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# Ambient noise from off-grid diesel engines electric power generators in an urban environment

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## Abstract

**Purpose** – The aim of this paper is to investigate the impacts of the noise from the diesel engine power generators used for production activities in an urban environment.

**Design/methodology/approach** – This study has used the Enterprise Edition of NoiseMap 2000 Version 2.7.1 to investigate the impacts of the noise from the diesel engines electric power generators used in a factory in Ikorodu, an urban environment in Lagos, Nigeria. Five sections of the factory with diesel engines electric power generators were considered. The immediate and distant environments covering about 10 km of the factory host environment were considered as receptors to the noise for this study.

**Findings** – It was found out that when all the generators operate simultaneously in the factory, the ambient noise was 30.0-152.5 dB(A) with the minimum contribution within the factory being 70.0-84.4 dB(A) and the maximum contribution of 57.2-70.8 dB(A) outside the factory fence line. Though the maximum noise is 152.5 dB(A), the maximum noise of 70.8 dB(A) beyond the fence line shows a compliance with 70 dB(A) industrial and commercial area limit but breaches the 45 dB(A) and 55 dB(A) residential area limit of the World Bank.

**Research limitations/implications** – As much as it would be desirable ambient noise level could not be measured in all the receptors' locations covered by the modeling. However, the capability of the modeling software adopted makes this to have no negative impact on the quality of the findings of this study.

**Practical implications** – The study will assist the public to determine the noise level safe region around diesel engine electric power generators.

**Originality/value** – The paper highlights the challenges in which ambient noise from the use of off-grid generators used for industrial purposes could pose to the neighboring receptor environments.

**Keywords** Environment, Modelling, Power generation, Noise level, NoiseMap

**Paper type** Research paper

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## 1. Introduction

Power consumption in the developing countries is a major problem that affects all the facets of economy including industrialization. It is estimated that about one-third of electricity production in the world goes to the USA while the rest two-thirds goes to the other countries of the world (Malago and Mkoma, 2012). Despite the huge potential of Africa to generate energy due to the abundance of natural resources, it is the poorest continent in terms of energy utilization with a total energy consumption of $<3$ percent of global primary energy demand (Agboola, 2011). Many communities in Nigeria have no or limited access to large scale or integrated electricity through national grid (Stephen *et al.*, 2012). Nigeria, which has been described as a country with large and energy hungry population (Nnaji, 2011), is faced with a continued electricity problem making goods and services to be very costly because industries generate their power themselves through the use of generators (Osueke and Ezeh, 2011). In a population of over 160 million, only about 40 percent of Nigerians have access to electricity from the national grid (Adams *et al.*, 2011).

The use of generators by individuals and industries has been a replacement for supplying power whenever there is shutdown from the national grid in the country. Use of generator has been a more stable supplement to the national grid that is characterized by frequent and persistent outages (Olabiyi *et al.*, 2012). According to World Bank (2005), well over 90 percent of Nigerian businesses have generators as backups. The most common form of off-grid supply for industries are generators running on diesel. Aside the toxic air pollutants emitted from these generators, they also emit a high level of noise (Parvathi and Gopalakrishnan, 2003). Noise from generators are generated through aerodynamics effects, forces from combustion process and mechanical excitation from rotating and reciprocating engine components (Heywood, 1988).

Domestic and industrial use of generators has been recognized as a source of noise which impacts can have both short-term and long-term effects on humans and the environment. Noise pollution from industrial and commercial activities in urban areas represent a significant environmental hazard to public health (Sonibare *et al.*, 2003; Vlachokostas *et al.*, 2012). Noise induced hearing loss, psychological changes and abnormal increase in blood pressure are likely health effects of prolonged exposure to noise in man (El-Fadel *et al.*, 2002; Dursun *et al.*, 2006; Franssen *et al.*, 2002; Babisch *et al.*, 2005; Prasher, 2003; Kisku and Bhargava, 2006; Sobotova *et al.*, 2010). It is estimated that about 120 million people have developed hearing difficulty due to noise pollution (Hamoda, 2008). Annoyance, speech intelligibility and sleep disturbance have also been associated with noise pollution as the psychosocial and physiological negative effects they may have on individuals (Babisch *et al.*, 2009; Mehdi *et al.*, 2011; Fhyri and Klaboe, 2009; Murphy *et al.*, 2009; Murphy and King, 2010).

Noise at a certain level may cause damage to aquatic life (Frid *et al.*, 2012). Can *et al.* (2011) posited in their study that there is a very good correlation between noise levels and ultrafine particles emission. The higher the noise level, the higher the airborne ultrafine particles. However, less attention is being paid to noise as a source of environmental pollution by the various Nigerian environmental agencies (Odigure and Abdulkareem, 2000).

Odigure *et al.* (2004) applied the principle of mathematical modeling and computer simulation to predict the noise pollution migration pattern from the use of generators in the oil rich Niger Delta area of Nigeria. The simulation result showed that generators power rating and the distance away from the generators have effect on the radiated noise. Tandon *et al.* (1997), Tandon (2000), Wang and Crocker (2002) and Mogal *et al.* (2011) conducted studies on noise control from machineries and mechanical structures focussing on the muffler system. Some of the recent studies that made use of acoustic software to model the environmental impact of noise (Diniz and Zannin, 2004; Guedes *et al.*, 2011; Xie *et al.*, 2011).

