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Noise Impact Assessment of Thermal Plant Facilities on Receptor Environments

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Abstract

Noise pollution is considered as a serious environmental nuisance in the urban areas. This study has used the VDI code 2714 to investigate the impacts of the noise from all the power generation and ancilliary facilities in the proposed Independent Power Plant, Agbara, Ogun State receptor environment. Kriging interpolation method in Surfer^R 8.0 software to predict noise emission levels within the fence line of the proposed Independent Power Plant. Calculations of possible noise levels at some receptors locations around the plant were carried out using the VDI code 2714. Four operation scenarios were considered in this study. The scenarios considered include: Noise emission from power generation facilities only (Scenario 1); Noise from the use of Compressors and Transformers (Scenario 2); Noise emission from the operation of power generation and ancillary equipment (Scenario 3); and Noise emission from the use of Backup Generators (Scenario 4). The maximum noise from the four scenarios were 112.34, 114.58, 116.61 and 110.01 dB(A), respectively, which is above the 8-hour 90 dB(A) limit recommended by the Federal Ministry of Environment (FMEnv). The operation of the proposed power plant will not have significant impact on the receptor environments except for Karogbaji which receives less than 12 dB(A) for the worst-case scenario (Scenario 3). The modeling results show that the predicted noise levels generated by the proposed operation would generally be within the established noise criteria at all the receptor locations under all conditions.

Keywords: Impact, Noise, Power plant; Receptor environment; Sound pressure level;

Introduction

Nigeria, Africa's most populous nation, has been known for epileptic power supply occasioned by inadequate electricity generation facilities. Backup power generation facilities are always being employed to complement the shortfall (Adeniran, Yusuf, Amole, Jimoda, & Sonibare, 2017). In a bid to solve the nation's energy crisis, the energy sector was privatized to give opportunities to private investors to build power plants. Thermal power plants are now being adopted by independent power producers to increase energy generation and supply in the country. Our previous studies have shown that the operation of these sprawling independent power plants (IPP) facilities are associated with the emission of air pollutants (Adeniran, Yusuf, Fakinle, & Sonibare, 2018; Adeniran, Yusuf, Jimoda, Adesanmi, & Sonibare, 2016; Adesanmi et al., 2016).

Noise pollution is an underestimated emerging environmental nuisance that has affected the quality of life in most urban areas of the world (Carrier, Apparicio, Séguin, & Crouse, 2016; Abbaspour, Karimi, Nassiri, Monazzam, & Taghavi, 2015; Francis, Ortega, & Cruz, 2009). The principal sources of noise in an urban environment include traffic, backup generators, industries, construction activities, public address systems, public work, commercial activities and neighbourhood (Sonibare et al., 2014; Berglund, Lindvall, & Schwela, 1995). Increase in population, industrialization and commercial activities in a community may increase the level of noise (Ikpe & Torriti, 2018). Previous studies have reported noise as an environmental health hazard which may cause sleep deprivation, increase stress level and increase annoyance in people (Khaiwal et al., 2016; Frei, Mohler, & Röösli, 2014). Cases of cardiovascular morbidities and mortalities have also be linked to exposure to environmental noise (Münzel, Gori, Babisch, & Basner, 2014).

The present study sought to identify and evaluate the impacts of noise resulting from the facilities used in generating power in the proposed IPP. These impacts covered both within the plant's fence line and its immediate environment. The specific objectives are to establish the sound power level (SPL) of each of the turbines and other equipment in the plant; estimate the noise propagation towards some important receptor locations both in the plant and its host environment.

Methodology

Overview of evaluation

The location of the proposed IPP is in Agbara, a fast growing industrial area in Ogun State, Nigeria. The study used the VDI code 2714 to investigate the impacts of the noise from all the power generation and ancilliary facilities in the receptor environments of the proposed Agbara Independent Power Plant, Agbara, Ogun State and Surfer^R 8.0 software to predict noise levels within the fence line of the site.

The calculated noise levels was compared with the occupational noise standards of the Federal Ministry of Environment (Table 1), the fence line recommended limits of the World Bank (Table 2), and the World Health Organization Guidelines for some specific environments (Table 3). This was to determine the exact contribution of the plants's activities to the ambient noise levels of its host environment.

