# DISPERSION MODELLING OF AIR EMISSION FROM A RICE MILLING PLANT

**Akeredolu, F. A.[1], Sonibare, J. A.[1], *Fakinle, B. S.[2] and Jimoda, L. A.[3]**

[1]Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

[2]Department of Chemical Engineering, Landmark University, Omu-Aran, Kwara State, Nigeria.

[3]Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Corresponding Author: Bamidele Sunday Fakinle, Email: xdales@yahoo.com, fakinle.bamidele@lmu.edu.ng.

**ABSTRACT**

*The study investigated the air quality impacts of Rice Mill using the ISC-AERMOD View. Contributions of steam boiler and electric power generators in the mill to ground level concentrations of criteria air emissions were established.The maximum ground level concentrations of air pollutants presently emitted by the steam boiler are 1-hour averaging period concentrations of 1.4 – 177.3 µg/m$^3$ with 24-hour level of 0.3 – 43.5 µg/m$^3$. Simultaneous operations of the steam boiler and electric power generators give 1-hour averaging period concentrations of 29.7 – 257.8 µg/m$^3$ with 24-hour levels of 8.8 – 95.8 µg/m$^3$ . The simultaneous operations of the steam boiler and the electric power generators add about 0.41 – 84.78% of the respective investigated air pollutants limits to the ambient air quality of the host environment. Occasionally the daily $NO_X$ limits from this* ***scenario 2*** *could breach the ambient limit whenever all the three electric power generators are simultaneously operated with the steam boiler.*

*Keywords: rice mill, criteria pollutants, dispersion modelling, air quality, rice husk.*

## 1.0 INTRODUCTION

Rice is a very important staple food in Nigeria and the world at large. It is one of the major sources of Carbohydrate which is an essential element for energy, Human development and body growth (Adegun, 2012). In agricultural history, the domestication and cultivation of rice is one of the most important event. According to Okeke (2017) the raw material needed for commercial production of rice is the rice seeds or seedling.

Rice grain consist of husk and brown rice. The brown rice contains bran which comprises the outer layer and the edible portion. The rice mill operation is the removal of husk (dehusking) and bran to obtain the edible portion for consumption. The milling is wherein the rice grain is transformed into the form that is suitable for consumption. The extent of rice recovery during milling depends on many factors like variety of rice, degree of milling required, quality of equipment used and the operators (Poonam, 2014).

Due to increase population growth rate as well as consumers' demand of rice in Nigeria, the country has become the highest rice producing country in West Africa and the third largest in Africa. (WARDA, 1996). During rice processing, several streams of materials are generated which include the husks, the bran and the milled rice kernel. The rice kernel is further processed for consumption while the bran and the husk biomass waste generated are of environmental concern.

The availability of energy for rice processing is of outermost concern. One of the major sources of energy in Nigeria is the fossil fuel which it utilization has caused serious environmental impact such as global warming by greenhouse gases and acidification by SOx and NOx. In this study the environmental impact assessment of a rice milling facility located in Nigeria was carried out. This was with the view of determining the impact of the rice milling company activities on the ambient environment base on the source of energy used for its operation.

## 2.0 METHODOLOGY

### 2.1 Study Area Description

This Study is conducted in an Agro-allied Industries Limited which is an agricultural products processing company. The company currently owns and operates a 50 MT per day Rice processing Mill producing parboiled head rice and delivers to the final customer through its distributors. It is located in Kwara State, a location of about 7 km from Ajese-ipo and 4 km from Offa (Figure 1). The site accommodates the Factory, the administrative building and a warehouse which occupy about ten (10) hectares of the total land size (100 hectares). The Rice Mill has 2 x 1500 tonnes bulk storage silos with tempering bins. There is a Mechanical reception hopper that allows fast sack tipping before movement to the Cleaning and destoning section in the Mill. Four soaking/steaming tanks are present with continuous flow drier and holding bin to rice mill and tempering bins. Inside the Double Flow, the parboiled paddy is dried carefully and efficiently with low, un-compacted, bed. There is also a low volume air that slowly cools the paddy in resting bins after which there follows distribution of paddy, water and steam to the tanks. In the multistage rice mill are husking, paddy separation, whitening, polishing, sifting, optical sorting and sacking. Also located in the mill is an air conditioned room on platform for optical sorter with overhead bins and sacking station. The husk fired steam boiler that assists in steam generation. It operates in the factory with husk store, ash settling chamber in brickwork and fan equipped with cyclone and chimney. The Rice Mill operates 2 - 3 shifts per day.


**Figure 1: The Rice Mill Facility Site and Area of Influence**

## 2.2 Emission Inventory

A very important step in air emission dispersion modelling is the air emission inventory. This is to identify sources of air emissions in a facility on which dispersion modelling is carried out. It was carried out in this study and with it sources of air emissions in the Rice Mill were identified. The identified major point sources of air emissions in the Rice Mill include the steam boiler where rice husk is used to generate steam for parboiling and utilities that consist of the three diesel-powered electric power generators where electricity is generated to meet its power requirements.

Criteria air pollutants of interest in this study are: carbon monoxide (CO), oxides of nitrogen ($NO_X$), suspended particulate matter (SPM), and sulphur dioxide ($SO_2$). Emission rates and stack parameters used as model input were obtained from project details. The emissions sources obtained in the study are as summarized in Table 1.