This present study investigates the impacts of noise associated with operation of diesel-engine-operated electric power generators in a factory located at Ikorodu, Lagos State, Nigeria. For the impact assessment, an evaluation was carried out on the noise emanating from the power plants using their sound power level (SPL). The noise impact evaluation was carried out to identify the impacts from the diesel engines electric power generators used for production activities in the premises of the factory. These impacts covered both within the factory fence line and its immediate environment. This study was considered important because of the status of Lagos as an emerging megacity.

## 2. Materials and methods

### *2.1 Study area*

This study was conducted in a factory in Ikorodu, a city and local government area in Lagos State – the industrial and economic capital of Nigeria (Figure 1). The study area is located along the Lagos Lagoon, and it shares a boundary with Ogun State, Nigeria. Ikorodu, being a part of Lagos, is among the fastest growing urban center in Nigeria. Rapid population and industrial growth in Ikorodu has affected the demand for electricity as a major source of energy. As of the 2006 Census Ikorodu had an enumerated population of 535,619 (NPC, 2012).

Diesel engine electric power generators are engaged in the factory at Ikorodu, Lagos State to privately generate electricity for its activities. These are to meet up with the electric power requirements in the factory since there is presently heavy shortage of electricity from the national grid. The factory is divided into five sections and each of these is installed with their dedicated diesel engine electric power generators. In all the five sections of the factory, there is a total 22 units of electric power generators with total installed capacity of 24,108 kVA.

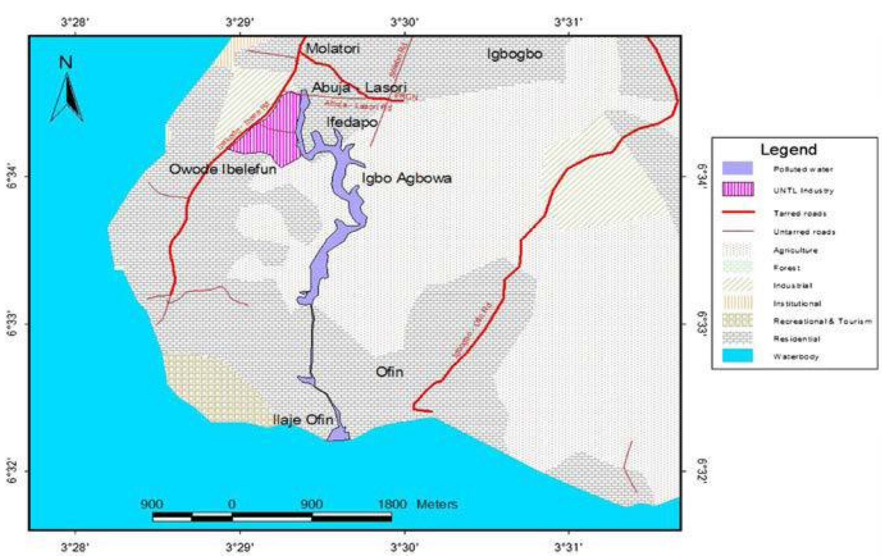


**Figure 1.**
Map showing the location of the study area

*2.2 Noise measurements*

Noise measurements were taken with a digital, battery-powered, sound pressure level meter (EXTEC Instruments, US Model 407735). To measure the noise levels the sampling locations, the sound level meter was placed at a distance of at least 3 m from any barrier or other sound reflecting sources and at about 1.2-1.5 m above ground level. Measurements were taken by setting the sound level meter to the "A" weighting network of the meter.

*2.3 Noise sources in the factory*

The only sources of noise considered in this study are the noise from the 22 units electric power generators. This modeling considered noise from each of the sections of the factory where electric power generators are installed for smooth production activities. The average values of the measured noise level in each section of the factory were considered as inputs for the NoiseMap software.

*2.3.1 Noise sources from the spinning and weaving section*. The noise sources in this section of the factory are from GRT 1, GRT 2, GRT 3, GRT 4, GRT 5, GRT 6, GRT 7 and GRT 8. The SPL from each of GRT 1, GRT 2, GRT 3, GRT 4 and GRT 5 power generators is 107 dB(A) while that of GRT 6 is 109 dB(A). From GRT 7, the SPL considered is 113 dB(A) while 127 dB(A) is the SPL fed into the modeling tool for GRT 8.

*2.3.2 Noise sources from the printing and dying section*. In this section the noise sources identified presently operating in the factory include GRT 9, GRT 10, GRT 11, GRT 12 and GRT 13 power generators. While the SPL of each of GRT 9, GRT 10, GRT 11 and GRT 12 power generators is 127 dB(A), that of GRT 13 power generator is 103 dB(A).

*2.3.3 Noise sources from the motel section*. In the motel section of the factory, there are units of GRT 14, GRT 15, GRT 16 and GRT 17. The SPL of these generators are 103, 115, 107 and 107 dB(A), respectively.

*2.3.4 Noise sources from the filament section*. The filament section of the factory has four units of generators including GRT 18, GRT 19, GRT 20 and GRT 21 electric power generator each of which has SPL of 123 dB(A).

*2.3.5 Noise sources from the fiber section*. The fiber section of the factory is powered by a unit of GRT 22 electric power generator which has a SPL of 107 dB(A).

