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LEVELS, TRENDS AND EXPOSURE DOSES OF NOISE EMITTED BY SMALL SCALE ENTERPRISES IN ABEOKUTA, SOUTH-WESTERN NIGERIA

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ABSTRACT

Monitoring of noise levels and their impact are common in large scale and corporate industrial establishments while the small scale industries have not received sufficient attention. Consequently, the present study examined the levels and pattern of noise emission from small-scale enterprises that are generally ignored from compliance monitoring of the relevant agencies. The study utilises the results of noise emission quantification, determination of safe distance to the selected small-scale enterprises and impact on human as input for noise policy formulation. Three types of small-scale enterprises sampled from seventy-five (75) sites in Abeokuta were selected for noise measurement using a portable noise meter. Questionnaire and field observation were employed to assess the impact of noise on machine operators and their apprentices. Mean noise emission from the aluminum slitting machines ranged from 103.9 – 118.4 d(BA), iron welding machines; 97.0 – 108.8 d(BA) and food grinding machines; 91.6 to 108.2 d(BA). Daily Noise Dose (DND) from these three types of machine workshops were 800 – 19230% (aluminum slitter), 200 – 2400% (iron welder), and 100 – 3305% (food grinder). Time Weighted Average (TWA) for 8 hours noise exposure values were 94.0 – 107.8, 88.0 – 98.8 and 85.0 – 100.2 respectively. The spatial dimension of noise emission from the studied machines showed that acceptable levels were obtained at 20 meters from the machines sites. As predictors of variations in noise emission, the age of the machines explained 8.3 – 13.6%, 17.2 – 17.8% and 29.1 – 55.4% of noise emitted by food grinders, aluminum slitters and iron welders. The capacities of the studied machines predicted 7.9 – 13.5%, 18.4 – 30.5 and 43.9 – 56.3% of the noise emitted by iron welders, aluminum slitter and food grinders respectively. While the noise levels at the sites of the machines were significantly higher than the permissible limit, 25% of the workers were exposed for upwards of 10 hours daily and 30% for more than five years. The array of health problems; stress, dizziness, tinnitus, sleep disturbance and speech interference, experienced by the machines operators may not be unconnected to their non-use of Personal Protective Equipment (PPE) to minimize noise hazard. Policy formulation for public protection from noise pollution should prescribe limit for small scale enterprises, enforce noise level compliance, monitor wearing of appropriate PPE by machine operators and maintained a minimum of 20 meters between the sites of these machines and other human activities.

Keywords: Noise pollution, environmental quality, public health, spatial dimension, regression, Nigeria

INTRODUCTION

Assessment of noise pollution levels and their impacts on human population began in the workplace several decades ago and has dominated acoustic research to date. To a large extent, occupational noise studies have focussed on large-scale and corporate industries while small-scale enterprises are given minimal consideration in the Third World Countries. Generally, micro and small-scale enterprises outnumber large firms by a wide margin and also employ many more people, by aggregate. The observed upsurge and rapid expansion of small and medium-scale enterprises (SMEs) is an offshoot of the modern capitalist development (Gibson and van der Vaart, 2008; Onyebueke, 2013). SMEs have comparative advantages of efficiency in job creation, innovativeness and rapid growth than the larger firms.

Considering the findings of the available few studies in Nigeria, abysmally high noise levels were emitted by small and medium-scale industries compared to large-scale industries (Sonibare *et al*., 2004). The fact that SMEs are unorganised spatially, unregulated and sometimes unregistered, make them to evade environmental compliance monitoring by relevant agencies. Moreover, the fewness of employees engaged by each of them has relegated the health concerns of their workforce to the background. Noise control and protection of exposed workers are the least concerns of most small enterprises. In Nigeria, the informal sector employs a minimum of 70 percent of the active labour force and contributes more than 58 percent to Gross National Income (Akinrinola, 2011; Scheider, 2002). Notable among the micro and small–scale enterprises found within or around residential areas in urban Nigeria are; food grinders, concrete-block moulders, wood millers, aluminium cutters and iron welders (Egunjobi, 1983; Oguntoke *et al.* 2012a). High noise levels generated by the machines used by these enterprises are injurious to human health and well-being, particularly, the infirmed, children and the elderlies (Sexton *et al*. 1993; Stansfeld and Matheson, 2003). Hence, beyond the economic gains, the rapid growth of SMEs, their deregulated nature and gross informality portend negative implications for environmental quality and health of their workers.