**Table 1: Air Emission Source Characteristics of the Rice Mill Project**

| Air Emission Source | Coordinates | | Exit Temp (°C) | Air Pollutant | Emission (g/s) | Release Height (m) | Stack Diameter (m) | Exit Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|
| | Latitude (North) | Longitude (East) | | | | | | |
| Husk fired steam boiler cyclone stack | 08° 12.404'N | 004° 46.432'E | 750 | PM* | 0.5000 | 11.6 | 0.36 | 15 |
| | | | | $NO_X$* | 0.0352 | | | |
| | | | | $SO_2$* | 0.0204 | | | |
| | | | | CO* | 2.6000 | | | |
| 500 kva Generator (1) | 08° 12.410'N | 004° 46.408'E | 110 | PM | 0.0010 | 3.0 | 0.3 | 8.94 |
| | | | | $NO_X$ | 0.1182 | | | |
| | | | | $SO_2$ | 0.0136 | | | |
| | | | | CO | 0.0086 | | | |
| 500 kva Generator (2) | 08° 12.412'N | 004° 46.410'E | 110 | PM | 0.0010 | 3.0 | 0.3 | 8.94 |
| | | | | $NO_X$ | 0.1182 | | | |
| | | | | $SO_2$ | 0.0136 | | | |
| | | | | CO | 0.0086 | | | |
| 200 kva Generator | 08° 12.414'N | 004° 46.412'E | 100 | PM | 0.0004 | 2.5 | 0.2 | 6.40 |
| | | | | $NO_X$ | 0.0473 | | | |
| | | | | $SO_2$ | 0.0054 | | | |
| | | | | CO | 0.0034 | | | |

***Calculated from rice husk emission factors reported by Irfan et al., (2014) for gases and Mantananont and Patumsawad (2016) for particulates**

### 2.3 Emission Modelling

The ISC-AERMOD View was used investigate the air emission dispersion modelling. It is a user-friendly interface for four U.S. EPA air dispersion models: ISCST3, ISC-PRIME, AERMOD and MET developed for Microsoft Windows which uses pathways consisting runstream file as basis for functional organization. Its version 8.2.0, serial number AER00005543, licensed to the Environmental Engineering Research Laboratory, Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria was used.

The identified point emission sources with all the parameters listed in Table 1 were considered as input parameters into the modelling while Table 2 was used to investigate their impacts on the ambient air quality.

From the identified sources of air emission in the Rice Mill project, two air emissions scenarios were considered to establish potential ground level concentrations of air pollutants within the site and surroundings. The operating scenarios investigated were Scenario 1 where process air emissions from the Rice Mill were considered where operation was assumed to be full with rice husk fired steam boiler in the Mill and Scenario 2 which assumed full operation of the rice-husk-fired steam boiler simultaneously in operation with the three diesel-fired electric power generators.

**Table 2: Standards of Ambient Air Quality**

| Air Pollutants | Averaging Period | Maximum Concentration ($\mu g/m^3$) | |
|---|---|---|---|
| | | FMENV[a] | World Bank[b] |
| CO | 1 – Hr | - | 30,000 |
| | 8 – Hr | 22,800 | 10,000 |
| | 24 – Hr | 11,400 | - |
| $NO_X$ | 1-Hr | - | 200 |
| | 24 – Hr | 75 – 113 | - |
| | Annual | - | 40 |
| PM | 1-Hr | 600 | |
| | 24-Hr | 250 | |
| $SO_2$ | 1-Hr | 260 | |
| | 24-Hr | 26 | |

*[a]Source: FEPA (1991); [b]Source: World Bank (2007*

### 2.4 Meteorological Parameters

Meteorological information is essential in ISCST air dispersion modelling. Both the surface and upper air observations were compiled using meteorological data from the Lakes Environmental meteorological observations on the study area (Met Data Order # MET 134283). It has winds having prevalence for a south-westerly direction (Figure 2).