*2.4 Noise level determination*

Calculations of possible noise levels at some receptors locations around the factory were carried out with NoiseMap 2000 software as earlier indicated. NoiseMap 2000, the latest version of WS Atkins' noise calculation software, is used by many major companies and governmental authorities (NoiseMap, 2006). It is available as separate modules: RoadNoise 2000; RailNoise 2000; and SiteNoise 2000 with a number of other applications, such as noise insulation assessments, planning applications, noise barrier design, environmental impact assessments, designing housing layouts and creating environmental liability databases. It uses UK standard calculation procedure and BS 5228. It has now been used to process noise in greater London called London Noise Maps and made available to the public (Xie *et al.*, 2011).

NoiseMap 2000 imports ordnance survey and other digital maps to generate accurate noise maps for a combination of noise sources, including predicted noise levels for road traffic, railways and industrial sites. A NoiseMap 2000 model can be built either by importing the information from a digital map, tracing the model on-screen over a scanned map or digitizing. A copy of the factory area of influence digital map was imported into NoiseMap for source exact location identification. The typical outputs from the model are: plant data, working and ground type, activity data, barrier data, contour data and receptors location to noise sources, among others.

*2.5 Noise emission sources scenarios*

Six modeling scenarios were considered in this modeling exercise and each of these was based on the five different sections of the factory where electric power generators are installed. The scenarios are all operation scenarios assuming the "worst case" situation where all the installed generators in each of the sections work simultaneously. In the sixth scenario, it was assumed that all the diesel electric power generators in the factory are simultaneously in operation. Noise levels from these scenarios were generated for a picture of the contribution of the factory diesel electric power generators on the ambient host environment to be ascertained. In the modeling, 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 Nigeria's Federal Ministry of Environment (Table I), that of the World Bank (Table II) and that of the World Health Organization (WHO) (Table III) in the impact assessment for a complete investigation.

**Table I.** 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:** Federal Environmental Protection Agency (1991)

**Table II.** 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:** World Bank (1998)

**Table III.** Guidelines values for community noise in specific environments

| Specific environments | Critical health effect(s) | Noise level (dB(A)) |
|---|---|---|
| Outdoor living area | Serious annoyance, day-time and evening | 55 |
| | Moderate annoyance, day-time and evening | 50 |
| Dwelling, indoors | Speech intelligibility and moderate annoyance, day-time and evening | 35 |
| Inside bedrooms | Sleep disturbance, night-time | 30 |
| Outside bedrooms | Sleep disturbance, window open (outdoor values) | 45 |

**Source:** Berglund *et al.* (1999)

*2.6 Receptor locations*
The immediate and distant environments of the factory 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 factory (Figure 1).

## 3. Results and discussion
The modeling outputs as obtained from the six scenarios considered in this study are herein presented. Table IV summarizes these electric power generators noise sources with their SPL.

*3.1 Spinning and weaving section electric generators' noise*
As presented in Figure 2, the noise from the spinning and weaving section electric power generators is 30-122.5 dB(A) with the maximum retained within the factory premises. The major receptors of noise outside the factory include Igbogbo, Molatori, Owode Ibalefun, Ifedapo and Igbo Agbowa which receive 34.9-39.7, 49.5-54.3, 44.6-49.5, 49.5-54.3 and 34.9-39.7 dB(A), respectively. Generally outside the factory premises, these section electric power generators contribute the maximum noise of 54.3-59.2 dB(A) to the ambient noise level of the factory host environment.

*3.2 Printing and dyeing section electric generators' noise*
From the electric power generators in the printing and dyeing section of the factory, the ambient noise into the environment is 30.0-155.0 dB(A) as summarized in Figure 3. While the minimum noise from the electric power generators in this section within the factory is 71.7-85.6 dB(A), the maximum outside its fence line is 57.8-71.7 dB(A).

| Factory section | Source | Location (m) *X* | *Y* | Sound pressure level (dB(A)) |
|---|---|---|---|---|
| Spinning and weaving (Scenario 1) | GRT 1 | 3,063.4 | 5,926.6 | 107 |
| | GRT 2 | 3,102.2 | 5,907.0 | 107 |
| | GRT 3 | 3,141.1 | 5,906.9 | 107 |
| | GRT 4 | 3,179.9 | 5,887.8 | 107 |
| | GRT 5 | 3,209.0 | 5,877.4 | 107 |
| | GRT 6 | 3,228.4 | 5,877.1 | 109 |
| | GRT 7 | 3,267.3 | 5,877.2 | 113 |
| | GRT 8 | 3,277.0 | 5,867.5 | 127 |
| Printing and dyeing (Scenario 2) | GRT 9 | 3,052.7 | 5,683.7 | 127 |
| | GRT 10 | 3,091.6 | 5,683.6 | 127 |
| | GRT 11 | 3,140.2 | 5,683.4 | 127 |
| | GRT 12 | 3,188.7 | 5,683.2 | 103 |
| | GRT 13 | 3,227.6 | 5,663.6 | 103 |
| Motel (Scenario 3) | GRT 14 | 3,256.2 | 5,537.1 | 105 |
| | GRT 15 | 3,256.0 | 5,469.1 | 103 |
| | GRT 16 | 3,255.8 | 5,420.5 | 115 |
| | GRT 17 | 3,255.4 | 5,342.8 | 107 |
| Filament (Scenario 4) | GRT 18 | 2,876.9 | 5,460.9 | 123 |
| | GRT 19 | 2,944.9 | 5,450.9 | 123 |
| | GRT 20 | 3,080.8 | 5,411.5 | 123 |
| | GRT 21 | 3,168.2 | 5,401.4 | 123 |
| Fiber (Scenario 5) | GRT 22 | 2,778.5 | 5,179.5 | 107 |

