was carried out in compliance with statutory requirements and in line with national and international policy on the protection and conservation of the environment. Ambient air quality monitoring is required to determine the existing quality of air in the project area. The ambient air quality objectives/standards are pre-requisite for developing management programme for effective management of ambient air quality and to reduce the damaging effects of air pollution. Measured baseline data were compared with Federal Ministry of Environment (FMEnv) standards and International Finance Corporation Standards. Concentrations of PM₁₀ and PM_{2.5} were compared with International Finance Corporation Standards. Air emission levels for fertilizer manufacturing (IFC, 2007); Nigerian Ambient air quality standards and International Finance Corporation (IFC) limits are presented in Appendix.

The ambient air quality monitoring survey was carried out at 9 locations (Table 1) within the proposed project geographical zone. Measurement of the real concentration levels of sulphur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), hydrogen sulphide (H₂S), total hydrocarbon (THC), volatile organic compounds (VOCs), ammonia (NH₃), total suspended particulate matter (TSP), particulate matter (PM₁₀), & particulate matter (PM_{2.5}) are expressed in microgram per cubic meter (µg/m³) and gives an understanding of the baseline existing environmental setting and condition of the project area. Statistical descriptors were used to compute the geometric mean, standard deviation and the 75th percentile (3rd quantile) concentrations of generated data during sampling at all locations. Secondary historical data on meteorological parameters played an important role in identifying the general meteorological status of the project area. Site specific data was compared with secondary historical data in order to identify changes which may have taken

place due to the various developments in the area. Data obtained from field survey was supplemented by baseline assessment of secondary historical data from various locations. Historical data used are sourced from the monthly air quality monitoring reports by IEPL environmental consultant. Monitoring survey results are reported and discussed in detail in chapter 4. Collated secondary data was used to understand the ambient air quality scenario of the project area in the dry season.

Air Quality Sampling Procedure

Air quality sampling within the project area and its environs was done for a period of eight hours per day for each location and readings of all the parameters taken every hour. The eight hour monitoring period was carried out from day to day so that reading could be taken from early morning to late at night over the monitoring period. Sampling methodology adopted for this study was in compliance with Environmental Standards and Guidelines (FMENV 1991).

Table 1: Monitoring Location

Code	Location	Coordinates	
		N	E
AQ1	Aleto Community	N 04° 49' 12.64"	E 07° 05' 41.66
AQ2	Flare Area	N 04° 50' 03.42"	E 07° 06' 39.80"
AQ3	NG Receipt facility Area	N 04° 50' .33.33"	E 07° 06' 21.70"
AQ4	Urea bagging Plant	N 04° 50' 27.04"	E 07° 05' 58.76"
AQ5	Weigh Bridge	N 04° 49' 58.80"	E 07° 05' 35.20"
AQ6	Main Gate	N 04° 48' 54.48"	E 07° 05' 54.10"
AQ7	Akpajo Community	N 04° 49' 37.90"	E 07° 05' 15.80"
AQC1	Agbonchia Njuru (Control 1)	N 04° 47' 64.40"	E 07° 06' 98.10"
AQC2	Rumukrushishi Town (Control 1)	N 04° 51' 07.60"	E 07° 03' 38.00'

Measurement of Gaseous Pollutants

Madur GA-21 plus multi-gas analyser equipment was used for ambient air quality measurement. The multi-gas analyser automatically extracts atmospheric air and sent through the analyser gas sensors for the determination of pollutant gases of interest (SO_x,

VOC, O₃, NO_x, CO, H₂S, and THC). Instrument measurement principles and ranges of parameters are shown in Tables 2 and 3 respectively.

Measurement of Suspended Particulate Matter (TSP, PM₁₀ and PM_{2.5})

A mini-volume portable air sampler (Airmetrics ®) with a pre-weighed membrane filter (45µm) is used to collect particulate matter. After sampling, the membrane filter was dried in a desiccator and weighed to the nearest milligram. Measuring the mass of particulate matter and dividing by the volume of air calculated the mass concentration (gravimetric).

Table2: Gas components and suitable measuring principles

Parameter	Recommended method of determination
Particulate matters/Dust	Laboratory analysis method
H ₂ S	Electrochemical method
NO ₂	FTIR / NDIR (cold) and converter / Calculation
SO ₂	NDIR (cold and hot) / FTIR / DOAS-UV
VOC	FID (Flame Ionization Detector)
THC	IR sensor

Table3: Measurement range for parameters

Parameter	Range	Accuracy	Resolution
CO	0 to 10,000 ppm H ₂ comp.	< 5 ppm, 0 to 99 ppm, < 5% of m.v., 100 to 2,000 ppm < 10% of m.v., 2,001 to 10,000 ppm	1 ppm
NO ₂	0 to 500ppm	< 5 ppm, 0 to 99 ppm, < 5% of m.v., 500 ppm	0.1 ppm
SO ₂	0 to 5,000ppm	< 5 ppm, 0 to 99 ppm, < 5% of m.v, 100 to 2,000 ppm < 10% of m.v., 2,001 to 5,000 ppm	1 ppm
H ₂ S	0 to 300ppm	< 2 ppm, 0 to 39.9 ppm, < 5% of m.v., 40 to 300 ppm	0.1 ppm
THC	0 – 100ppm	±0.5ppm	0.01ppm
Noise	30 – 130dB (A)	±1.5dB	0.1dB

Noise Study

Noise levels were monitored at the nine locations within the project zone alongside air quality monitoring.

Noise Measurement Instrument

Smart Sensors (models AR844 and AR854) and TES (model 1352H) digital sound level meters were used. The Smart Sensors and TES digital sound level meters measure sound pressure level and are commonly used in noise studies.