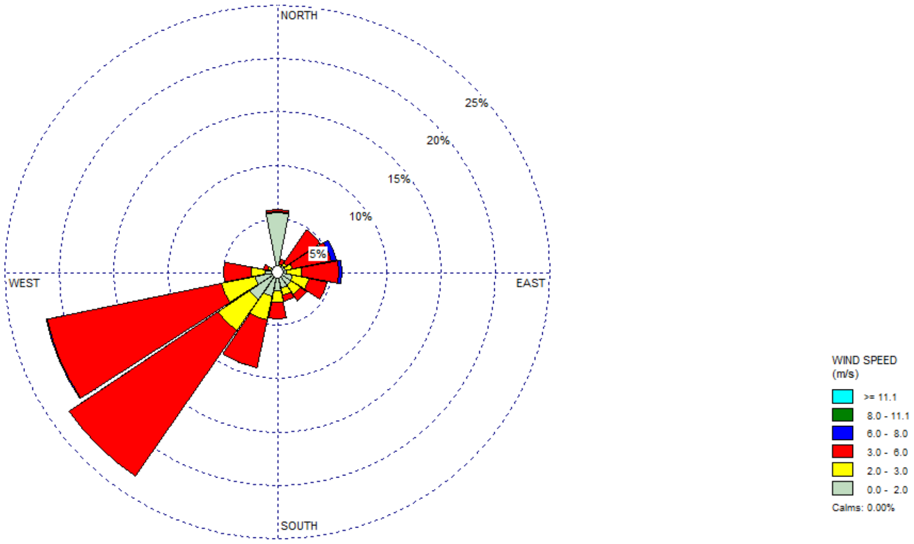


**Figure 2: Generated Windrose from the Wind Data used for the Study**

## 3.0 RESULTS AND DISCUSSION

### 3.1 Ground Level Concentrations of Criteria Pollutants

Presented in Figure 3 the present 1-hour averaging period CO concentrations from the Rice Mill Steam Boiler as investigated in ***scenario 1*** are 41.5 – 177.3 $\mu g/m^3$ while its 8-hour and 24-hour averaging period concentrations are 7.0 – 97.5 $\mu g/m^3$ (Figure 4) and 2.5 – 43.5 $\mu g/m^3$ (Figure 5). Its 1-hour ground level $NO_X$ are 0.56 – 2.40 2.5 – 43.5 $\mu g/m^3$ (Figure 6) with 24-hour and annual averaging period concentrations of 0.03 – 0.59 2.5 – 43.5 $\mu g/m^3$ (Figure 7) and 0.0019 – 0.1814 2.5 – 43.5 $\mu g/m^3$ (Figure 8) respectively. While its 1-hour SPM are 7.99 – 34.09 $\mu g/m^3$ (Figure 9) the 24-hour levels are 0.47 – 8.37 $\mu g/m^3$ (Figure 10). This ***scenario 1*** emits 1-hour $SO_2$ concentrations of 0.33 – 1.39 $\mu g/m^3$ (Figure 11) with 24-hour levels of 0.02 – 0.34 $\mu g/m^3$ (Figure 12).

From the simultaneous operations of both the steam boiler and the diesel electric power generators in the Rice Mill as investigated in ***scenario 2***, the 1-hour averaging period ground level CO are 43.5 – 185.1 µg/m$^3$ (Figure 13) with 8-hour and 24-hour levels of 7.1 – 99.3 µg/m$^3$ (Figure 14) and 2.5 – 46.8 µg/m$^3$ (Figure 15) respectively. Their 1-hour, 24-hour and annual $NO_X$ averaging period concentrations are respectively 34.0 – 257.8 µg/m$^3$ (Figure 16), 2.0 – 95.8 µg/m$^3$ (Figure 17) and 0.2 – 21.0 µg/m$^3$ (Figure 18). Their 1-hour SPM are 8.2 – 35.0 µg/m$^3$ (Figure 19) with 24-hour levels are 0.48 – 8.75 µg/m$^3$ (Figure 20). Both their 1-hour and 24-hour $SO_2$ averaging period concentrations are respectively 3.95 – 29.67 µg/m$^3$ (Figure 21) and 0.2 – 11.0 µg/m$^3$ (Figure 22).