**Table IV.** Identified electric generator noise sources from the factory

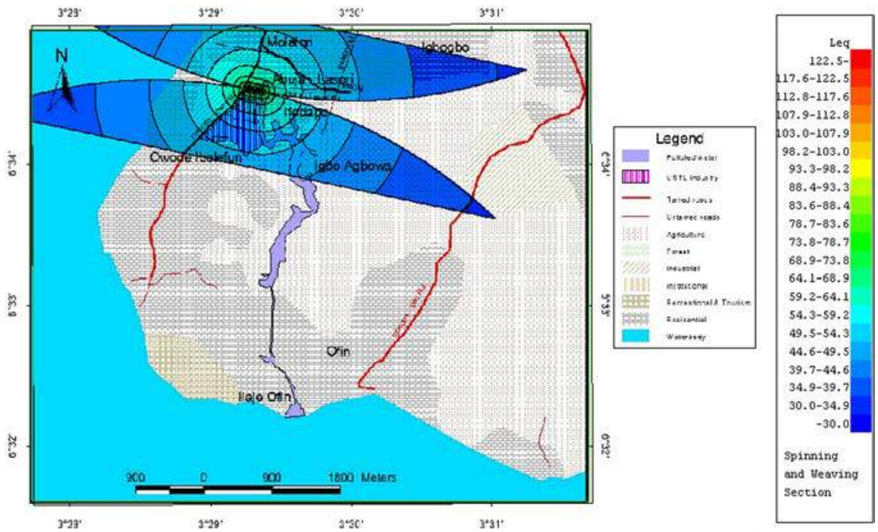


**Figure 2.**
Spinning and weaving section electric generators' noise from the factory

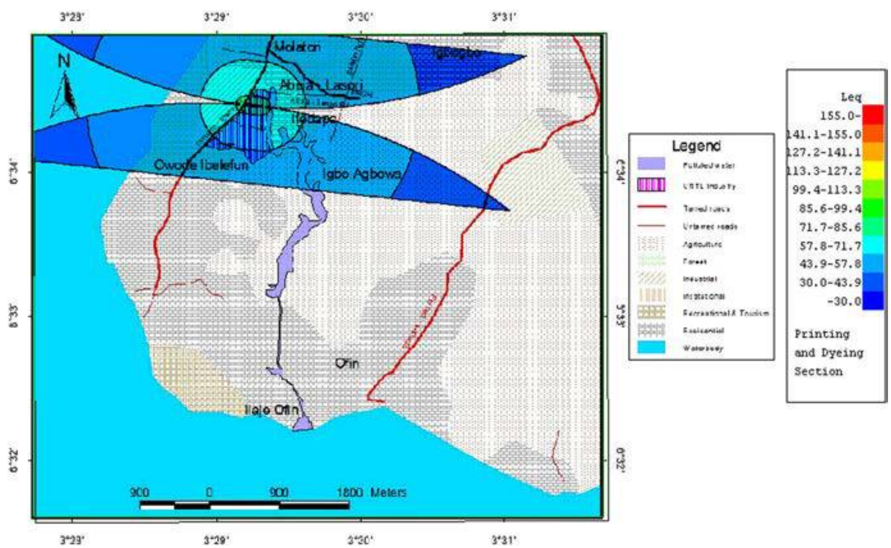


**Figure 3.**
Printing and dyeing section electric generators' noise from the factory

In the sensitive receptors around the factory, the factory's contribution to ambient noise level are 30.0-43.9, 43.9-57.8, 43.9-57.8, 57.8-71.7 and 43.9-57.8 dB(A) for Igbogbo, Molatori, Owode Ibalefun, Ifedapo and Igbo Agbowa, respectively.

*3.3 Motel section electric generators' noise*

In the motel section of the factory (Figure 4), noise from the diesel electric power generators range between 30.0 and 127.5 dB(A). Within the factory, the minimum noise from the section's electric power generators is 51.7-62.5 dB(A) and outside it, the maximum noise contribution from the section's generators is 40.8-51.7 dB(A). From this section's electric power generators, receptors in Owode Ibalefun and Ifedapo receive