The digital sound level meters are designed according to following standards:

- International electrician committee standard: IEC PUB 651 TYPE2
- US national standard: ANSI S 1. 4 TYPE2

The sound level meters were in-field calibrated by means of calibrator (piston-phone or other approved calibrator conforming to ANSIS1.4.

Methods of Noise Measurement

Field measurement of noise levels at different locations in project area and its environs was conducted in the month of September for the wet season period. A systematic monitoring of noise levels was carried out at pre-determined locations within and outside the project boundary area using Smart Sensor (models AR854) and TES (model 1352H) sound pressure level meters which give instant, real time readings according to regulatory noise measurement standards. The instruments were set on the A-weighting scale and fast response. Measurement of sound pressure levels were carried out at 15minutes intervals in an eight (8) hour working day. The instruments were placed 3 to 10 meters above ground level in accordance with ISO 9613 noise measurement procedure (Ugbebor et al., (2017).

Method of Noise Analysis

Measured noise levels were statistically analysed to determine baseline scenario around the project zone. The following noise level descriptors were determined and evaluated from measured data.

- Equivalent continuous equal energy level (L_{eq})
- The maximum A-weighted and fast time noise leveln (L_{max})
- A-weighted sound pressure level exceeded 10% of a given measurement interval (L_{10})
- A-weighted noise level exceeded for 50% of a given measurement period (L_{50})
- A-weighted sound pressure level exceeded 90% of a given measurement interval (L_{90})

Statistical Descriptors (ISO 1996-1:2003 & ISO 9613-2)

(a) Average Noise levels

Average values of noise levels obtained during field measurement was computed using the following Equation (Davis and Cornwell, 2008)

$$L_{avg} = 20 \log \frac{1}{N} \sum_{j=1}^N 10^{\left(\frac{L_j}{20}\right)}$$

where

L_{avg} = average noise level (in dB ref : $20 \mu Pa$)

N = number of measurements

L_j = the jth noise level (in dB ref : $20 \mu Pa$)

j = 1,2,3,.....N

- **L₉₀** The level exceeded for 90% of the time during a specified period. This value was considered the background level.
- **L₅₀** The level exceeded for 50% of the time. This value was considered the median noise level.
- **L₁₀** The level exceeded for 10% of the time. This value was to represent maximum noise level.
- **L₁** The level exceeded for 1% of the time. This value was considered the peak noise level

(b) Equivalent Noise level (Leq)

The Leq is the equivalent continuous equal sound pressure level, which is equivalent to the same sound energy as the actual fluctuating sound measured in the same period. This is a cumulative metric that provides a more accurate quantification of noise exposure for a specified period and it is calculated to determine the steady-state noise level over a specified time period.

Leq is computed as defined by ISO 9613-2 using the following equation (Keily, 1996)

$$Leq = 10 * \log \left(\frac{1}{T} \int_0^T \frac{P^2(t)}{P_0^2} dt \right)$$

where:

T is the total time

P is the instantaneous A - weighted sound pressure in pascals

P_0 is the reference sound pressure (= $20 \mu Pa$)

t is the specified time interval, in seconds

For discrete sampling employed in this study the following formula was used to compute the values of L_{eq} for both the wet and dry seasons.

$$L_{eq} = 10 \log \left(\left(\frac{1}{T} \right) \sum_{i=1}^{i=n} 10^{L_i/10} (t_i) \right)$$

where :

L_i = the noise level in dB(A) of the i th measurement

T = total time

n = the total number of measurements taken

t_i = fraction of total measurement time

Modeling Methodology

The mathematical simulation of the dispersion of air pollutants emissions from the new ammonia/urea plant is presented and discussed in this section. Two modelling approaches were employed in the modelling - Level 1 assessment and Level 2 assessment (IFC, 2007). A screen view model was applied for first level assessment (IFC, 2007), while ISC-AERMOD View model was used for second level assessment. Both models are approved by the United States Environmental Protection Agency (USEPA) for air pollutants dispersion modelling.

A screening model was applied for first level assessment to provide the worst-case pollutant concentrations, while ISC- AERMOD was used for second assessment to provide an in-depth modeling approach to determine long-range (24-hour) scenarios.

Screen view version 4.0 is a screening-level air quality model approved by the United States Environmental Protection Agency (USEPA) and International Finance Corporation (IFC) for the **estimation of worst-case ground level concentrations** for a single source as well as concentrations in the cavity zone, and concentrations due to inversion break-up and shoreline fumigation (Lake Environmental, 2011).

The screen view model has a built-in, meteorological data matrix that represents a spectrum of different combinations of meteorological conditions that could possibly occur in the area. It calculates concentrations under these different combinations of meteorological

conditions. From this output, the highest (worst-case) concentration is selected. Screening models are generally limited to providing the worst-case one-hour concentrations at a receptor. Screening models are considered to provide conservative concentration estimates, and as such are used as a flagging device that indicates the potential for unacceptable air quality (British Columbia Ministry of Environment, 2008).

Although Level 1 assessments are useful in many situations, often the complete distribution of concentrations in time and space are of interest. This distribution provides the spatial pattern of maximum concentrations at different time averages surrounding the source area, and/or the identification of areas where certain specified concentration thresholds are exceeded as well as their exceedance frequencies (British Columbia Ministry of Environment, 2008).