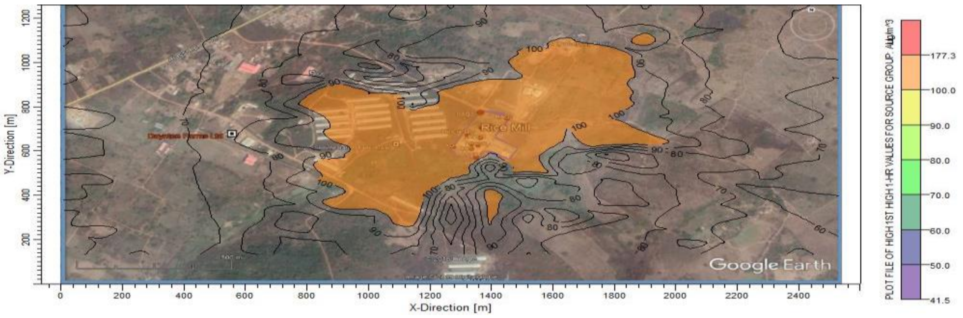


**Figure 3: Isopleth of 1-Hour Ground Level CO from the Rice Mill Boiler (Scenario 1)**

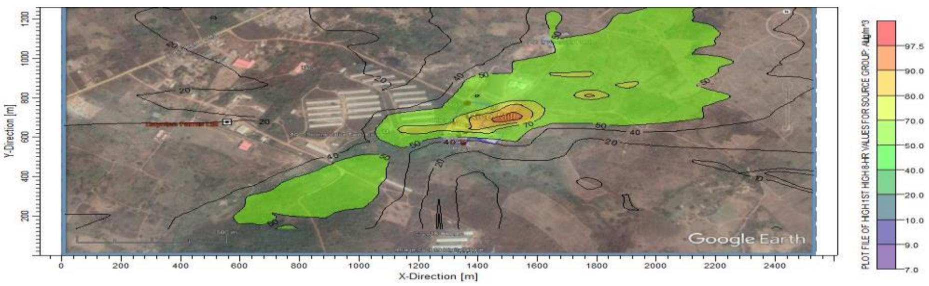


**Figure 4: Isopleth of 8-Hour Ground Level CO from the Rice Mill Boiler (Scenario 1)**

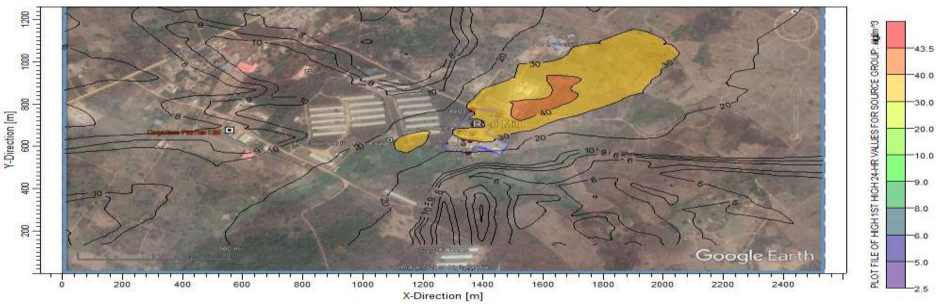


**Figure 5: Isopleth of 24-Hour Ground Level CO from the Rice Mill Boiler (Scenario 1)**

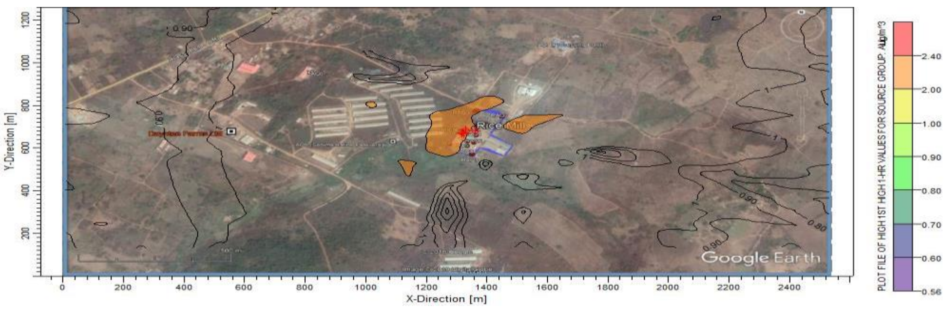


**Figure 6: Isopleth of 1-Hour Ground Level $NO_X$ from the Rice Mill Boiler (Scenario 1)**

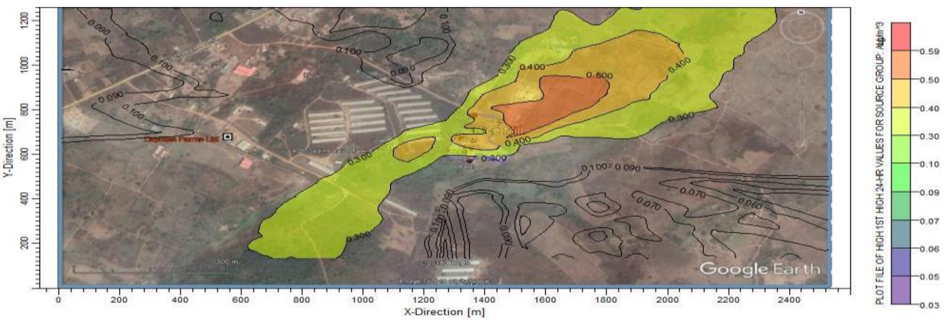


**Figure 7: Isopleth of 24-Hour Ground Level $NO_X$ from the Rice Mill Boiler (Scenario 1)**

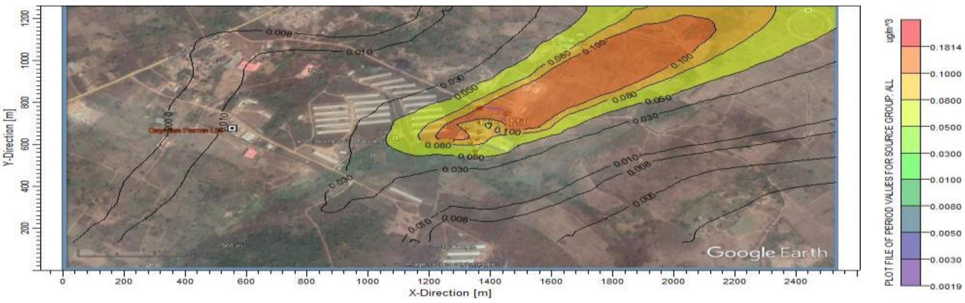


**Figure 8: Isopleth of Annual Ground Level $NO_X$ from the Rice Mill Boiler (Scenario 1)**

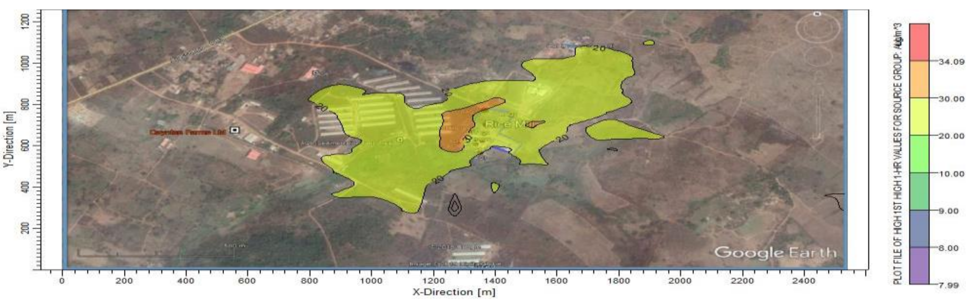


**Figure 9: Isopleth of 1-Hour Ground Level SPM from the Rice Mill Boiler (Scenario 1)**

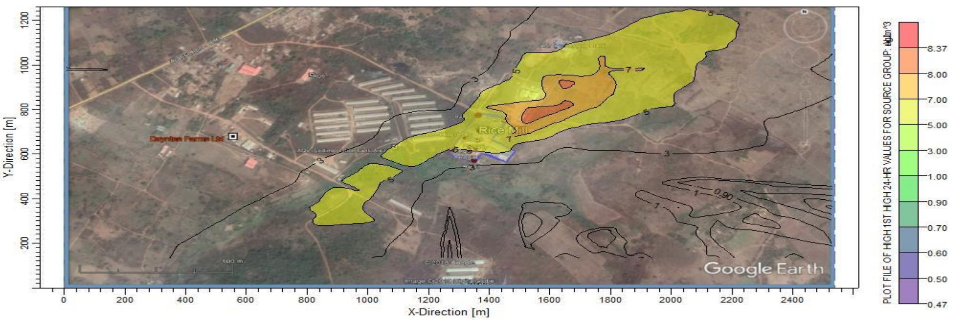