According to the findings of Sonibare *et al.* (2004), the levels of noise emitted by small-scale tanneries were higher than levels assessed in some large-scale industries. This probably motivated authors to seek for quick intervention of relevant agencies, by way of setting and enforcing noise limits for the small-scale industry. Agreeing with the aforementioned authors, Oguntoke *et al.* (2012a), submitted after monitoring noise levels at selected small-scale block factories that more research attention should be given to acoustic characterisation of many more small-scale enterprises. With disproportional high noise level, spatial preference for residential areas, non-use of protective equipment by workers and the exemption of SMEs from compliance monitoring in Nigeria, more studies are required to inform appropriate policy formulation. This to a large extent, will safeguard the health of workers and nearby residents who are exposed to high daily noise dose with the resultant auditory and non-auditory impacts (NIOSH, 1996; Smith *et al*., 2005).

Notable non-auditory impact of noise exposure among humans includes frequent headache, dizziness, nervousness, irritability, loss of sleep, anger, dissatisfaction, depression, anxiety, agitation, cardiovascular and gastric disorders and increased blood cholesterol level (Abel, 1990; Kieman, 1997; Fields, 1998). Due to poor awareness of noise as a precursor to most of these abnormal responses, drug-therapy is often adopted as the panacea instead of personal protection from noise pollution. Another emerging problem associated with human exposure to noise is partial deafness or hearing impairment. In the Developed and Third World Countries, cases of sensorineural and conductive hearing disorders are on the increase. For instance, the increased cases of poor auditory discrimination and speech perception among children have been linked to their exposure to high noise levels (Evans and Maxwell, 1997). Similarly, cases of raised blood pressure, stress and defects in reading ability and incessant feeling of helplessness are escalating among children (Evans and Lepore, 1993, Evans *et al*. 2001) due to their exposure to noise pollution.

Globally, over 275 million people are affected by hearing impairments, which are largely noise-induced and 80 percent of them are in low- and middle income countries (WHO, 2012a). As a result, millions of years of healthy life are lost due to occupational noise-induced hearing loss. Higher proportion of this health problem among men has been attributed to their exposure to noise pollution in the work environment (Hear-it.org, 2012). The spatial disaggregation of occupational noise impact showed that the developing countries accounted for about 3.8 million years of healthy life on an annual basis in 2000 compared to 0.3 million years in developed countries (Nelson *et al*., 2005). In the same vein, Noise induced hearing loss (NIHL) represents a much heavier burden in the developing countries where the available medical facilities are grossly inadequate to treat the already existing diseases.

According to the WHO (2001) guideline on community noise, the limit of human exposure to noise is set at 85 dB (A) while in Nigeria, noise limit in the workplace is fixed at 90 dB (A) by the National Environmental Standards Regulation and Enforcement Agency (NESREA, 2007). Although noise emission at levels above 90 dB (A) in the work environment is prohibited by NESREA Act of 2007, little is done to enforce compliance by establishments. Worse still, occupationally exposed workers are not mandated to wear protective gadgets so as to minimise the impact of noise on their health and well-being. Hence, the present study seeks to portray the levels and trend of noise emission from small-scale enterprises that are generally exempted from compliance monitoring and are less studied.

THE STUDY AREA

Abeokuta city is the political capital of Ogun state in the South-western part of Nigeria. It traverses parts of Abeokuta north, Abeokuta south, Odeda and Obafemi/Owode Local Government Areas (LGAs) with a land area of 1256 km^2. The population of the metropolis was put at 725,366 people in 2006; by estimation 980,827 people are currently living in the area. The city-region is located between Latitude 6°51′ – 7°2′′ N and Longitude 3°5′ –3°20′ E (Figure 1).

As the city witnesses rapid population growth from rural-urban migration, influx of people from Lagos, a nearby mega-city and natural increase, there has been a concomitant spatial spread of the city region. The spread of residential areas are observable at the fringes of the city. Due to the unavailability of sufficient white-collar jobs, most residents engage in micro-small scale businesses in order to earn income for their survival and family upkeep. Apart from the sale of products ranging from daily needs to food items, small enterprises that require some levels of skill acquisition are attractive to secondary school leavers who undergo training for two or three years before securing informal certification to own and operate aluminium and iron workshops. As a result of the informal nature of these workshops, activities are conducted without strict adherence to work-safety rules and more often workshop sites are selected without due consideration for welfare of the residents in the neighbourhoods.

MATERIALS AND METHODS

Two categories of data were collected for this study; noise measurement data and interview to elicit information from the workers of the selected SMEs and their apprentices. Due to the informal nature of the studied SMEs, the aggregate number of their sites was practically difficult to determine. Nevertheless, a total of 50 workshops/ sites were randomly sampled (15 aluminium slitting workshops, 15 iron welding workshops and 20 food grinding centres) from 21 locations/areas in Abeokuta city. The locations are Abiola way, Adatan, Adigbe, Alogi, Araromi, Asero, Brewery, Camp, Harmony estate (Alabata), Ibara, Ijaye, Isabo, Kuto, Lafenwa, Obantoko, Odo-Eran, Onikoko, Onikolobo, Osiele, Sapon and Somorin. At each of the sample sites in the selected locations, noise measurements were taken in three (3) replicates in addition to field interview.