The ISC-AERMOD View model was used at the second level modelling assessment to determine long range air pollutants transport and their impacts on surrounding receptors. Mathematical simulations of emissions air dispersion from new stationary sources on long term basis was achieved by the modelling code AERMOD using the graphical user interface (GUI) AERMOD View. AERMOD View is a steady-state Gaussian Plume Air Dispersion Model developed by the Atmospheric Studies Group (ASG) scientists. The model incorporates Industrial Source Complex Model (ISCST3), AERMOD model and Plume Rise Enhancements (ISC-PRIME).

ISC-AERMOD View is a USEPA Regulatory, refined, steady-state, multiple source, Gaussian plume air Dispersion Model. ISC- AERMOD View is widely accepted as the preferred model to use for industrial sources in air quality analysis. The model was used to simulate pollutant concentrations emitted from the proposed ammonia/urea plant. Therefore, using ISC-AERMOD View for cumulative impacts modelling gives conservatively high impacts from a distance point source. Results are compared with Federal Ministry of Environment (FMEnv) and International Finance Corporation (IFC) standards and guidelines.

Point source Emission data

In below table 4, indicated the summary of emission factors, and stack characteristics, adopted in the model for plant's stacks.

Modelling Data for IEFCL Train-2 EIA

Emission Rate Nm3/hr.

Boiler stack emission	– 124,938 Nm3/hr.
Reformer stack emission	– 295,326 Nm3/hr.
Granulator 1	– 11, 86, 000 Nm3/hr.
Granulator 2	– 180,900 Nm3/hr.

Reformer stack Flue Gas Emissions

Effluent	Flow / Conditions	Components	Discharge
101-B Reformer Flue Gas	363,700 kg/hr (wet basis) 120 deg.C MW 27.55	N ₂ = 71.0 mol% H ₂ O = 18.50 mol% CO ₂ = 7.30 mol% O ₂ = 2.10 mol% Ar = 1.10 mol% SO ₂ : 1.02ppm based on 10 ppm H ₂ S in NG fuel NO _x : 40 ppmv @ 3%O ₂	Vented to Atmosphere

Package Boiler stack Flue Gas Emissions

Source	Flow / Condition	Components	Discharge
Flue Gas from Package Boiler B-BF1301	Max case: 124,938 Nm3/h (153,674 kg/hr) (wet basis) For 125 t/h steam production 160°C Mol Wt 27.55 Nor case: 44,554 Nm3/h (55,295 kg/hr) (wet basis) 150°C Mol wt 27.8	Max case: SO _x ≤ 30 mg/Nm3 (at 3% O ₂ vol. dry basis) NO _x < 150 mg/Nm3 (at 3% O ₂ vol. dry basis) CO = 100 mg/Nm3 (at 3% O ₂ vol. dry basis) Particulate < 50 mg/Nm3 Matter (at 3% O ₂ vol. dry basis) H ₂ O = 19.65 wet vol.% CO ₂ = 8.61 wet vol.% O ₂ = 1.84 wet vol.% N ₂ = 69.9 wet vol.% Nor case: NO _x < 150 mg/Nm3 (at 3% O ₂ vol. dry basis) CO = 100 mg/Nm3 (at 3% O ₂ vol. dry basis) Particulate < 50 mg/Nm3 Matter (at 3% O ₂ vol. dry basis) H ₂ O = 16.6 wet vol.% CO ₂ = 6.9 wet vol.% O ₂ = 5.4 wet vol.% N ₂ = 71.1 wet vol.%	Vented to Atmosphere

Table 4: Summary of emission factors

Stack	No of Stack	Stack height (m)	Exit Temp (oC)	Exit Temp (ok)	Stack Diameter (m)	Maximum Concentration (mg/Nm3)			
						NO _x	SO _x	PM	NH ₃
Ammonia Reformer	1	35	120	413	3.65	150	2.90	50	N/A
Boiler Stack	1	40.6	160	433	2.2	@100% 150	@100% 30	@100% 50	N/A
Urea Granulation 1	1	55	50	323	5.5	N/A	N/A	50	50
Urea Granulator 2	1	55	50	323	2.1	N/A	N/A	50	50

N.A. = Not applicable

In the definition of emission factors, following assumptions have been made:

- All pollutants emissions emitted by the plant's stacks have been cautiously merged using the M parameter.
- In second level simulation, all plants stacks have been considered as a single stack with a total emission given by the emission of a single stack times the number of stacks at site.
- All NO_x emitted by plants have been cautiously considered NO₂;
- All SO_x emitted by plants have been conservatively considered SO₂;

In order to estimate the impact the stationary sources on the air quality of the area, the following characteristic of the emission sources were applied:

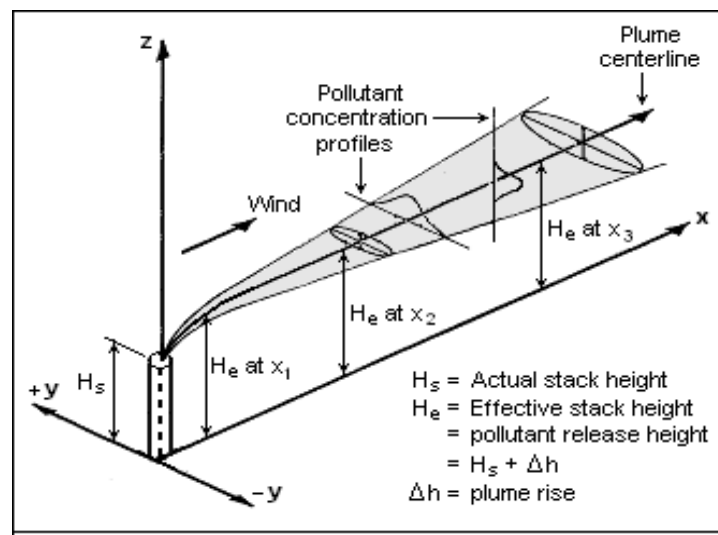
- Pollutants emission rate;
- Stack height;
- Stack gas temperature, stack inside diameter, and stack gas exit velocity (for plume rise computation);
- Location of the point of emission with respect to the surrounding topology characteristics;
- Full meteorology and stability class.