**Figure 10: Isopleth of 24-Hour Ground Level SPM from the Rice Mill Boiler (Scenario 1)**

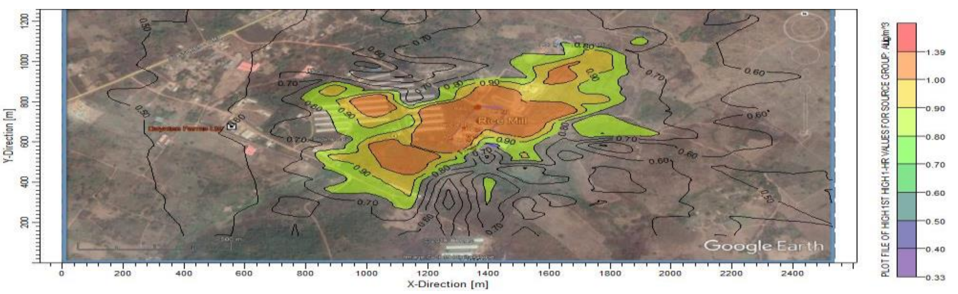

**Figure 11: Isopleth of 1-Hour Ground Level $SO_2$ from the Rice Mill Boiler (Scenario 1)**

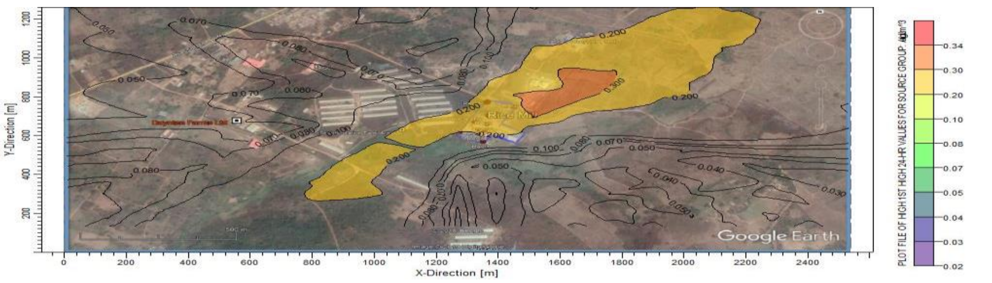


**Figure 12: Isopleth of 24-Hour Ground Level $SO_2$ from the Rice Mill Boiler (Scenario 1)**

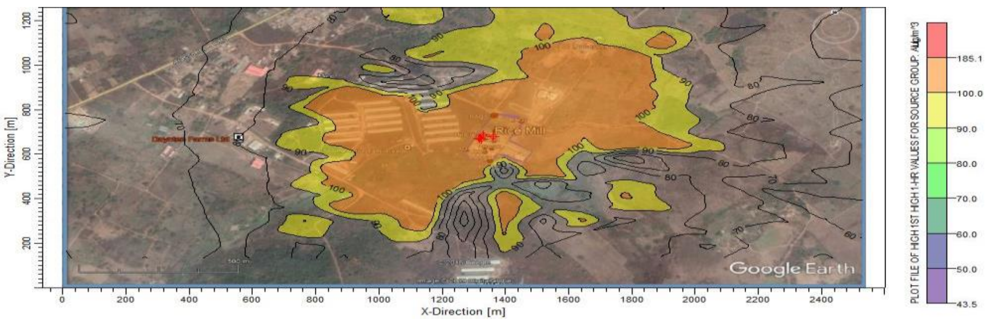


**Figure 13: Isopleth of 1-Hour Ground Level CO from the Boiler and Power Generator (Scenario 2)**

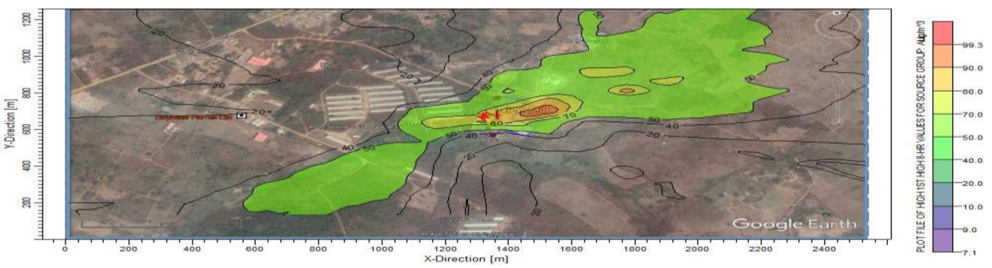


**Figure 14: Isopleth of 8-Hour Ground Level CO from the Boiler and Power Generator (Scenario 2)**

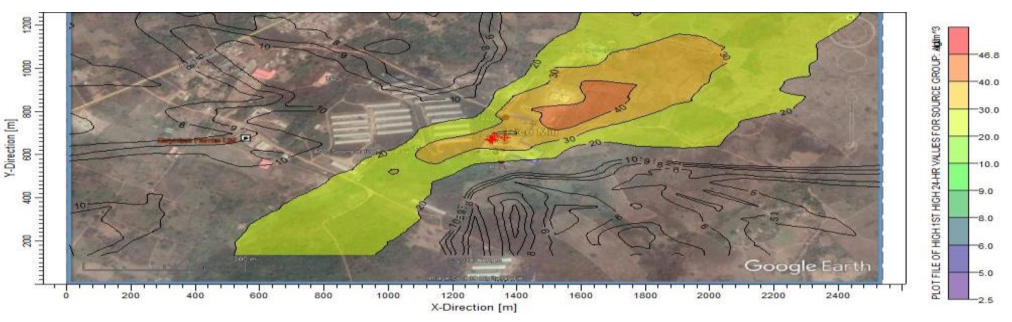


**Figure 15: Isopleth of 24-Hour Ground Level CO from the Boiler and Power Generator (Scenario 2)**

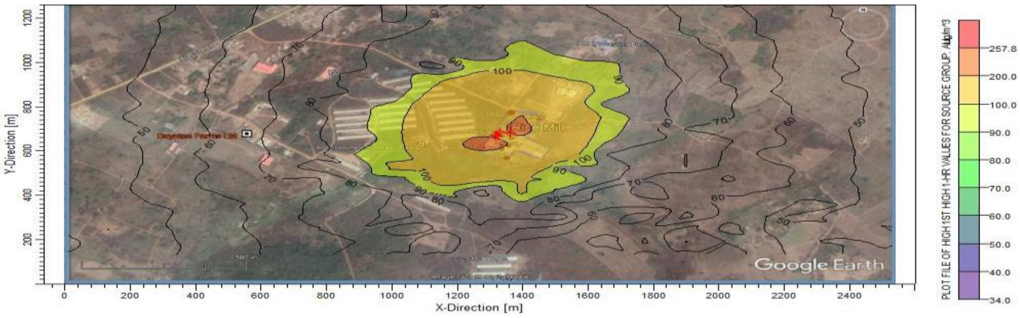


**Figure 16: Isopleth of 1-Hour Ground Level $NO_X$ from the Boiler and Power Generator (Scenario 2)**

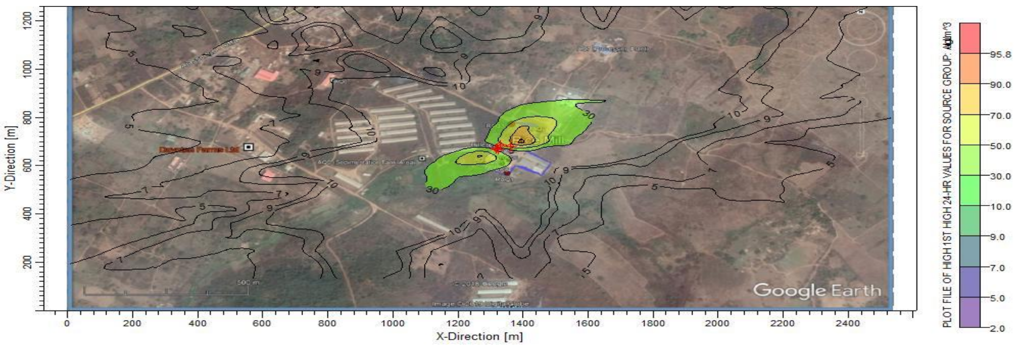


**Figure 17: Isopleth of 24-Hour Ground Level $NO_X$ from the Boiler and Power Generator (Scenario 2)**

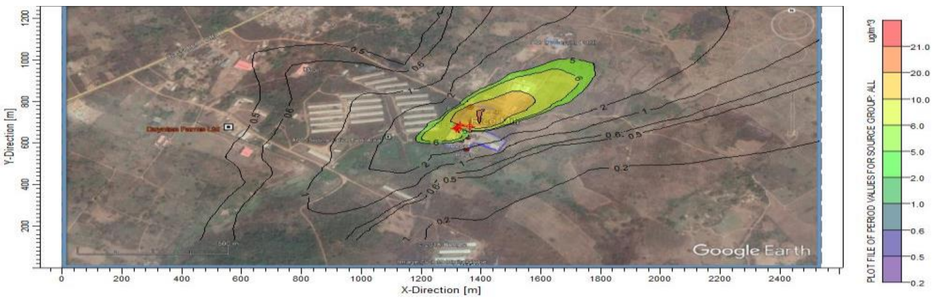