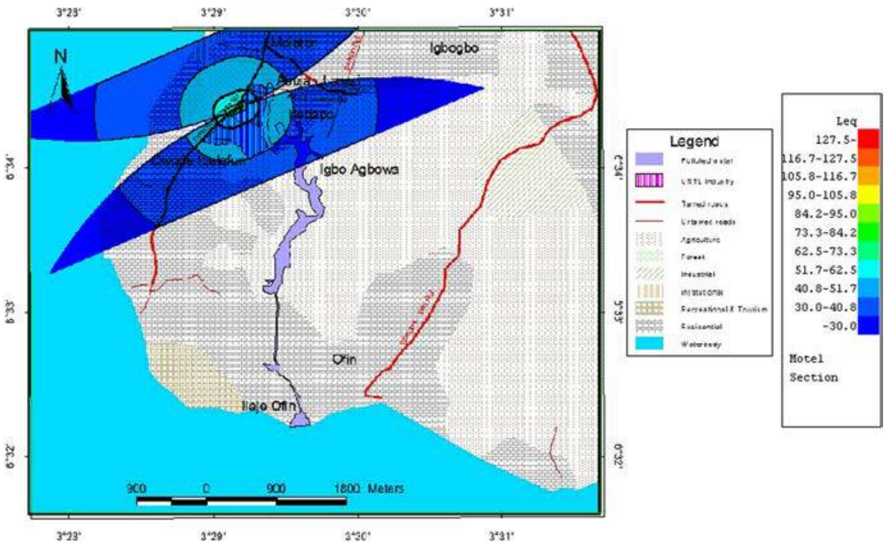


Figure 4.
Motel section electric generators' noise from the factory

ambient noise level of the range 30.0-40.8 dB(A) while those in the Igbogbo, Molatori and Igbo Agbowa receive insignificant noise.

*3.4 Filament section electric generators' noise*

Simultaneous operations of all the electric power generators in the filament section during peak period of production activities generate ambient noise level of 30.0-127.5 dB(A) with the minimum range of 62.5-73.3 dB(A) within the factory and a maximum of 40.8-51.7 dB(A) outside the factory (Figure 5). While Molatori, Owode Ibefun and Igbo Agbowa receives additional noise of 40.8-51.7 dB(A) from this section's electric power

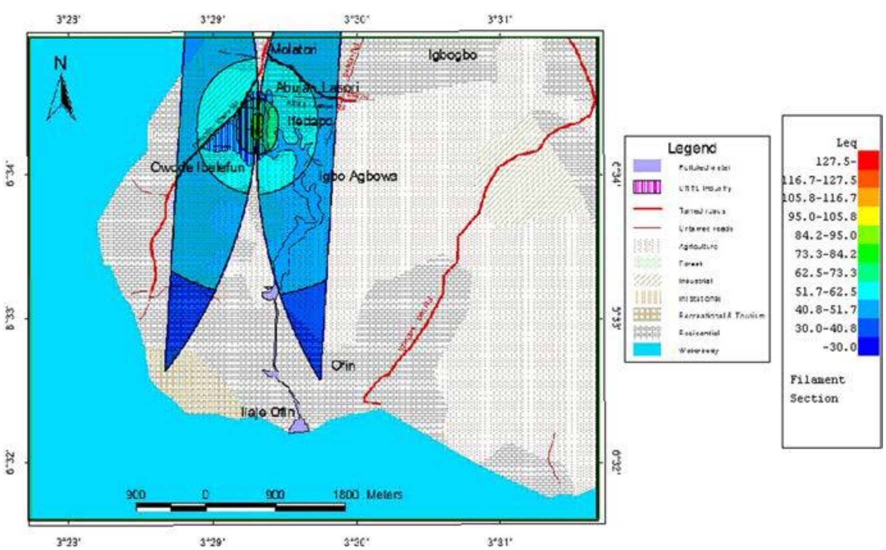


Figure 5.
Filament section electric generators' noise from the factory

generators in the factory, Ofin receives <30.0 dB(A) and Igbogbo receives very insignificant noise level from it.

*3.5 Fiber section electric generator' noise*

From the fiber section, the emitted noise into the ambient environment by its only electric power generator is 30.0-105.0 dB(A) as shown in Figure 6. Within the factory premises, the minimum contribution from the section's generator to the ambient noise is 46.7-55.0 dB(A) while outside the fence line, the maximum contribution is 30.0-38.3 dB(A). From this generator, receptors in Molatori, and Igbogbo receive insignificant noise contribution while Ifedapo, Owode Ibelefun and Igbo Agbowa all receive 30.0-38.3 dB(A).

*3.6 Noise from simultaneous operations of all the electric power generators*

From the "worst case" scenario when all the electric generators simultaneously operate to meet production demands, the ambient noise is 30.0-152.5 dB(A) with the minimum contribution within the factory being 70.0-84.4 dB(A) and the maximum contribution of 57.2-70.8 dB(A) outside the factory fence line (Figure 7). Owode Ibefun, Igbo Agbowa and Ifedapo receive 57.2-70.8 dB(A) from the factory. While Igbogbo receives nothing significant from the factory in this scenario, receptors in Molatori receive 43.6-57.2 dB(A).

*3.7 Impacts of the factory's diesel generators on ambient noise*

The maximum noise from the electric generators in the spinning and weaving section is 122.5 dB(A) which is above the eight-hour 90 dB(A) FMEnv limit. However, the maximum noise from the section at the factory's fence line is 54.3-59.2 dB(A) which fall within the 70 dB(A) industrial and commercial area limit of the World Bank thus poses no environmental challenge to the ambient noise of the environment. Though some receptors in the factory's neighborhood receive 34.9-54.3 dB(A), these are within the 55 dB(A) day-time limit of the World Bank and not too much above the night-time 45 dB(A) limit.