Sources of noise in the powerplant

The sources of noise considered in this study are the noise from Turbines, Compressors, Blowers, transformers, turbine generators, and the standby generators. This assessment considered noise from each of the sections of the plant.

Table 1: The Standard Noise Level as set by the Federal Ministry of Environment*

Duration per Day, hour	Permissible Exposure Limit (dB (A))
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Source: FEPA (1991); Sonibare *et al.* (2014)

Table 2: Maximum Allowable Log Equivalent (hourly measurements), in dB (A)*

Receptor	Day-time (7:00 – 22:00)	Night-time (22:00 – 7:00)
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Source: Berglund *et al.* (1995); Sonibare *et al.* (2014)

Table 3: Guidelines values for Community Noise in Specific Environments [b]

Specific Environments	Critical Health Effect(s)	Noise Level dB(A)
Outdoor living area	Serious annoyance, daytime and evening	55
	Moderate annoyance, daytime and evening	50
Dwelling, indoors	Speech intelligibility and moderate annoyance, daytime and evening	35
Inside bedrooms	Sleep disturbance, Night-time	30
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45

Source: Berglund *et al.* (1995); Sonibare *et al.* (2014)

Noise sources from the turbines section

The noise sources in this section of the Plant, 2 units of GE 6F.03 gas turbines, a unit TEWAC Steam Turbine generator, Heat Recovery Steam Generators and the associated installations such as the compressors, the pumps, air coolers, exhaust duct vibration and the Turbines inlets. The turbines inlets have high characteristics high frequencies and they are considered the mechanism that produce the most annoying and loudest noise. The three major noise sources in a power plant are from Draft fans (both induced and forced –types),Turbine generators and Air compressors.The maximum anticipated sound power level from each of the turbines is 105 dB(A) while that of the compressors, air coolers and pumps are 110, 106 and 106 dB(A), respectively.

Noise sources from the gas compression, auxilliary boilers and generators

The anticipated noise sources are the auxilliay generator and a boiler with SPL of 91 and 90 dB(A), respectively. In the gas station, there are provision for 9 compressors. Each compressor has an anticipated SPL of 105 dB(A).

Noise sources from transformers

Transformers are provided for plant electrical supplies. All transformers are non-PCB oil- filled and each transformer will be provided with a containment bund that will retain all the transformer oil in the event of a spillage. Pumps drain these sumps to an oil separator which and discharge to the site drainage system. The sumps are installed with high level alarms to avoid overflow. There is provision for two units of 2.5 MVA XFMR in the Agbara IPP. The anticipated SPL of these XFMR is 85 dB(A) each.

Noise sources from the standby generators section

During power outages from the National Grid system (a frequent occurrence in Nigeria) power required for the auxiliaries and for the gas turbine starting (cranking) motors will not be available. As a result, Agbara Power plans to install to XQ-8000 diesel units to provide the estimated 7.4 MVA required to "Black Start" the power station. These units will also be available to assist in the emergency shutdown required in the event of a total grid system collapse. A unit of the XQ-8000 standby generator has an anticipated SPL of 107 dB(A).

Noise level determination

Modeling of the noise emission within the fence line was accomplished using Kriging interpolation method in Surfer[R] 8.0 software. Calculations of possible noise levels at some receptors locations around the plant were carried out using the steps highlighted in the the VDI draft code 2714 'Outdoor Sound Propagation In 1976, the VDI code 2714 'Outdoor Sound Propagation' was issued by the VDI committee on noise reduction. The SPL at an environmental point is calculated from Equation 1(Marsh, 1982; Nanda, Tripathy, & Patra, 2009):