**Figure 18: Isopleth of Annual Ground Level $NO_X$ from the Boiler and Power Generator (Scenario 2)**

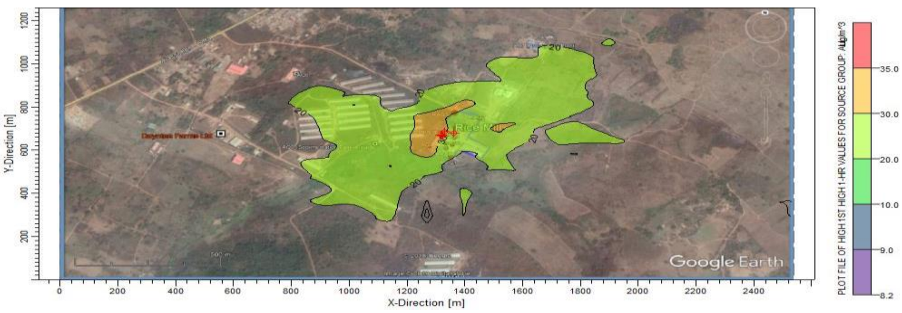


**Figure 19: Isopleth of 1-Hour Ground Level SPM from the Boiler and Power Generator (Scenario 2)**

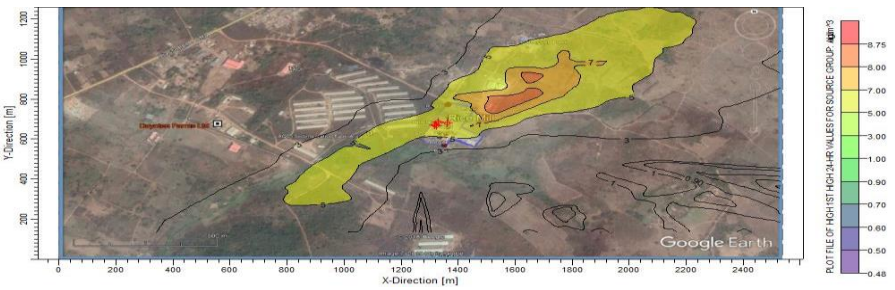


**Figure 20: Isopleth of 24-Hour Ground Level SPM from the Boiler and Power Generator (Scenario 2)**

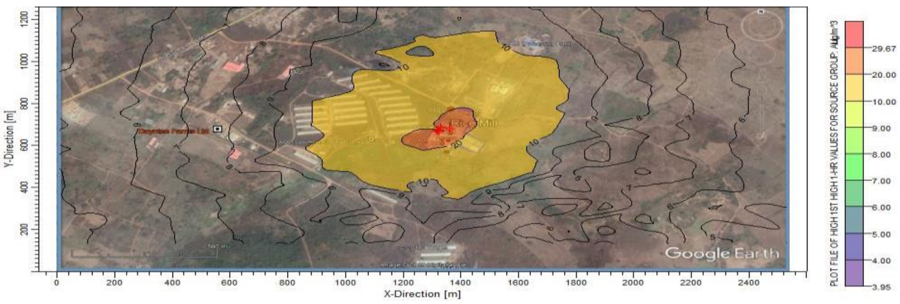


**Figure 21: Isopleth of 1-Hour Ground Level $SO_2$ from the Boiler and Power Generator (Scenario 2)**

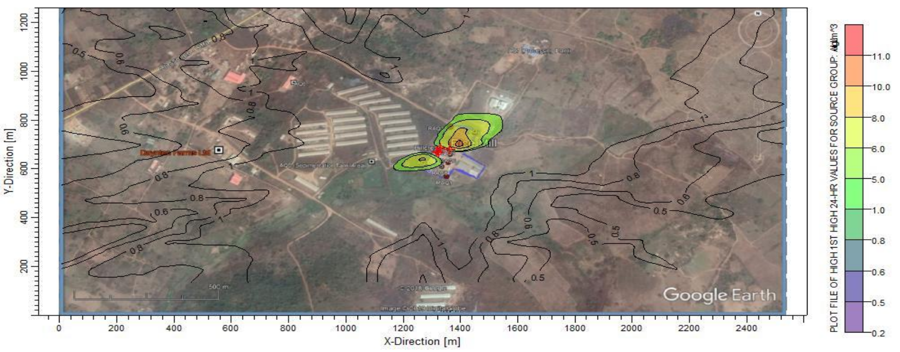


**Figure 22: Isopleth of 24-Hour Ground Level $SO_2$ from the Boiler and Power Generator (Scenario 2)**

## 3.2 Maximum Ground Level Concentrations Impact on Ambient Air Quality

Summarized in Table 3 are the maximum ground level concentrations of air pollutants presently emitted by the Rice Mill. From the steam boiler as investigated in scenario 1, the maximum 1-hour averaging period concentrations are 1.4 – 177.3 µg/m$^3$ with 24-hour averaging period maximum ground level concentrations of 0.3 – 43.5 µg/m$^3$ which are respectively 0.54 – 5.68% and 0.38 – 3.36% of their respective limits. While the minimum of these is from $SO_2$ the maximum is from CO. These maximum concentrations are around the boiler with the minimum in the northeast end of the Mill. The 1-hour averaging period cumulative maximum ground level concentrations of air pollutants from simultaneous operations of the steam boiler and the three diesel electric power generators as investigated in scenario 2 are 29.7 – 257.8 µg/m$^3$ with 24-hour levels of 8.8 – 95.8 µg/m$^3$ which are 0.62 – 11.42% and 0.41 – 84.78% of their respective limits. All these maximum concentrations of ground level air pollutants from the Rice Mill are within the set limit except in scenario 2 where the simultaneous operations of both the steam boiler and the diesel generator emits the 1-hour ground level $NO_X$ concentrations of about 128% of the limit.