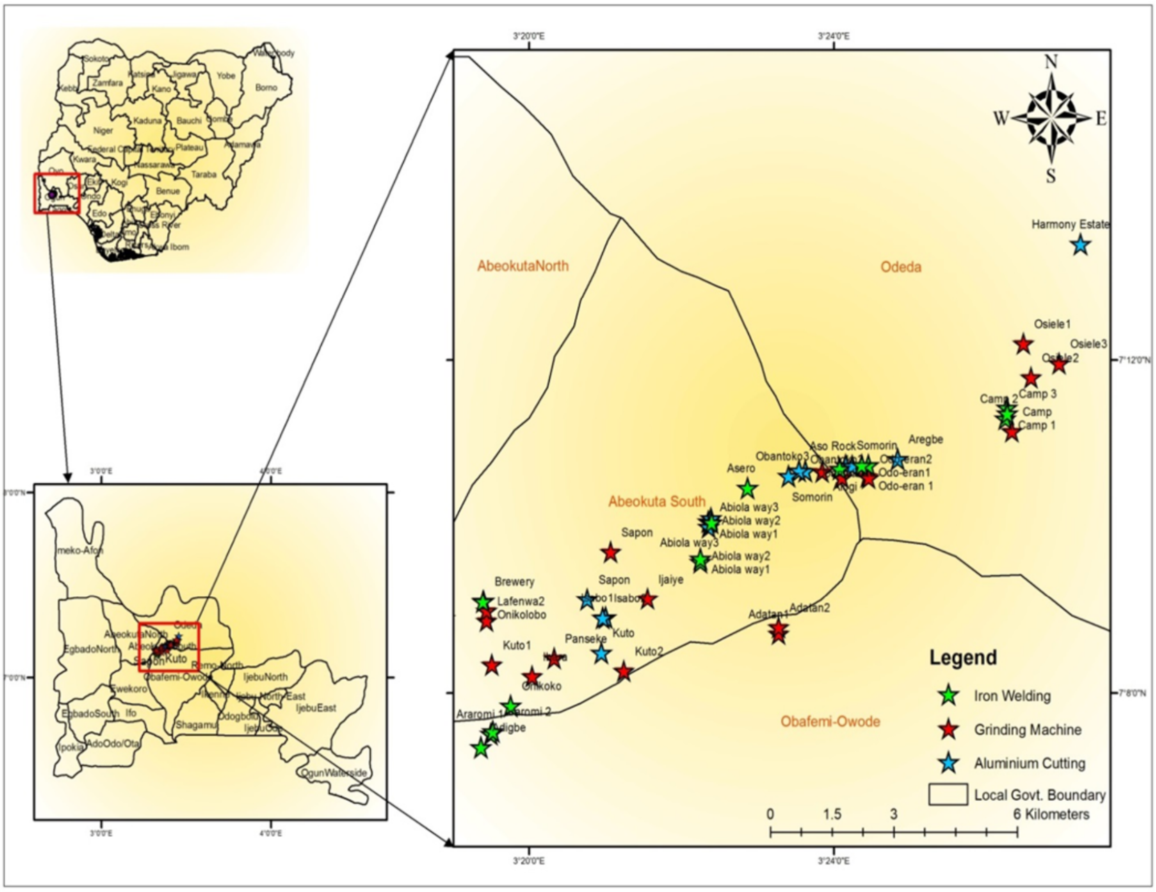

Figure 1: Map of the study area showing the sample sites in Abeokuta, Ogun state, Nigeria

Assessment of Noise levels at selected locations

A calibrated Smart Sensor Digital Sound Level Meter (model AR824 manufactured by Intell-Instruments™ Plus, United Kingdom) with a range of 30 – 130 dB(A) was employed to measure noise levels in three replicates at source (0 m), 10 and 20 m from the workshops. Sampling distance was limited to 20 m so as to minimize the interference of noise emitted by other human activities aside the targeted small-scale enterprises. The meter was calibrated prior to the commencement of the field work. New batteries were also inserted in the meter in order to ensure accurate readings of sound levels. Noise levels were measured with the sound level meter (microphone inserted) held in the direction of noise emission at 1.5 m above the ground level, being the average ear-ground height for adults (Onuu, 2000). At the sample point, the instrument was allowed to read for about 10 seconds after which the maximum and normal noise values were recorded. This process was repeated thrice (triplicate) for each of the sample sites. The control noise levels were obtained at each site by switching off the investigated machines, hence the background noise levels were taken as the control. This is considered conceptually ideal rather than taking the noise levels in a quiet environment such as botanical garden or an arboretum that is characterised by extremely low sound level. Noise monitoring was conducted between 9.00 am and 7.00 pm each day of the fieldwork so as to capture the more active period of the day.