Table 4: Identified Electric Generator Noise Sources from the Factory

S/N	Noise Source	Longitude (N)	Latitude (E)	Sound Pressure Level, dB(A)
1	Gas Turbine 1	6°30'4.23"	3°5'11.08"	110
2	Gas Turbine 2	6°30'3.29"	3°5'11.38"	110
3	Steam Turbine	6°30'2.53"	3°5'11.61"	110
5	Standby Generator 1	6°30'2.43"	3°5'10.86"	107
6	Standby Generator 2	6°30'2.68"	3°5'10.73"	107
7	HRSG1	6°30'3.63"	3°5'10.88"	105
8	HRSG2	6°30'2.91"	3°5'11.19"	105
9	Transformer 1	6°30'7.04"	3°5'12.44"	85
10	Transformer 2	6°30'6.97"	3°5'12.35"	85
11	Gas Compressor 1	6°30'7.33"	3°5'12.34"	105
12	Gas Compressor 2	6°30'7.30"	3°5'12.29"	105
13	Gas Compressor 3	6°30'7.26"	3°5'12.23"	105
14	Gas Compressor 4	6°30'7.36"	3°5'12.28"	105
15	Gas Compressor 5	6°30'7.34"	3°5'12.24"	105
16	Gas Compressor 6	6°30'7.31"	3°5'12.17"	105
17	Gas Compressor 7	6°30'7.40"	3°5'12.23"	105
18	Gas Compressor 8	6°30'7.37"	3°5'12.12"	105
19	Gas Compressor 9	6°30'7.32"	3°5'12.11"	105

$$L_p \, dB(A) = \sum_{allsources}^{\log} [L_w + K_1 - 10 \log (4\pi R^2) + 3dB - K_2 - K_3 - K_4 - K_5 - K_6 - K_7] \qquad 1$$

where: L_w= source power level re 10^{-12} watts; K_1 = source directivity index; -10 log $(4\pi R^2)$ = geometric spreading term including infinite hard plane coinciding with the source; R = source to receiver distance; K_2 = atmospheric attenuation = 10 log (1 + 0.0015R) dB(A); K_3 = attenuation due to meteorological conditions = $[(12.5/R^2) + 0.2]^{-1}$ dB(A); K_4 = ground effects = 10 log [3 + (R/160)] – K_2 – K_3 dB(A); K_5 = barrier value (0-10) = 10 log (3 + 20 d) dB(A); d = barrier path difference; K_6 = attenuation due to woodland areas; K_7 = attenuation due to built-up areas

Noise emission sources scenarios

Four modelling scenarios were considered in this modeling exercise and each of these is based on the different sections of the plant. The scenarios are

i. noise emission from power generation facilities only
ii. noise from the use of Compressors and Transformers
iii. noise emission from the operation of power generation and the ancillary equipment
iv. noise emission from the use of Backup Generators

Noise levels from these scenarios were generated from the plant's facilities on thus have impact the ambient host environment. In this modelling, it was assumed that there is continuous noise generation from the sources while in operation. The generated noise levels from each of the operation scenarios were then compared with the recommended limits of both the Federal Ministry of Environment and that of the World Bank in the impact assessment for a complete investigation.

Sound Pressure Level for each of the scenarios was estimated using Equation 2

$$SPL_{scenario\ i} = 10 \log_{10}\left[10^{\frac{SPL_{source\ 1}}{10}} + 10^{\frac{SPL_{source\ 2}}{10}} + \cdots + 10^{\frac{SPL_{source\ n}}{10}}\right] \qquad 2$$

where 'i' is the scenario number and 'n' is the number of sources in scenario i.

Receptor locations

The immediate and distant environments of the plant were considered as receptors to the noise from this study. Specifically, a 10 km radius within the factory location was given adequate attention. This radius is the major locations of interest and other important point of activities in the vicinity of the plant (Figure 1).