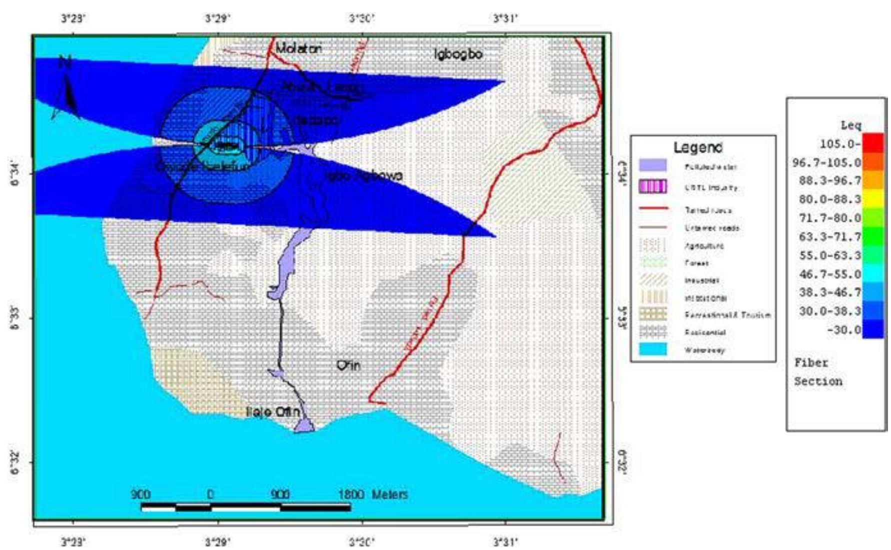


**Figure 6.**
Fiber section electric generators' noise from the factory

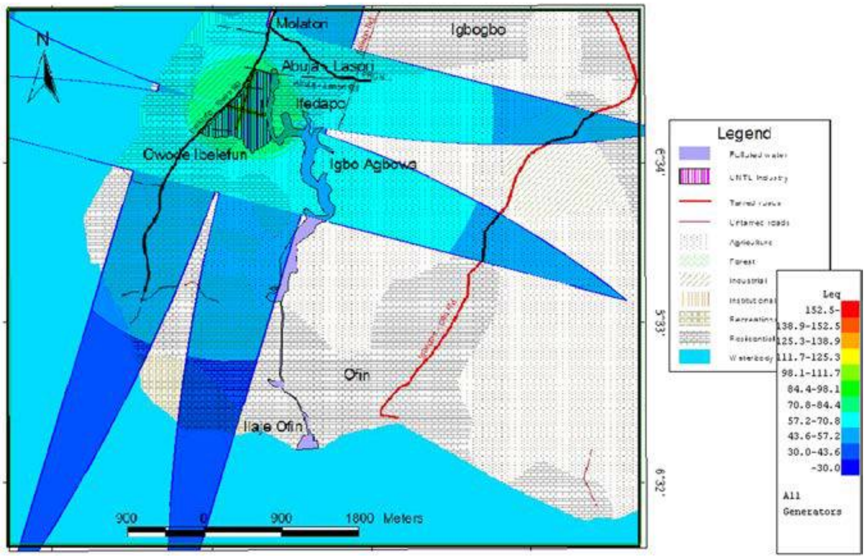


**Figure 7.**
All sections electric generators' noise from the factory

Simultaneous operation of all the electric generators in the printing and dyeing section of the factory result in maximum noise level of 155.0 dB(A) which is far above the 90 dB(A) FMEnv eight-hour limit. To work safely workers in this section must put on ear protectors. Though the maximum noise into the fence line ambient environment is 71.7 dB(A), this is considered compliant with the 70 dB(A) industrial and commercial area limit of the World Bank thus pose no environmental challenge to the host environment. However, contribution of ambient noise of 57.8-71.7 dB(A) to some neighboring host communities may compel the factory to limit its operation in this section to day-time only whenever there is shortage of power from the national grid to the factory.

Emissions of 127.5 dB(A) maximum noise into the ambient environment from the motel section and the filament section of the factory also indicate that workers in the sections power houses must be with ear protector whenever on duty. The maximum noise of 51.7 dB(A) from the two sections beyond the fence line of the factory ambient environment shows that noise from these sections comply with all the limits of the World Bank and that of the WHO for commercial and industrial area as well as the day-time and night-time periods thus the generators in this section of the factory can operate both in the day-time and night-time without disturbing the host communities. The trend is the same on the noise from the fiber section of the factory. Its maximum of 55.0 dB(A) to the factory's environment and 38.0 dB(A) to the fence line are all within set limits.

Though the maximum noise from the simultaneous operations of all the sections' electric power generators is 152.5 dB(A), the maximum noise of 70.8 dB(A) beyond the fence line shows a compliance with 70 dB(A) industrial and commercial area limit of the World Bank. While the workers in each of the sections' power houses must always be on ear protector when on duty, visitors must also be on ear protector always. However, the maximum noise level of 70.8 dB(A) by receptors in Agbowa and Ifedapo in the factory's neighborhood confirms the earlier suggestion that the factory may want to limit its operation to day-time whenever there is shortage of electricity to it from the national grid. Otherwise its night-time operation may be limited to one of the motel section, the filament section or the fiber section where the maximum noise from the factory beyond its fence line is within the 55 dB(A) day-time limit of the World Bank. If night-time operation must be carried out in all the sections, the power consumption may have to be reduced to pose no challenge to the ambient noise of the neighborhood.