In addition, the operators of the sampled machines were interviewed so as to elicit information on machine age, capacity and maintenance/servicing. This information collected through checklist method was used for determining the variability of noise emission from the machines. In all, 79 respondents comprising machine operators and their apprentices were selected for oral interview at each site where noise measurements were conducted. These respondents were those that gave verbal consent to participate in the data gathering.

Data analysis

Data collected on noise levels generated by the machines and the checklist were entered into Microsoft Excel spread-sheets and afterward imported into the SPSS software (SPSS® IBM™ version 20.0) for analyses. Statistical tools such as means, Analysis of Variance (ANOVA), Duncan Multiple Range Test (DMRT), correlation and regression were employed to analyse the data collected from field measurements.

Daily noise dose (D) and the Time weighted average (TWA - 8h) exposure of the machine operators and workshop workers were calculated using the formulae published by the United States Department of Health and Human services (1998). Fifteen (15) minutes monitoring period was used for computing the exposure period of workers at the respective workshops sampled for this study. Moreover, 85 dB(A) occupational exposure limit for 8 hours used by most international communities and 3 dB(A) exchange rate are engaged as reference in this study (CCOHS, 2016). The formulae for calculating D and TWA are presented as equations 1 and 2.

$$D = \left[\frac{C1}{T1} + \frac{C2}{T2} + \frac{C3}{T3} \ldots\ldots\ldots.. + \frac{Cn}{Tn}\right] 100 \quad \ldots\ldots \qquad 1$$

Where C1 . . . . Cn represent the total time of exposure to measured noise levels at the sampled site

T1 . . . . Tn stand for the permissible duration for the measured noise level

The allowable limit of D value is 100; any exceedance is unsafe

$$\text{TWA} = 10 \text{ x } \text{Log}\left(\frac{D}{100}\right) + 85 \quad \ldots\ldots \qquad 2$$

Where D represents daily noise dose as computed in equation 1

The maximum TWA value using this formula is 85 while lower values are preferable

RESULTS AND DISCUSSION

The sampled aluminum machines have capacities that ranged between 1400–2000 watts (Table 1). Mean noise emission from the machine workshops were from 103.9 – 118.4 dB(A). The minimum mean noise level was emitted by machine that had 1800 watts capacity while the maximum was measured at the workshop that operated on 2000 watts machine.

Table 1: Mean noise levels and Noise Dose emitted by Aluminum cutting machines

Location	Machine capacity (Wattage)	Mean Noise Level (dBA)	Noise dose (%)	TWA (8 hours)
Somorin	1800	103.9	800	94.0
Aso Rock	1600	110.5	5010	102.0
Aregbe	1400	113.5	6410	103.1
Obantoko 1	1800	114.7	3200	100.1
Obantoko 2	1400	107.8	7210	103.6
Obantoko 2	1450	105.5	1920	106.0
Abiola Way 1	1400	113.8	6410	103.1
Abiola Way 2	1450	113.2	4810	101.8
Sapon	1600	116.4	19230	107.8
Brewery	1400	112.9	6410	103.1
Kuto	1450	107.5	1400	96.5
Isabo 1	2000	115.3	9620	104.8
Isabo 2	2000	118.4	19230	107.8
Harmony Estate	1800	113.2	4810	101.8
Permissible limits		**85 dBA**	**100%**	**85.0**

TWA – Time Weighted Average for 8 hours

Similar to the pattern of mean noise emission from the sampled machines was the percentage of noise dose. The emission dose ranged between 800 and 19230% for 30 minutes of operation at 3 times per day. A slight variation observed in the pattern of noise dose was in respect of the machine sampled at Sapon. This machine had a lower mean noise level (116.4 dB(A) compared to a similar machine at Isabo 2 (second site) with a mean noise level of 118.4 dB(A).

The Time Weight Average (TWA 8 hours) of noise emission at the sample locations followed the same pattern presented by emission noise dose. In all the sampled workshops, noise level, noise dose and TWA (8 hours) were well above the maximum permissible limits of 85 dB(A), 100% and 85.0.

The sampled iron-welding machines from fifteen locations had capacities ranging from 2200 – 2350 watts (Table 2). The mean noise values emitted by the machines in the various workshops were from 97.0 – 108.5 dB (A). While the minimum level was generated by the machine (2350 watts) monitored at Onikoko, the highest was assessed from the machine (2200 watts) sampled at Brewery. It is noteworthy that the levels of noise emitted by the machines was not consistent with their capacities; while some machines with 2200 Watts emitted 99.8–108.5 dB(A), others with 2350 Watts emitted 97.0–106.1 dB(A).