In this modelling the emissions from each source was fully and accurately characterized.

Material balance computation was based on engineering knowledge of the process.

Further Assumptions

- 1 Kmole of any gas occupies 22.4m³ at 101.3kN/m² at 273K
- Density of Air at STP (ρ) = 1.29kg/m³
- Pollutants molecular weight: NO₂ = 46, SO₂ = 64, CO = 28, VOC (as C₂H₆)= 30
- Fuel type: Natural gas liquid (NGL)
- Modelling is based on dry gas, 11 percent O₂



Visualization of a Buoyant Gaussian Air Pollution Dispersion Plume.

Effective Release Height above Ground (H_{s1}).

The effective release height is calculated (Beychok, 2005). This is the plume height (h_e) that will occur during each wind speed and is given as:

$$h_e = h_s + \Delta h$$

$$H_{s1} = H_s + 4.56 \times 10^{-3} \left(\frac{H_r}{4.1868} \right)^{0.478}$$

Where: 4.1868 is a conversion factor (Joules to calories). Plume rise for the combusted gas is calculated in the SCREEN model for this effective release height (EPA, 1995).

Normalized plume rise: Estimate the normalized plume rise ($u\Delta h$) under neutral and unstable atmospheric conditions.

$$F_b = \frac{g}{4} v_s d_s^2 \left[\frac{T_s - T_a}{T_s} \right] = 3.12V \left[\frac{T_s - T_a}{T_s} \right]$$

where:

g = acceleration due to gravity (9.806 m/s²)

v_s = stack gas exit velocity (m/s)*

d_s = stack inside diameter (m)

T_s = stack gas exit temperature (K)*

T_a = ambient air temperature (K) (If no ambient temperature data are available, assume that $T_a = 293K$.)

$V = (\pi/4)d_s^2 v_s$ = actual stack gas volume flow rate (m³/s)

Normalized plume rise ($u\Delta h$) is then given by:

$$u\Delta h = 21.4F_b^{3/4} \text{ when } F_b < 55 \text{ m}^4/\text{s}^3$$

$$u\Delta h = 38.7F_b^{3/5} \text{ when } F_b \geq 55 \text{ m}^4/\text{s}^3$$

Merged parameters for Thermal Desorption Unit stacks

The two thermal desorption units have similar parameters and are located the same area close to each other. Therefore, all the emissions are analyzed as though coming from a single representative stack using the M parameter. The M parameter is hereby applied the TDU and scaled to represent the two stacks as follows:

$$M = \frac{h_s V T_s}{Q}$$

where:

M = merged stack parameter which accounts for the relative influence of stack height, plume rise, and emission rate on concentrations

h_s = stack height (m)

$V = (\pi/4) d_s^2 v_s$ = stack gas volumetric flow rate (m³/s)

d_s = inside stack diameter (m)

v_s = stack gas exit velocity (m/s)

T_s = stack gas exit temperature (K)

Q = pollutant emission rate (g/s)

The stack that has the lowest value of M is used as a "representative" stack. Then the sum of the emissions from all stacks is assumed to be emitted from the representative stack; i.e., the equivalent source is characterized by h_{s_1} , V_1 , T_{s_1} and Q , where subscript 1 indicates the representative stack and $Q = Q_1 + Q_2 + \dots + Q_n$.

Meteorology

The computational procedures given here for estimating the impact of a stationary source on air quality utilize information on the following meteorological parameters:

- Wind speed and direction
- Stability class
- Mixing height
- Temperature

Full Meteorology (All Stability Classes and Wind Speeds)

All the meteorological combinations between stability classes and their associated wind speeds are considered to identify the "worst case" meteorological conditions, that is, the combination of wind speed and stability that results in the maximum ground level concentrations. The wind speed and class combinations used by the SCREEN View model are given below

Stability Classes and Wind Speeds

Pasquill-Gifford Stability Class	10-Meter Wind Speed (m/s)												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	8.0	10.0	15.0	20.0
A	✓	✓	✓	✓	✓								
B	✓	✓	✓	✓	✓	✓	✓	✓	✓				
C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
E	✓	✓	✓	✓	✓	✓	✓	✓	✓				
F	✓	✓	✓	✓	✓	✓	✓						

Pasquill-Gifford Stability Classes

The Pasquill-Gifford stability classes represent six levels of atmospheric stability. Atmospheric stability is important as it influences the rate of dispersion of pollutants. Increased amounts of turbulence will cause pollutants to disperse more rapidly than with more stable atmospheric conditions. The Pasquill-Gifford stability classes range from A to F (1.0 to 6.0) and describe the ambient atmospheric stability as show in Table 5.

Pasquill-Gifford Stability Classes

Class	Value	Description
A	1.0	Very unstable
B	2.0	Unstable
C	3.0	Slightly unstable
D	4.0	Neutral
E	5.0	Slightly stable
F	6.0	Stable

CLIMATE AND METEOROLOGY

Data for this study was acquired via field work measurement (microclimatic data) for a period of 24 hours. Further data have been acquired for the development of the air dispersion study. During the course of fieldwork, a weather station was set up in an open ground, Latitude N04° 48' 57.6" Longitude E007° 05' 52.8" and allowed to run for a minimum of 24 hours in order to establish a microclimatic baseline of the study area. All precautions usually taken when setting up a weather station were observed for the onsite measurements according to the World Meteorological Organization (WMO) standard. These include setting up the weather station away from obstacles like buildings and tall vegetation, using an instrument shelter to display all temperature sensitive gadgets, orienting the instrument shelter so that the sun's radiation does not fall directly on the instrument during reading and setting up the weather station in an area representative of the study area's totality.