## 4. Conclusions

The impact of noise from the use of off-grid generators on the environment was considered from the five scenarios and when all the generators were working simultaneously. When all the electric generators simultaneously operate in the factory, the ambient noise was 30.0-152.5 dB(A) with the minimum contribution within the factory being 70.0-84.4 dB(A) and the maximum contribution of 57.2-70.8 dB(A) outside the factory fence line. Though the maximum noise is 152.5 dB(A), the maximum noise of 70.8 dB(A) beyond the fence line shows a compliance with 70 dB(A) industrial and commercial area limit but breaches the residential area limit of the World Bank.

However, the maximum noise level of 70.8 dB(A) by receptors in Agbowa and Ifedapo in the factory's neighborhood may require that the factory limit its operation to day-time whenever there is shortage of electricity from the national grid. Otherwise its night-time operation may be limited to one of the motel section, the filament section or the fiber section where the maximum noise from the factory beyond its fence line is within the 55 dB(A) day-time limit of the World Bank. If night-time operation must be carried out in all the sections, the power consumption may have to be reduced to pose no challenge to the ambient noise of the neighborhood.

Susceptible individuals in the receptor locations may suffer temporary and permanent health problems as a result of short- and long-term exposure to the noise especially when all the generators are working simultaneously. The modeling results suggest that there is need for the authorities and policy makers concerned to prefer preventive and regulatory measures to reduce off-grid generator related noise. Noise could be reduced at the source by incorporating a good muffling system into the generators, building of firewalls around the sources and the use of alternative such as solar energy system which do not make noise during operation. Efforts should be geared toward the provision of sufficient, constant and stable electricity from the national grid for residential and industrial use by the Nigerian government.

## References

Adams, S.O., Akano, R.O. and Asemota, O.J. (2011), "Forecasting electricity generation in Nigeria using univariate time series models", *European Journal of Scientific Research*, Vol. 58 No. 1, pp. 30-37.

Agboola, O.P. (2011), "Independent power producer (IPP) participation: solution to Nigeria power generation problem", *Proceedings of the World Congress on Engineering 2011, Vol III, July 6-8, London*.

Babisch, W., Beule, B., Schust, M., Kersten, N. and Ising, H. (2005), "Traffic noise and risk of myocardial infarction", *Epidemiology*, Vol. 16 No. 1, pp. 33-40.

Babisch, W., Houthuijs, D., Pershagen, G., Cadum, E., Katsouyanni, K., Velonakis, M., Dudley, M.L., Marohn, H.D., Swart, W., Breugelmans, O., Bluhm, G., Selander, J., Vigna-Taglianti, F., Pisani, S., Haralabidis, A., Dimakopoulou, K. and Zachos, I. (2009), "Annoyance due to aircraft noise has increased over the years – results of the HYENA study", *Environment International*, Vol. 35 No. 8, pp. 1169-1176.

Berglund, B., Lindvall, T. and Schwela, D. (1999), *Guidelines for Community Noise*, World Health Organization (WHO), Geneva, 141pp.

Can, A., Rademaker, M., Renterghem, T.V., Mishra, V., Poppel, M.V. and Touhafi, A., *et al.* (2011), "Correlation analysis of noise and ultrafine particle counts in a street canyon", *Science of the Total Environment*, Vol. 409 No. 3, pp. 562-572.

Diniz, F.B. and Zannin, P.H. (2004), "Noise impact caused by electrical energy substations in the city of Curitiba, Brazil", *Science of the Total Environment*, Vol. 328 Nos 1/3, pp. 23-31.

Dursun, S., Ozdemir, C., Karabork, H. and Kocak, S. (2006), "Noise pollution and map of Konya city in Turkey", *J. Int. Environmental Application & Science*, Vol. 1 Nos 1/2, pp. 63-72.

El-Fadel, M., Shazbak, S., Baaj, M.H. and Saliby, E. (2002), "Parametric sensitivity analysis of noise impact of multihighways in urban areas", *Environmental Impact Assessment Review*, Vol. 22 No. 22, pp. 145-162.

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

Fhyri, A. and Klaboe, R. (2009), "Road traffic noise, sensitivity, annoyance and self-reported health – a structural equation model exercise", *Environment International*, Vol. 35 No. 1, pp. 91-97.

Franssen, E.A.M., Staatsen, B.A.M. and Lebret, E. (2002), "Assessing health consequences in an environmental impact assessment – the case of Amsterdam Airport Schiphol", *Environmental Impact Assessment Review*, Vol. 22 No. 6, pp. 633-653.

Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers, S.I. and Kenchington, E. (2012), "The environmental interactions of tidal and wave energy generation devices", *Environmental Impact Assessment Review*, Vol. 32 No. 1, pp. 133-139.

Guedes, I.C.M., Bertoli, S.R. and Zannin, P.H.T. (2011), "Influence of urban shapes on environmental noise: a case study in Aracaju – Brazil", *Science of the Total Environment*, Vol. 413, pp. 66-76.

Hamoda, M.F. (2008), "Modeling of construction noise for environmental impact assessment", *Journal of Construction in Developing Countries*, Vol. 13 No. 1, pp. 79-89.

Heywood, J.B. (1988), *Internal Combustion Engine Fundamentals*, McGraw-Hill Inc, New York, NY.

Kisku, G.C. and Bhargava, S.K. (2006), "Assessment of noise level of a medium scale power plant", *Indian Journal of Occupational and Environmental Medicine*, Vol. 10 No. 3, pp. 133-139.