## 3.3 Impacts of the Rice Mill Project on the Host Airshed

As obtained from scenario 1, steam boiler of the Rice Mill presently adds about 0.38 – 5.68% of the respective investigated air pollutants limits to its host environment. Similarly simultaneous operations of the steam boiler and the electric power generators of the Rice Mill add about 0.41 – 84.78% of the respective investigated air pollutants limits to the ambient air quality of the host environment. Occasionally the daily $NO_X$ limits from this ***scenario 2*** could breach the ambient limit.

**Table 3: Maximum Ground Level Concentrations of Air Pollutants from the Rice Mill**

| Air Pollutant | Averaging Period | Concentration | | Designation/Nearest Community |
|---|---|---|---|---|
| | | Predicted (μg/m$^3$) | % of Standard | |
| **Scenario 1 (Rice Mill Boiler)** | | | | |
| CO | 1 – Hour | 177.3 | 0.59 | Within the Rice Mill |
| | 8 – Hour | 97.5 | 0.98 | East End of the Rice Mill |
| | 24 – Hour | 43.5 | 0.38 | Around the Boiler |
| $NO_X$ | 1 – Hour | 2.4 | 1.20 | Around the Boiler |
| | 24 – Hour | 0.59 | 0.52 | East End of the Rice Mill |
| | Annual | 0.18 | 0.45 | Southwest End of the Mill |
| PM | 1 – Hour | 34.1 | 5.68 | Southwest End of the Mill |
| | 24-Hour | 8.4 | 3.36 | Northeast End of the Mill |
| $SO_2$ | 1 – Hour | 1.4 | 0.54 | Around the Boiler |
| | 24-Hour | 0.3 | 1.15 | Northeast End of the Mill |
| **Scenario 2 (Rice Mill Boiler and Diesel Generators)** | | | | |
| Air Pollutant | Averaging Period | Concentration | | Designation/Nearest Community |
| | | Predicted (μg/m$^3$) | % of Standard | |
| CO | 1 – Hour | 185.1 | 0.62 | Generator House |
| | 8 – Hour | 99.3 | 0.99 | Northeast End of Rice Mill |
| | 24 – Hour | 46.8 | 0.41 | Northeast End of Rice Mill |
| $NO_X$ | 1 – Hour | 257.8 | 128.90 | Generator House |
| | 24 – Hour | 95.8 | 84.78 | Northeast End of Rice Mill |
| | Annual | 21.0 | 52.50 | Generator House |
| PM | 1 – Hour | 35.0 | 5.83 | Generator House |
| | 24-Hour | 8.8 | 3.52 | Northeast End of Rice Mill |
| $SO_2$ | 1 – Hour | 29.7 | 11.42 | Generator House |
| | 24-Hour | 11.0 | 42.31 | Northeast End of Rice Mill |

## CONCLUSIONS

The ISC-AERMOD View version 8.2.0 has been used in this study to determine the actual contribution of steam boilers and electric power generators in a Rice Mill to air pollutants of its host environment. Ground level concentrations of Carbon Monoxide (CO), Oxides of Nitrogen ($NO_X$), Particulate Matter (PM) and Sulphur Dioxide ($SO_2$) associated with the project were estimated. All the anticipated maximum ground level concentrations of air pollutant associated with the Rice Mill are within their respective limits except $NO_X$ that could occasionally breach its limit. Continuous adherence of the Mill to its present attitude of keeping one of the electric power generators on standby will assist to keep the daily $NO_X$ within its set standard.

## REFERENCES

Adegun, I. K., Adepoju, S. A. and Aweda, J. A. (2012) A Mini Rice Processing Machine for Nigeria Farmer. Journal of Agricultural Technology 8(4): 1207 – 1216

FEPA. (1991). Guidelines to Standards for Environmental Pollution Control in Nigeria. Federal Environmental Protection Agency (FEPA), Lagos.

Irfan, M., Riaz, M., Afif, M.S., Shahzad, S.M., Saleem, F., Rahman, N., Berg. L.V.D and Abbas F. (2014) Estimation and characterization of gaseous pollutant emissions from agricultural crop residue combustion in industrial and household sectors of Pakistan. Atmospheric Environment, 189 - 197

Mantananont, N and Patumsawad, S (2016) Particulate matter and gaseous emission rate from combustion of Thai lignite and agricultural residues in a fixed-bed combustor . Energy Sources, Part

A: Recovery, Utilization, and Environmental Effects. 38:4, 478-484, DOI: 10.1080/15567036.2013.783655

NESREA (2007) National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007. Federal Republic of Nigeria.

NESREA (2013) National Environmental (Air Quality Control) Regulations, National Environmental Standards and Regulations Enforcement Agency, Abuja.

Okeke, C. G. and Oluka, S. I. (2017) A Survey of Rice Production and Processing in Southeast Nigeria. Nigerian Journal of Technology. 36(1): 227 – 234

Poonam, D. (2014) Rice Milling. IOSR Journal of Engineering. 4(5): 34 – 42.

USEPA (2000) EPA. Compilation of Air Pollutant Emission Factors Volume I: Stationary Point and Area Sources, 5th ed. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park NC 27711, USA, 1995.

WARDA (1996) West Africa Rice Development Association Annual Report.

World Bank (2007) Pollution Prevention and Abatement Handbook WORLD BANK GROUP, Washington DC.

World Bank (2016) Environmental, Health, and Safety Guidelines for Annual Crop Production. WORLD BANK GROUP, Washington DC.