Table 2: Mean Noise levels and Noise Dose emitted by Iron welding machines

Location	Machine capacity (Watts)	Mean Noise level dB(A)	Noise dose (%)	TWA (8 hours)
Brewery	2200	108.5	2000	98.0
Camp 1	2200	104.5	1000	95.0
Camp 2	2200	99.8	300	89.8
Camp 3	2200	103.2	800	94.0
Obantoko 1	2200	103.9	800	94.0
Obantoko 2	2200	103.0	600	92.8
Obantoko 3	2200	107.6	2000	98.0
Asero	2350	106.1	1200	95.8
Abiola Way 1	2200	102.4	600	92.8
Abiola Way 2	2350	103.8	600	92.8
Abiola Way 3	2200	102.8	600	92.8
Araromi 1	2350	97.0	200	88.0
Araromi 2	2350	108.8	400	91.0
Adigbe	2200	101.2	2400	98.8
Onikoko	2350	97.0	250	89.0
Permissible limits		**85 dBA**	**100%**	**85.0**

TWA – Time Weighted Average for 8 hours

Noise dose and TWA (8 hours) showed a similar pattern, noise dose level was highest (2400%) at Adigbe, followed closely by 2000% at Obantoko (third site) and Brewery. The lowest dose (200%) was computed for the machine sampled at Araromi (first site). All sampled iron-welding machines emitted noise above 85 dB(A), 100% noise dose and 85.0 TWA (8 hours).

All the food grinding machines sampled in the study locations had capacities that ranged between 4470 and 5220 watts (Table 3). The levels of noise emitted at the workshops were from 91.6 to 108.2 dB(A). While the lowest level was monitored at Sapon, the highest was emitted by the workshop at Alogi. Noise dose and TWA values were highest at Odo-Eran (3305%), Alogi, Somorin and Lafenwa (2400%) followed by 2000% at Onikolobo. At five of the selected locations (Odo-Eran 1, Osiele 2, Osiele 3, Kuto 1, and Panseke), both noise dose and TWA were within the permissible limits.

Table 3: Mean Noise levels, Noise Dose and TWA (8 hours) of grinding machines

Location	Machine capacity (Watts)	Mean Noise Levels dB(A)	Noise dose (%)	TWA (8 hours)
Alogi	4470	108.2	2400	98.8
Somorin	5220	107.2	2400	98.8
Odo-Eran 1	4470	92.3	100	85.0
Odo-Eran 2	4470	101.1	3305	100.2
Odo-Eran 3	4470	97.2	350	90.4
Osiele 1	4845	92.1	250	89.0
Osiele 2	4470	92.3	100	85.0
Osiele 3	4470	94.4	100	85.0
Adatan 1	4470	92.6	300	89.8
Adatan 2	4845	93.6	300	89.8
Kuto 1	4470	92.4	100	85.0
Kuto 2	5220	97.4	300	89.8
Lafenwa 1	4845	93.1	250	89.0
Lafenwa 2	4845	107.2	2400	98.8
Panseke	5220	93.2	100	85.0
Ibara	5220	97.3	400	91.0
Ijaiye	4845	93.1	300	89.8
Onikolobo	4470	101.1	2000	98.0
Sapon	4470	91.6	125	86.0
Camp	4845	93.1	300	89.8
Permissible limits		**85 dBA**	**100%**	**85.0**

TWA – Time Weighted Average for 8 hours

The Time Weight Average (TWA 8 hours) of noise emission at the sampled locations followed the same pattern presented by noise dose. In most of the sampled workshops, noise level, noise dose and TWA (8 hours) were well above the permissible limits of 85 dB(A), 100% and 85.0.

Exposure to high noise levels, which translates to noise pollution have implications for the auditory and non-auditory health of workers (operators and apprentices) and nearby persons who interact with the workshops environment on daily basis. Worse still, the workers and nearby people do not wear any personal protective equipment or install any physical barrier between themselves and the noise pollution sources.

Spatial variation in the level of Noise emitted by the sample machines

At distances of 10 and 20 m from the sampled aluminum slitting machine workshops, mean noise levels declined from 79.8 – 95.2 dB(A) to 73.3 – 87.2 dB(A). This decline was recorded at all aluminum slitting sites. Moreover, there were significant variations in the mean level of noise among the workshop sites at 10 m and also at 20 m (Table 4). At 10 m from the aluminum slitting machine workshops, noise levels exceeded the permissible limit in more than 60% of the sample sites. Mean noise levels were only within the permissible limits at 20 m, where readings were generally below 85 dB(A). This spatial trend across distances is similar to the safe distance assessed by Tsepav *et al.* (2011) in the study of some facilities that emit noise in Lappai, Nigeria.