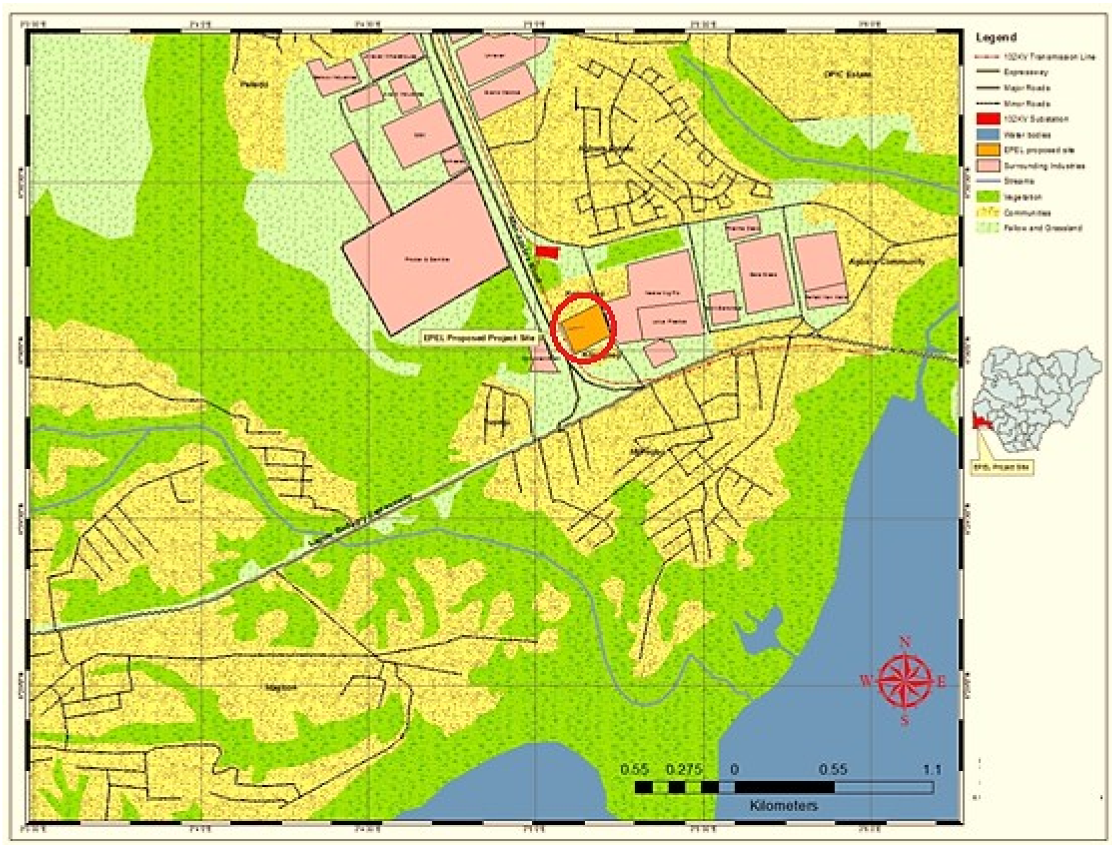

Figure 1: Proposed Project Site for Agbara IPP, Agbara, Ogun State, Nigeria

Results and Discussion

Noise Emission from Power Generation Facilities only

As presented in Figure 2, the noise associated with the operation of the power generating facilities is 10 - 125 dB(A) with the maximum retained within the factory premises. The major receptors of noise outside the power plant premise include Opic Estate, Agbara Estate, Agbara Community, Karogbaji, Morogbo, Petedo, Ilupeju and Magbon. Generally, outside the factory premises, this Scenario do not contribute to the ambient noise level of the host environment except for Karogbaji which receives an average insignificant sound pressure level of 6.84 dB(A) (Table 5).

Noise from the use of compressors and transformers

From the operation of the ancillary equipment (compressors and transformers), the ambient noise into the environment is 5.0 dB(A) –111.0 dB(A) as summarized in Figure 3. While the minimum noise from this Scenario within the factory is 5–105 dB(A), the maximum at its fence line contribution is 100-110 dB(A). In the sensitive receptors around the Power Plant, the plants' contribution to ambient noise level are insignificant except for Karogbaji which receives an average insignificant sound pressure level of 9.08 dB(A) (Table 5).