SOIL SAMPLING

Systematic sampling design (systematic line transect, reference for the Fertilizer plants site area) was employed to collect soil by establishing plots across the sampled area. Stratified sampling applied was simply the process of identifying portions within the overall area. Transects samples were taken at particular points along lines. Samples were evenly/regularly distributed in a spatial context at every 20 x 20 meters (Quadrant) along transect lines. This method was used since sampling area is made up of sub-sets of known size. These sub-sets make up different proportions of the total, and therefore sampling was stratified to ensure that results are proportional and representative of the whole.

Soil samples were collected at depths of 0-15cm and 15-30cm, representing top and bottom samples, with the aid of the following main equipment: a Dutch Hand Auger, Hand gloves, a spool and hammer. The first 30cm from the ground level is the soil depths at which most (>80%) of the plants feeder roots & soil micro-organisms are concentrated, most affected by erosion and most exposed to spills/pollution.

At each sampling station, three (3) samples were taken for each depth and mixed to give one representative sample. The following sub-samples were taken for each depth, namely:

- Samples for physico-chemical parameters which were put into polythene bags;
- Samples for hydrocarbon analysis which were put into glass bottles and stored in ice – packed coolers;
- Samples for hydrocarbon and microbiological analysis, collected in McCartney bottles and stored in ice-packed coolers.

A soil profiling is carried out to obtain a representative image of the various types of soils and of the soil horizons present on the site using the bucket auger boring method.

Soil samples were taken in two ways, according to the kind of tests to be performed.

They are:

- Disturbed samples which do not represent exactly how the soil was in its natural state before sampling;
- Undisturbed samples which represent exactly how the soil was in its natural state before sampling.

Disturbed samples are used for the more simple tests that will be performed and particularly for those tests which are performed in the field. Undisturbed samples are necessary for the more geotechnical tests which must be performed in the laboratory for more detailed physical and chemical analyses. Undisturbed samples are collected with greater care for the represent exactly the nature of the soil. For a complete study of the soils disturbed and undisturbed samples are needed.

The auger boring method is a way to obtain soil samples from different depths by drilling, without having to dig a pit. This way, a continuous series of soil samples is taken which

makes it possible to assemble a core showing the soil horizons. The auger boring method is fast and provides only disturbed samples. An auger is used in most soils above the water table and in cohesive soils below the water table.

The basic steps to follow when sampling with an auger are:

- Drill the auger into the soil to a depth of 30 cm;
- Pull the auger up carefully to keep the soil in place, just as it was in the ground, and place the soil sample on a sheet of plastic or newspaper;
- Continue drilling 30 cm at a time; place the successive sections one after the other to assemble a core showing the soil horizons;
- Make a drawing of the core; measure and write the depths at which you observe the various horizons;
- If you reach water, drill more carefully but try to continue drilling for another 30 to 40 cm.

A standard bucket auger is a metal cylinder about 30 cm long and 18 cm in diameter. It has a cutting edge on the bottom surface which enables it to cut through most soils easily. Generally, bucket augers are equipped with an extension shaft and handle which allow you to take samples at greater depths, usually down to 2.4 m. A sample taken with a bucket auger is slightly disturbed but it is acceptable for most sampling purposes and it provides a sample large enough for further laboratory analysis.

Soil Sampling Locations and Sample ID

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°07'07.17"	N04°47'46.94"
SS3	SS3 (Flare Area); Top and Bottom	E07°06'19.94"	N04°50'02.66"
SS4	SS4 (Agip Metering); Top and Bottom	E07°06'19.93"	N04°50'35.96"
SS5	SS5 (IRC); Top and Bottom	E07°05'25.98"	N04°50'03.31"
SS6	SS6 (Weigh Bridge); Top and Bottom	E07°05'34.90"	N04°49'53.97"
SS7	SS7 (Akpajo); Top and Bottom	E07°05'15.80"	N04°49'37.92"
SSC1	SSC1 Oyigbo Road; Top and Bottom	E07°07'07.17"	N04°47'46.90"
SSC2	SSC2 Rumukrushi; Top and Bottom	E07°03'38.40"	N04°51'07.68"

VEGETATION STUDIES

Plant Identification is a basic activity and one of the primary objectives of systematics. Although identification is a separate activity or process, in practice it involves both classification and nomenclature.

The methods of plants identification used include (1).visual Observation (2) Polyclaves (3). Taxa, Characters and Data Matrices (4) Comparison (5) Construction of Identification Keys (habit, leaf arrangement, petal, Locule, stamen, Fruit)

The University of Port Harcourt herbarium (Library for the collection of preserved plants stored, catalogued, and arranged systematically for study) was used as a critical resource for biodiversity, ecological and evolutionary research studies.

WILDLIFE

This involved a survey/census of mammals, birds' reptiles and amphibians around the study area. Direct count method, using a pair of binoculars, was employed for the census of reptiles, birds and other animals sighted during the study. The presence of some of the animals were ascertained by probing such humid habitant like logs, heaps of dead decaying leaves, forest undergrowths, ponds and burrows. Thus all sighted, captured or dislodged animals were identified often on the spot to possible taxonomic levels using field guides and keys (Walkey et al 1968; Elgood 1960; Happold 1987; Brach 1988).