Table 4: Variation in mean Noise Levels at distances from Aluminum Slitting workshops

Location	0 m	10 m	20 m	Control
Somorin	103.9 ± 1.5^{a}	84.0 ± 2.6^{bc}	75.6 ± 2.9^{a}	71.9 ± 1.4^{e}
Aso Rock	110.5 ± 5.9^{cd}	85.5 ± 4.2^{cd}	83.6 ± 2.1^{cde}	65.0 ± 1.9^{bc}
Aregbe	113.5 ± 0.6^{def}	81.8 ± 1.0^{abc}	74.7 ± 3.9^{a}	64.1 ± 1.1^{b}
Obantoko 1	114.7 ± 1.4^{efg}	93.4 ± 2.1^{fg}	81.7 ± 0.8^{bcd}	66.5 ± 0.7^{c}
Obantoko 2	107.8 ± 3.4^{bc}	92.2 ± 2.0^{fg}	81.3 ± 1.3^{bc}	63.8 ± 0.4^{b}
Obantoko 3	105.5 ± 3.2^{ab}	92.8 ± 0.8^{fg}	80.6 ± 1.3^{bc}	65.6 ± 0.8^{bc}
Abiola way 1	113.8 ± 0.2^{def}	95.2 ± 0.9^{g}	84.1 ± 2.6^{cde}	68.8 ± 0.5^{d}
Abiola way 2	113.2 ± 0.5^{def}	94.8 ± 4.1^{g}	87.1 ± 0.7^{e}	65.3 ± 1.2^{bc}
Abiola way 3	112.2 ± 0.3^{de}	84.6 ± 0.4^{bcd}	79.1 ± 1.2^{b}	64.0 ± 0.9^{b}
Sapon	116.4 ± 0.6^{fg}	92.6 ± 0.6^{fg}	85.1 ± 1.2^{de}	61.4 ± 1.0^{a}
Brewery	112.9 ± 0.4^{def}	87.8 ± 1.3^{de}	81.1 ± 0.8^{bc}	69.8 ± 0.9^{d}
Kuto	107.5 ± 0.6^{abc}	79.8 ± 0.9^{a}	75.2 ± 0.6^{a}	61.6 ± 1.2^{a}
Isabo 1	115.3 ± 0.4^{efg}	90.5 ± 0.9^{ef}	81.0 ± 1.4^{bc}	64.8 ± 0.3^{bc}
Isabo 2	118.4 ± 0.9^{g}	93.0 ± 2.7^{fg}	87.2 ± 4.0^{e}	64.9 ± 0.6^{bc}
Harmony Estate	113.2 ± 0.7^{def}	81.7 ± 0.7^{ab}	73.3 ± 2.1^{a}	61.4 ± 0.2^{a}

Locations with same superscripted alphabet (a, b, c, …..) column-wise have no significant variation at $p \leq 0.05$

Similarly, mean noise levels declined from 81.2 – 91.5 dB(A) at 10 m to 71.7 – 86.3 dB (A) at 20 m from iron welding workshops. The background noise (control) ranged between 56.0 and 73.0 d BA. While the mean noise levels were above the permissible limit of 85 d BA except at three sites, only one site had noise value that exceeded the limit at 20 m from the iron welding workshops. Humans that were found at 20 m away from the iron welding workshops were not exposed to noise pollution.

Table 5: Variation in mean Noise levels at distances from Iron Welding workshops

Location	0 m	10 m	20 m	Control
Brewery	108.5 ± 1.1^{fg}	91.2 ± 1.0^{d}	85.5 ± 2.1^{h}	70.8 ± 1.6^{f}
Camp 1	104.5 ± 0.6^{de}	90.2 ± 0.8^{d}	74.8 ± 0.4^{bc}	73.0 ± 0.2^{f}
Camp 2	99.8 ± 0.5^{b}	83.2 ± 0.5^{a}	73.3 ± 0.7^{abc}	71.8 ± 1.0^{f}
Camp 3	103.2 ± 1.5^{cd}	90.2 ± 0.7^{d}	81.9 ± 2.0^{fg}	67.9 ± 2.0^{e}
Obantoko 1	103.9 ± 0.8^{cd}	89.9 ± 0.8^{d}	86.3 ± 0.5^{h}	60.1 ± 1.6^{bc}
Obantoko 2	103.0 ± 1.0^{de}	87.5 ± 0.8^{bc}	72.8 ± 1.7^{ab}	58.4 ± 1.0^{b}
Obantoko 3	107.6 ± 0.5^{cd}	91.5 ± 2.1^{d}	84.0 ± 1.2^{gh}	59.4 ± 0.9^{bc}
Asero	106.1 ± 1.0^{fg}	91.0 ± 2.8^{d}	80.1 ± 0.2^{ef}	56.0 ± 2.7^{a}
Abiola way 1	102.4 ± 1.0^{ef}	90.0 ± 0.3^{d}	81.9 ± 2.9^{fg}	67.5 ± 2.9^{e}
Abiola way 2	103.8 ± 0.1^{de}	89.4 ± 1.1^{c}	75.6 ± 2.6^{cd}	71.9 ± 0.1^{f}
Abiola way 3	102.8 ± 0.4^{cd}	86.9 ± 0.9^{b}	71.7 ± 1.0^{a}	59.7 ± 1.0^{bc}
Araromi	97.0 ± 1.7^{a}	81.2 ± 1.1^{a}	75.1 ± 0.3^{bc}	59.6 ± 0.8^{bc}
Adigbe	101.2 ± 0.4^{bc}	86.7 ± 0.8^{b}	74.1 ± 0.1^{abc}	61.0 ± 0.4^{bc}
Araromi	108.8 ± 0.4^{g}	86.9 ± 0.6^{b}	78.4 ± 1.3^{e}	61.4 ± 1.3^{c}
Onikoko	97.0 ± 4.3^{a}	82.9 ± 0.3^{a}	77.8 ± 0.3^{de}	64.0 ± 0.3^{d}