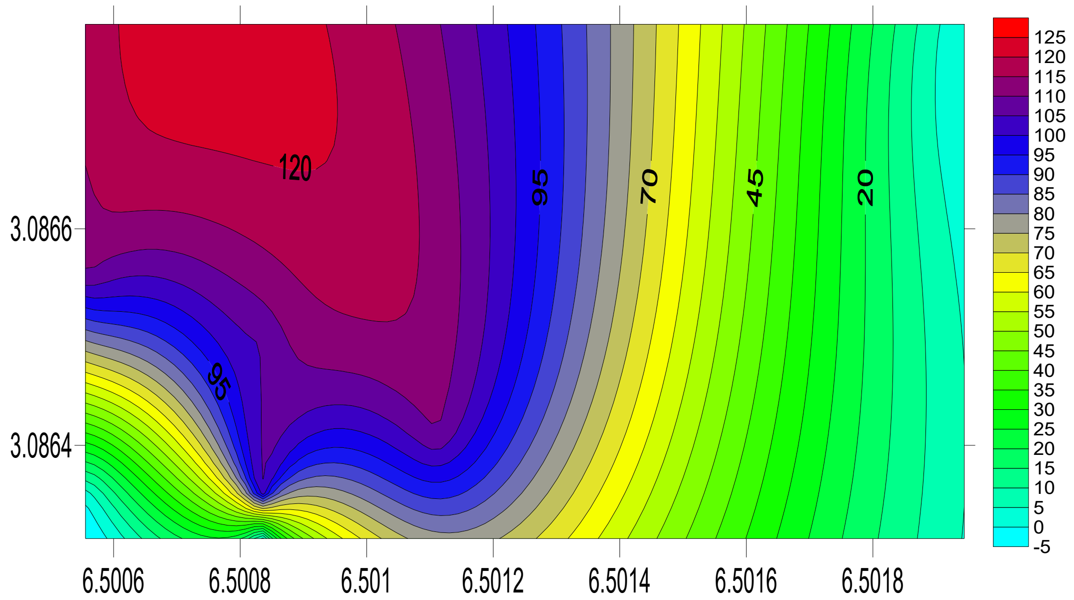

Figure 2: Noise from the operation of power generation facilities only

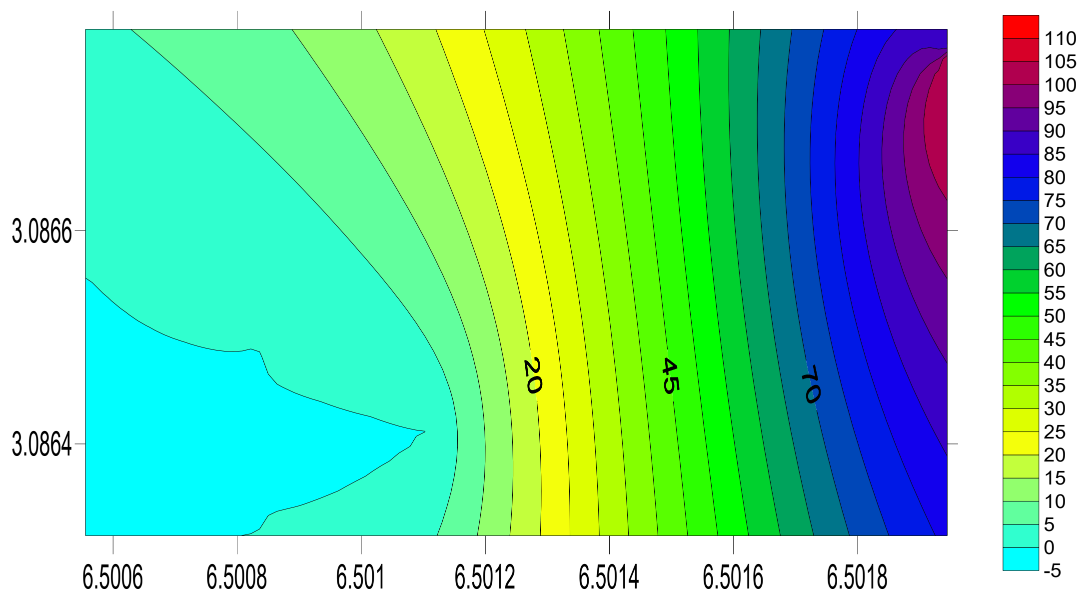

Figure 3: Noise from the use of Compressors and Transformers

Noise emission from the operation of power generation and ancillary equipment

Noise emission from the operation of power generation and ancillary equipment of the power plant (Figure 4), range between 5.0 and 135 dB(A). Within the factory, the minimum noise from this scenario is 85.0 and the maximum noise contribution from the Scenario is 135 dB(A). In the sensitive receptors around the Power Plant, the plant's contribution to ambient noise level are insignificant except for Karogbaji which receives an average insignificant sound pressure level of 11.12 dB(A) (Table 5).