Malago, J.S. and Mkoma, S.L. (2012), "Assessment of noise pollution and population exposure in central areas of Morogoro municipality, Tanzania: impact of use of portable fuel generators", *Journal of Chemical, Biological and Physical Sciences*, Vol. 2 No. 2, pp. 1115-1122.

Mehdi, M.R., Kim, M., Seong, J.C. and Arsalan, M.H. (2011), "Spatio-temporal patterns of road traffic noise pollution in Karachi, Pakistan", *Environment International*, Vol. 37 No. 1, pp. 97-104.

Mogal, S.P., Behera, R.K. and Pawar, S.Y. (2011), "Design and development of muffler for diesel generator set for reduction of noise", *International Journal of Engineering Science and Technology*, Vol. 3 No. 4, pp. 3591-3595.

Murphy, E. and King, E.A. (2010), "Strategic environmental noise mapping: methodological issues concerning the implementation of the EU Environmental Noise Directive and their policy implications", *Environmental International*, Vol. 36 No. 3, pp. 290-298.

Murphy, E., King, E.A. and Rice, H.J. (2009), "Estimating human exposure to transport noise in central Dublin, Ireland", *Environmental International*, Vol. 35 No. 2, pp. 298-302.

National Population Commission (Nigeria), (NPC) (2006), "Population census", available at: www.npc.gov.ng (accessed October 11, 2012).

Nnaji, B. (2011), "Power sector outlook in Nigeria: government renewed priorities", presentation at Securities and Exchange Commission, Abuja, June.

NoiseMap (2006), "Bronchure on NoiseMap enterprise and server editions", *Atkins Acoustic, Noise and Vibration*, pp. 1-4.

Odigure, J.O. and AbdulKareem, A.S. (2000), "Mathematical modeling of pollutants' migration from gas flaring in the Niger – delta area", *J. Assoc. Adv. Model. Simul. Enterprises*, Vol. 62 No. 3, pp. 57-68.

Odigure, J.O., AbdulKareem, A.S. and Adeniyi, O.D. (2004), "Mathematical modeling and computer simulation of noise radiation by generator", *Australian Journal of Technology*, Vol. 7 No. 3, pp. 111-119.

Olabiyi, B.A., Adegbola, A.A. and Kolawole, O.P. (2012), "A review of installation, operation and maintenance of internal combustion engine (ice) powered lighting sets in a developing country", *Journal of Emerging Trends in Engineering and Applied Sciences*, Vol. 3 No. 4, pp. 572-575.

Osueke, C.O. and Ezeh, C.T. (2011), "Assessment of Nigeria power sub-sector and electricity generation projections", *International Journal of Scientific & Engineering Research*, Vol. 2 No. 11, pp. 1-7.

Parvathi, K. and Gopalakrishnan, A.N. (2003), "Studies on control of noise from portable power generator", in Bunch, M.J., Suresh, V.M. and Kumaran, T.V. (Eds), *Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December*, Department of Geography, University of Madras and Faculty of Environmental Studies, Chennai and York University, York, pp. 328-338.

Prasher, D. (2003), "Estimation of hearing damage from noise exposure", Report on the technical meeting of exposure – response relationships of noise on health, World Health Organisation and European Centre for Environment and Health, Bonn, September 17-19, 2002.

Sobotova, L., Jurkovicova, J., Stefanikova, Z., Sevcikova, L. and Aghova, L. (2010), "Community response to environmental noise and the impact on cardiovascular risk score", *Science of the Total Environment*, Vol. 408 No. 6, pp. 1264-1270.

Sonibare, J.A., Latinwo, I., Akeredolu, F.A. and Solomon, B.O. (2003), "Assessment of ambient industrial noise level in the three industrial estate of Kano, Nigeria", *Journal of Environmental Studies and Policy*, Vol. 6 No. 1, pp. 35-44.

Stephen, O.O., Yanli, L., Wei, Z. and Hui, S. (2012), "Impact of PV generation for small autonomous electricity generation in Nigeria", *Transnational Journal of Science and Technology*, Vol. 2 No. 7, pp. 81-90.

Tandon, N. (2000), "Noise reducing designs of machines and structures", *Sadhana*, Vol. 25 No. 3, pp. 331-339.

Tandon, N., Nakra, B.C., Sarka, B. and Adyanthaya, V. (1997), "Noise control of two wheeler scooter engine", *Applied Acoustics*, Vol. 51 No. 4, pp. 369-380.

Vlachokostas, C., Achillas, C., Michailidou, A.V. and Moussiopoulos, N. (2012), "Measuring combined exposure to environmental pressures in urban areas: an air quality and noise pollution assessment approach", *Environment International*, Vol. 39, pp. 8-18.

Wang, C.N. and Crocker, M.J. (2002), "A theoretical study of mufflers with open ended intruding perforated tubes", *Int J Acoust Vib*, Vol. 7 No. 3, pp. 172-176.

World Bank (1998), *Pollution Prevention and Abatement Handbook*, World Bank, Washington, DC.

World Bank (2005), *Energy Sector Management Assistance Program. Nigeria: Expanding Access to Rural Infrastructure Issues and Options for Rural Electrification, Water Supply and Telecommunications*, The International Bank for Reconstruction and Development, Washington, DC.

Xie, H., Kang, J. and Tompsett, R. (2011), "The impacts of environmental noise on the academic achievements of secondary school students in greater London", *Applied Acoustics*, Vol. 72 No. 8, pp. 551-555.

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