The indirect method which makes use of evidence of animal's presence (Dasmann 1963) was used for species which do not offer themselves readily for observation. Interviews with hunters also provided further information on the wildlife diversity abundance and use in the area.

LAND USE AND LAND COVER

The land use pattern of a region is an outcome of natural and socio –economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressures.

The land use types found in the proposed project environments were measured and observed directly from the field (See Appendix 2.1 - thematic land use map).

Land cover is the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. The two primary methods used for capturing information on land cover are field survey and analysis of remotely sensed imagery. At any one point or place, there may be multiple and alternate land uses, the specification of which may have a political dimension

HYDROGEOLOGY & GEOLOGY SURVEYS

Geologic Site Characterization

Conventional boring method, which consists of the use of the light shell and auger hand rig, were used in the boring operation. During the boring operations, disturbed samples were regularly collected at depths of 0.75 m intervals and also when change of soil type is noticed. Undisturbed cohesive soil samples will be retrieved from the boreholes with conventional open-tube sampler 100 mm in diameter and 450 mm in length. The open-tube sampler consists essentially of a lower end and upper end screwed into a drive head which is attached to the rods of the rig. The head has an overdrive space and incorporates a non-return valve to permit the escape of air or water as the samples enters the tube. The sampler is driven into the soil by dynamic means using a drop hammer. On withdrawal of the sampler, the non-return valve assists in retaining the sample in the tube. All samples recovered from the boreholes were examined, identified and roughly classified in the field.

Standard Penetration Tests (SPT) was performed at every 1.5 m advance through cohesion-less soils. The main objective of this test is to assess the relative densities of the cohesion-less soils penetrated. In this test, a 50mm diameter split spoon sampler is driven 450mm into the soil with a 63.5 kg hammer falling freely a distance of 760 mm. The sampler is driven into the soil in two stages. The initial 150 mm penetration of the sampler is the seating drive and the last 300 mm penetration, the test drive.

Cone Penetration Testing (CPT)

Hydraulically operated, GMF type, static penetrometer of 50KN capacity was used in the cone resistance soundings. Mechanical mantle cone with friction jacket was used in the operation. Discontinuous sounding procedure was adopted in the test. The cone in its retracted position is first forced into the ground a distance of 10cm by the application of

force to the outer sounding tubes. The cone is then pushed out a distance of about 4cm by the application of force to the inner rods only and the magnitude of the force required to achieve this, is measured on the pressure gauges and recorded. This is the cone resistance.

Borehole Drilling

Three boreholes were drilled in the area in a triangular array. This is to capture the water flow direction and the heterogeneity of the subsurface across the area.

Design and construction of the monitoring borehole.

The drilling involve the boring of 5" diameter hole from surface to about 14-20m respectively or to the bottom of identified portable water productive aquifer, for screen and casing installation. Verticality of the hole was maintained while drilling cuttings were sampled and collected at every 3.05m interval and at any change in lithology.

Casing/screen installation

Polyvinyl chloride (PVC) 4" 8bar casing pipe and screen slot of 1mm (machine slotted) were used for installation. The screen was coupled to the blinded casing shoe and lowered from the surface downward into the aquifer zone using conventional method. The casing pipe were incorporate to the screen head to form a continuous length of intake structure. The pipe were incorporated using suitable adaptors, jointing kits, centralizers, bottom bunk/casing shoe etc. That were required for proper casing installation.

Well construction (gravel packing / cement grouting)

And artificial filter park (rice gravel) was placed around the length of the well screen annulus. Well-sorted, rounded river washed gravel about 10mm – 15mm was placed from bottom to above the screen zone and sealed off by filter sand and finally by cement grouting.

Water Chemistry

Water samplings were done with relevant water sampler for Physico-chemistry, BOD and micro-biological analyses. All field samples both soil and water were properly labelled and stored in appropriate condition (ice chest for water) before sending to the laboratory for analyses. Laboratory microbial analyses were done using various media and microbiological techniques. GPS was also used to capture the coordinates of the various sampling locations.

ID	Sample description/location	Coordinates	
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"

AQUATIC STUDIES

Sampling Protocol

The hydrology of the project area consists of Okulu stream, which is the only water body close to the project area. To be able to predict the present status of the environment, sampling stations were established in such a manner as to adequately represent the present condition of the various water body sampled. This informs the choice of five (5) surface water distributed thus, three (Upstream, Midstream and Downstream) stations were located on the Okulu Stream (Indorama treated effluent recipient water body), while control station were cited in Agbonchia and Rumukrushu to enable comparison of both water chemistry. The same stations were adopted for the assessment of sediment and hydrobiology in the cause of this study. The table below present sampling locations and coordinate for each station.

Surface Water/Sediment/Hydrobiology

Sample code	Sampling location	Coordinates	
		North	East
SW1	Up Stream	N04°48'43.70"	E07°06'42.60"
SW2	Midstream	N04°48'43.70"	E07°06'42.60"
SW3	Down Stream	N04°48'27.40"	E07°06'04.30"
SWC1	Agbonchia Stream	N04°48'33.80"	E07°07'27.50"
SWC2	Rumukrushu	N04°51'07.60"	E07°03'38.00"

Treated Effluent Stream

Effluent Stream	Sampling location	Coordinates	
		North	East
Eff.	Indorama Sluice Gate	N04°49'25.70"	E07°06'20.50"

Surface water

Physico chemical

A total of five (5) stations were sampled for water. A water sampler was used to collect water samples at designated locations. Standard field methods were used in the sample collection at the site as recommended by FMENV. To ensure the integrity of some unstable physicochemical parameters *in-situ* measurements of temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), turbidity, salinity and total dissolved solids (TDS)

were carried out in the field using water quality checker Horiba U-10. To maintain analytical accuracy duplicate and blank samples were included in the analyses. Distilled water used for analysis conforms to ASTM D 1193 Type 1. Only qualified and trained personnel were employed in the laboratory work.