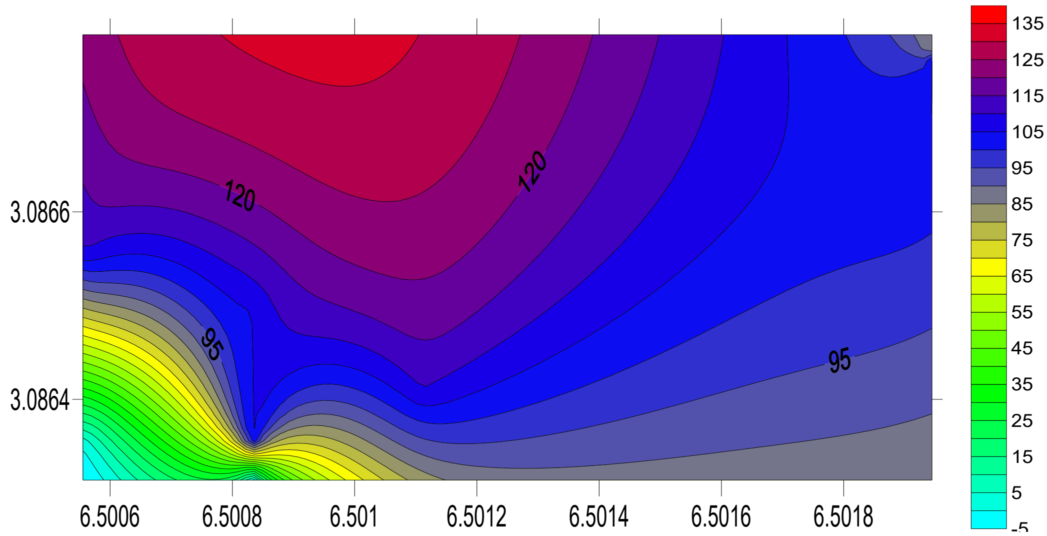

Figure 4: Noise emission from the operation of power generation and ancillary equipment

Table 5: Maximum Noise Contribution to the Nearby Communities

Receptor Location		Distance and Direction away from Site		Noise Level dB(A)			
Code	Designation	Distance (m)	Direction	Scenario 1	Scenario 2	Scenario 3	Scenario 4
C1	Opic Estate	1272.51	NE	0	0	0	0
C2	Agbara Estate	644.11	N	0	0	0	0
C3	Agbara Community	974.02	NE	0	0	0	0
C4	Karogbaji	141.39	N	6.84	9.08	11.12	4.51
C5	Morogbo	534.14	SE	0	0	0	0
C6	Petedo	1555.29	NW	0	0	0	0
C7	Ilupeju	549.85	SW	0	0	0	0
C8	Magbon	1838.07	SW	0	0	0	0

Noise emission from the use of backup generators

Operations of the use of backup power generators in the plant during power black-out from National grid generate ambient noise level of less than 80 dB(A) within the Plant's fence line (Figure 5). None of the identified receptor locations receives additional noise except Karogbaji which receives an average of 4.51 dB(A).

Impact of the power plant's activities on ambient noise

For all the scenarios considered, it is anticipated that the emitted noise from the operation of the proposed power plant will be attenuated within the 200 m radius of the plant (Figure 6). At 5 meters away from the fence line, the noise levels were 81.88, 83.42, 85.46 and 78.86 dB(A) respectively for Scenarios 1, 2, 3 and 4. These predicted noise levels are below the 8-hour 90 dB(A) FMEnv limit. At 30 metres away, the noise levels became 46.92, 49.16, 51.20, and 44.60 dB(A), respectively for Scenarios 1, 2, 3 and 4. These predicted noise levels at 30 m away from the fence line are below the 70 dB(A) WHO's limit for industrial and commercial environments. The predicted levels were also below the 50 dB(A) sleep disturbance limit except for Scenario 3.