Locations with same superscripted alphabet (a, b, c, …..) column-wise have no significant variation at $p \leq 0.05$

The sampled food grinding machines equally had reduced noise levels at 10 and 20 m compared to the levels monitored at sources (Table 6). Mean noise levels declined from 68.6 – 86.5 dB(A) (10 m) to 63.7 - 75.6 dB(A) (20 m) compared to 47.1 – 60.7 at the control sites (background noise). At 10 m, the mean noise levels were generally within the permissible limit except at one site, Adatan 2 (86.5 d BA). Distance can be used as an environmental factor for preventing humans from exposure to noise pollution from point-sources. According to Kabir and Madugu (2010), Tajudeen and Okpuzor (2011) and Oguntoke *et al*. (2012b), distance from the source of pollution has been identified as a strategy for ameliorating or preventing exposure to pollution hazard and the associated impacts.

The level of noise emitted by the food grinding machines were relatively lower at all distances (0, 10 and 20 m) compared to the iron welding and aluminum slitting machines.

Generally, noise levels measured at distances away from all the food grinding machines declined from 0 m (91.6 – 108.2 dB(A) to 10 m (68.8 – 82.1 (dB(A) and 20 m (63.0 – 75.4 dB(A) as shown in Table 6.

Table 6: Variation in mean Noise levels at distances from Food Grinding machines

Location	0 m	10 m	20 m	Control
Alogi	108.2 ± 5.3^{i}	79.5 ± 0.8^{h}	71.8 ± 0.6^{h}	55.0 ± 4.0^{b}
Somorin	107.2 ± 1.0^{h}	82.1 ± 0.9^{i}	75.4 ± 0.7^{j}	57.9 ± 2.9^{bc}
Odo-Eran 1	92.3 ± 0.6^{abc}	71.9 ± 1.7^{bc}	68.7 ± 0.9^{c}	47.9 ± 2.1^{a}
Odo-Eran 2	101.1 ± 0.8^{g}	74.3 ± 0.9^{ef}	69.6 ± 0.5^{cdef}	47.6 ± 2.5^{a}
Odo-Eran 3	97.2 ± 0.6^{f}	77.1 ± 0.5^{g}	71.1 ± 0.2^{gh}	47.2 ± 2.1^{a}
Osiele 1	92.1 ± 0.8^{ab}	73.8 ± 0.3^{de}	70.6 ± 1.1^{efgh}	58.9 ± 1.5^{bc}
Osiele 2	92.3 ± 0.6^{abc}	68.6 ± 0.8^{a}	63.8 ± 0.8^{a}	56.7 ± 4.2^{bc}
Osiele 3	94.4 ± 0.2^{e}	70.6 ± 1.2^{b}	63.7 ± 0.6^{a}	57.9 ± 1.2^{bc}
Adatan 1	92.6 ± 0.4^{bcd}	74.6 ± 0.9^{ef}	65.4 ± 1.6^{b}	60.7 ± 0.6^{c}
Adatan 2	93.6 ± 0.2^{de}	86.5 ± 0.5^{j}	69.2 ± 0.7^{cde}	58.9 ± 1.5^{bc}
Kuto 1	92.4 ± 0.2^{abc}	68.5 ± 0.5^{a}	64.0 ± 0.8^{a}	56.7 ± 4.2^{bc}
Kuto 2	97.4 ± 0.2^{f}	77.1 ± 0.5^{g}	71.3 ± 0.2^{gh}	65.7 ± 0.7^{d}
Lafenwa 1	93.1 ± 0.4^{bcd}	75.3 ± 0.5^{f}	71.0 ± 0.2^{fgh}	58.9 ± 1.5^{bc}
Lafenwa 2	107.2 ± 0.4^{h}	80.6 ± 0.7^{h}	75.6 ± 0.4^{i}	59.2 ± 0.1^{bc}
Panseke	93.2 ± 0.1^{cd}	69.3 ± 0.5^{a}	63.0 ± 0.9^{a}	47.2 ± 2.1^{a}
Ibara	97.3 ± 0.3^{f}	77.5 ± 0.6^{g}	70.9 ± 0.8^{fgh}	47.1 ± 2.4^{a}
Ijaiye	93.1 ± 0.4^{cd}	73.9 ± 0.5^{def}	70.2 ± 0.7^{defg}	49.4 ± 0.4^{a}
Onikolobo	101.1 ± 0.5^{g}	74.3 ± 0.8^{ef}	69.0 ± 0.7^{cd}	47.7 ± 2.5^{a}
Sapon	91.6 ± 0.7^{a}	72.8 ± 0.8^{cd}	68.6 ±1.2^{c}	58.5 ± 1.2^{bc}
Camp	93.1 ± 0.4^{cd}	74.4 ± 0.5^{ef}	69.2 ±0.8^{cde}	59.7 ± 0.6^{c}