Samples for BOD measurement were collected in Winkler's bottles, while water samples for heavy metals analyses were collected in glass containers and acidified with concentrated nitric acid to avoid precipitation.

Sample Preservation and Storage

The water samples collected were stored in ice-packed coolers and preserved in accordance with Federal Ministry of Environment Guidelines and Standards. All water samples for heavy metals were preserved by the addition of concentrated HNO_3 , while concentrated HCl was added to the samples for the analyses of total hydrocarbon.

Microbiology

Methods of Sample Collection

(a) Water samples were collected in accordance with the procedures described in standard methods for water and wastewater analysis (APHA, 2005 21st Edition). The same is accepted and adopted by FMENV as standards for Nigeria. According to the procedure, 200 ml of sterilized sample bottle was used for collecting water sample under the watch of FMENV supervisor.

(b) The samples were preserved in an ice-cooled container and transported to the laboratory for analysis.

Quality Control Measures

- i) Clean sterile containers were used for sample collection to avoid external contamination of the sample.
- ii) Sample was transported in an ice packed cooler to the laboratory and analysed within 2 hours of collection or stored in refrigerator for analysis at other days.
- iii) Procedures for sample collection were done aseptically and in accordance with standard procedures.
- iv) Only adequately trained personnel were used for the sampling.
- v) The personnel to be involved in the project were briefed on the scope of work.

- vii) Equipment used for *in situ* measurements were adequately calibrated prior to use and checked by the supervising officer.
- viii) Blank samples were taken to determine the measure of contamination introduced from sampling procedure.
- ix) Sampling equipment was washed with sterilized water after use to prevent cross contamination.
- x) Pre-rinsing and overfilling of sample containers are avoided to prevent loss of preservative, dilution of preservative and loss of air space.

Methods of Sample Analysis

(a) Enumeration of Bacteria

Serial dilution procedure as described by Obire and Wemedo (1996); Ofunne (1999) was employed for cultivation and enumeration of bacteria and fungi in the water samples. The ten-fold serial dilution was used to obtain appropriate dilutions of the samples. Aliquots of the required dilutions were plated in duplicates onto the surface of dried sterile nutrient agar (for total heterotrophic bacteria). In case of total/Faecal coliform bacteria, the most probable number (MPN) technique described by Collins and Lyne, (1980) was employed for estimation of their numbers in water. Appropriate volumes of undiluted water samples were inoculated into test tubes of MacConkey broth medium. All inoculated media were incubated at 37°C for 24 hours or 3-7 days except for fecal coli form bacterial set up incubated at 44.5°C.

(b) Enumeration of microorganisms

- (i) Nutrient agar medium used for enumeration of total heterotrophic bacteria prepared according to manufacturer's specifications.
- (ii) MacConkey broth medium for estimation of total/faecal coli form bacteria in water.

(c) Quality Control Measures

- (i) Samples were analyzed in FMEnv accredited standard microbiological laboratory in accordance with standard procedures.
- (ii) Procedures for cultivation and enumeration of bacteria were carried out aseptically to avoid contamination from external sources.
- (iii) All media and glass wares used were sterilized in an autoclave at 121°C for 15 minutes.

Sediment

Sediment Samples were collected at the water sampling points using an Eckman grab sampler. Sediment samples for physiochemical analysis were collected in polythene bags, while those for microbiology analysis were collected in Aluminium foil.

Similarly all the sediment samples were temporarily stored in ice packed coolers prior to transfer to the laboratory.

Hydrobiology

Plankton & Zooplankton

Phytoplankton and Zooplankton composite samples were collected quantitatively by filtering 100litres of water through 55µm Hydrobios plankton net. All samples (concentrated to 100ml) collected for phytoplankton analysis were preserved in Lugol's iodine, while samples collected for Zooplankton analysis were preserved in 4% buffered formaldehyde in 250ml polyethylene bottles. In the laboratory, the phytoplankton and zooplankton were identified and counted using a Wild-Lietz Stereo Zoom dissecting microscope and a Nikon Compound Research microscope. Representative species of zooplankton were mounted in polyvinyl lactophenol tinted with lignin pink after dissecting the relevant taxonomic parts. Individuals of each identified taxon in each sample were enumerated using a Petri dish and Sedgwick – Rafter counting cell. Density computations were expressed in numbers of cells per 1000l based on number of each species observed per 100 liters of samples filtered. Enumeration of numbers of cells per 1000l was computed using the following formula:

$$\text{Number of cells/ 1000l} = \frac{[\text{N} \times 1000]}{\text{Initial volume of water filtered}}$$

Where N = Cells counted per sample i.e.

$$\frac{\text{Counts x fraction}}{\text{No of fields counted}} \times \frac{1}{\text{Vol of chamber x 100}} \times \frac{100}{1}$$

Where subsamples from the original 100ml concentrated samples were used, N was first computed from the original sample before estimating the density. Identifications were made to the lowest possible taxonomic level using relevant identification keys (Nwankwo, 2004, Witkowski *et al.*, (2000), Rosowski, (2003), Siver, (2003), and Iain and David (2009).

Benthic Fauna

Quantitative samples for benthic fauna were collected at each station using the Ekman Grab (0.0225m²) and sieved in the field using 250 and 500µm Tyler sieves. All samples were preserved in wide mouthed plastic containers by adding some quantities of 40% formaldehyde and stained with Rose Bengal solution (0.1 sensitivity) (Zabbey, 2002; Idowu and Ugwumba, 2005).