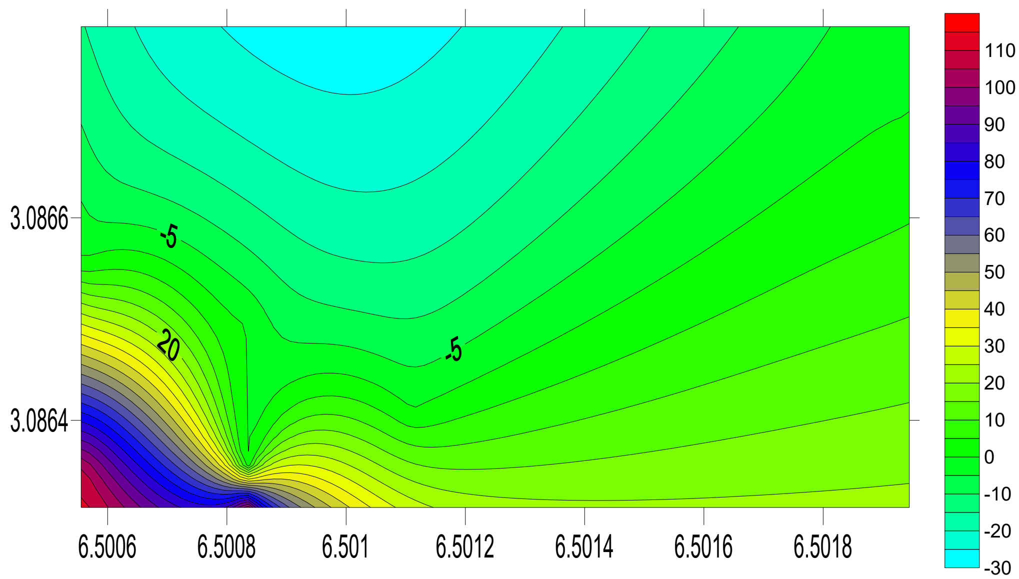

Figure 5: Noise emission from the use of Backup Generators

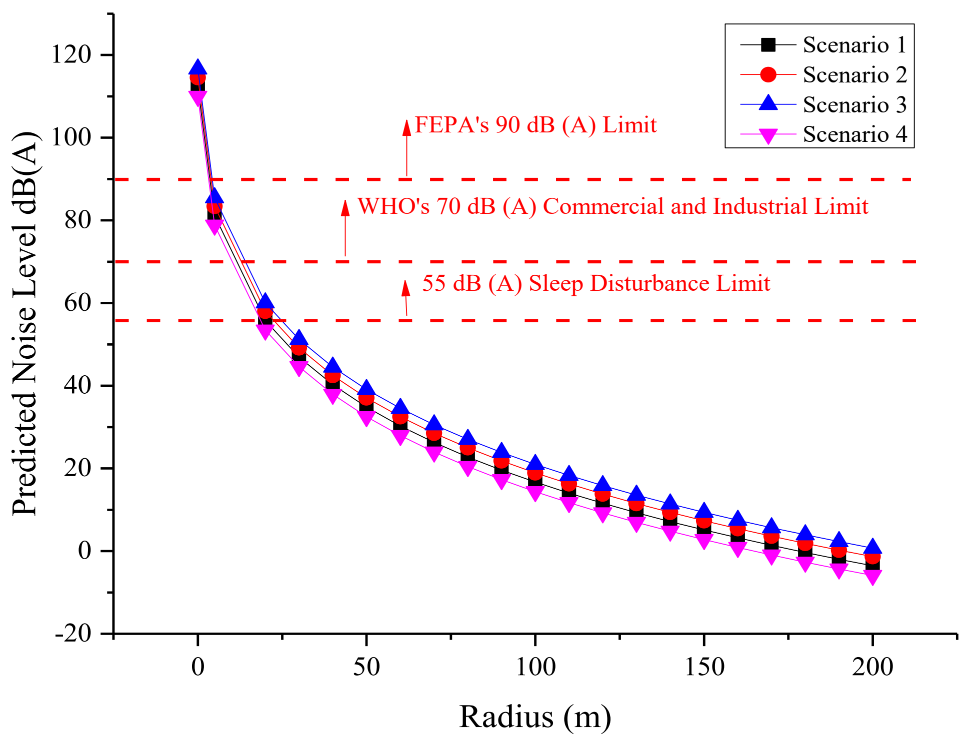

Figure 6: Attenuation of Sound Pressure Levels within for the four scenarios

Conclusion

This study has investigated the impacts of emissions from the operation of the proposed Agbara Independent Power Plant, Agbara, Ogun State within the fence line and on the receptor environments using Kriging interpolation in Surfer^{R} 8.0 and the VDI code 2714, respectively. The scenarios considered include: Noise emission from power generation facilities only (Scenario 1); Noise from the use of Compressors and Transformers (Scenario 2); Noise emission from the operation of power generation and ancillary equipment (Scenario 3); and Noise emission from the use of Backup Generators (Scenario 4). From the four scenarios considered, the maximum noise levels were above the FMENv limit. The anticipated noise levels are however within the 70 dB(A) industrial and commercial area limit of the World Bank at 10 m away from each of the major equipment and thus pose no environmental challenge to the host environments.

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