Laboratory analysis was carried out by using the binocular dissecting microscope and Nikon compound microscope for sorting, dissection of relevant taxonomic parts, and preparation of slides. Specimens were identified to the lowest possible taxonomic level using reliable identification keys and texts (Pennak, 1978; Barnes, 1980). Faunal densities were computed in numbers per m².

In addition to determining the relative abundance by direct count of the individuals' encountered, basic statistical measurement of diversity indices were used to describe the plankton community structure. PAST (Paleontological Statistics) software package for data analysis was used to compute the diversity (Hammer *et al.* 2001). Four diversity indices namely, Shannon-Wiener (H'), Dominance index (D) Evenness (E) or Equitability (J) and Margalef (d) each representing a different aspect of the faunal diversity were used (Green, 1971; Shannon and Weaver, 1963; Robinson and Robinson 1971, Ogbeibu 2014).

Socio-Economic

Approach

It is assumed that the socio-economic context to be considered for this study is constituted by the communities closest to the proposed Fertilizer Plant, which are likely to be the most affected by the project from a socio-economic point of view. The proposed project is arousing a lot of interest and expectations are high, albeit with uncertainties also over its social and environmental consequences. There are a number of instruments that can be used to collect data in this circumstance; for this survey, the questionnaire and focused group interviews were the primary means of data collection.

In social research, both the objective and subjective data are required to adequately assess respondents and their situation. In this survey, the objective data include age, function in the community, and expected impacts. The subjective data include specific questions

through which the respondents were able to express their opinions and preferences as regards themselves and their environment.

Design of the Survey

This is a one-shot cross sectional study of the affected settlements. The impact assessment will put in perspective a project whose effects on the social well-being of settlements should be evaluated. This survey is predicated on household behavior pattern and characteristics. A household is a group of people who live in one house, use the same kitchen (i.e., eat from the same table). They contribute their resources and share the burden of group members together. Usually, there is a head who is often a man. A minority of cases may exist where a woman, presides over the household because she is a widow or was never married. The household was the basic unit of inquiry in this study.

The questionnaire was structured into several sub-sections to address issues like, demography, economic activities, social environment, perception of project operations, living conditions and quality of life, utilities and infrastructure, community relations, security, conflict and conflict resolution. The questions were both structured and unstructured. The unstructured ones were more, because of the preponderance of qualitative variables in the survey – the approach being to maximize an understanding of the respondents' state of mind on the issues of concern. The questionnaire is reproduced as enclosed appendix of this report.

Data Management and Analysis

Pertinent activities were divided into three phases: database design and implementation phase, statistical analysis phase, and qualitative/descriptive data analysis phase. The data analysis' strategy was to capture both qualitative and quantitative information and present them in an electronically managed form. The software used is the Statistical Package for Social Sciences (SPSS) version 17.0. The SPSS is a versatile statistical package with the capability of analysing numerical data tied to variable names.

The outputs are in the form of frequencies, percentages, graphs, descriptive and advanced statistics, if required. The analysis using SPSS was carried out at two levels: the individual community member and his household, and the study community as a whole. In this

analysis, simple frequency tables and percentages were developed. To have achieved this, almost all the information had to be coded into numerical terms. Qualitative responses were tackled by looking at the broad classes of response and numerals awarded. The code book was a modification of the original questionnaire with numerical values.

Health-Impact

An integrated descriptive, cross-sectional study design was adopted for the community health survey. It involved community-based households and facility-based surveys. Quantitative data was complemented by qualitative information by way of key informant interviews of opinion leaders of the community to understand other socio-cultural and economic characteristics of the people that influenced their health statutes. Specifically, in depth interviews of the nurses in private and government medical centers were conducted. The Health Impact Assessment of the project area was conducted in and around the facilities, the communities to determine the baseline characteristics of the health status of the project area against which future impacts of the project can be compared. Secondly to determine the probable/potential impacts of the project on the health of the workers within the IEPL facility and of the people around the communities (Agbonchia, Aleto, Akpajo, and Elemenwo) so as to determine the type of intervention/s needed to ameliorate these negative potential impacts.

These communities were sampled by the health personnel to obtain information regarding mortality and morbidity rates, demographic or population

Structures, types of health outcome hazards, most prevalent diseases, less prevalent diseases, disease vectors, nutrition, health facility infrastructure capability and usage, service delivery, average family size, sexual reproductive health, immunization status and coverage, sewage and waste management system, air quality, water quality, radiation sources and levels were considered.

Data collection

From each of the communities, a total of Four Hundred respondents were randomly selected using village listing as the main frame.

A total of 81 respondents were used in the study.

- The study instruments consisted of Structured Questionnaires;

- Physical and clinical examinations and observation carried out to the extent of the suitability of the environment and availability of the facilities. Invasive techniques were not used;
- Informal discussions with the respondents;
- Group focus discussion (GFD) sessions;
- Key informant interview;
- Health facility survey.

Secondary data was generated from Health Centers, Hospitals records. Information was also sought from traditional Birth attendants and numerous chemist/patent medicine shops. Traditional medicine practitioners and spiritual healing homes/churches which played significant roles because they complemented orthodox health care delivery services in all the communities. The data were generated by medical personnel who administered the questionnaire, conducted the group focus discussion session (GFD) and key informant discussion sessions. The respondents were mainly adults and opinion moulders who are resident in the communities. There were a preponderance of male respondents (about 75-80%) than females. About 60% had formal education.