Locations with same superscripted alphabet (a, b, c, …..) column-wise have no significant variation at $p \leq 0.05$

Considering the level of noise emitted by each machine, there was irregular pattern of noise reduction from 0 – 20 m. Hence, sites that were found in one homogenous class at source (0 m) were separated into different groups at 10 m and likewise at 20 m. Considering all sampled food grinding machines, noise levels were lowest at the control sites (47.1 – 73.0 dB(A). Since the monitored background noise levels at the various sites (control) were below the permissible noise limit, higher noise levels assessed at distances from the machines showed their noise pollution impact.

The level of noise emitted by the food grinding machines were relatively lower at all distances (63.0–108.2 dB(A) compared to the iron welding (71.7 – 108.8 dB(A) and aluminum slitting machines (75.2 – 118.4 dB(A) – Tables 4, 5 and 6.

The level of noise emitted by the sampled machines showed significant positive correlation ($p<0.05$) with age and capacity of each machine (Table 7). Correlation coefficients (R) of machine age and noise generated ranged from R=0.169 to R=0.744 for all machines and between R=0.062 and R=0.662 for machine capacities. This positive association implies that noise emission from each machine will be high with high machine capacity and increased age of use. Age of machine and the capacity have been identified as two of the factors that determine machine noise generation (Mbuligwe, 2004).

In analyzing the explanatory factors of the monitored noise levels in the selected aluminum slitting machine workshops, machine age and capacity accounted for 17.2 and 30.5 % of the variations in noise levels at 0 m and 17.8 and 18.4% at 20 m (Table 7).

At the iron welding workshops, age of the machines and their capacities explained 55.4% and 7.9% of the emitted noise levels. Machine ages and capacities accounted for 29.1 and 10.7% of the variations in the level of noise emitted at 10 m from the workshops and, 36 and 13.5% of the variations in the levels of noise emitted at 20 m from the machines locations.

For the food grinding machines, age of machine was the only significant explanatory factor at 0 m; it accounted for 13.6% of the variation in the noise levels. At 10 m, 43.9 and 8.3% of the variations in the noise levels was explained by machines ages. Machine age and capacity accounted for 56.3 and 13.3% of the variations in the emitted noise levels ($p< 0.05$).

Between machine age and capacity used as explanatory factors, the former had a stronger influence on variations in the levels of noise emitted by iron welding machines. In the cases of aluminum slitting machines and food grinding machines, the machine capacities was the stronger determinant factor.

Among the sampled machine operators, 85 percent considered the work area to be noisy; 77 percent attributed the noise to the operation of aluminum slitting, iron welding and food grinding machines (Table 8). About 57 percent indicated that the noise so emitted by these machines was deleterious to their health. While 17 percent have hearing ailments, only 4 percent reported such ailments to health facilities. Generally, self-medication was adopted by some of the workers (14%).

Table 7: Regression of Noise levels against the capacity and age of sampled machines

Model	R	R^2	R^2 (%)	Std. error	F value	Sig. level
Aluminum slitting machines						
0 meters						
Machine Capacity (W)	0.522	0.305	30.5	2.281	18.83	0.001
Machine Capacity (W), Age (year)	0.691	0.477	47.7	2.000	13.90	0.001
10 meters						
Machine Capacity (W)	0.429	0.184	18.4	5.358	9.72	0.003
Machine Capacity (W), Age (year)	0.602	0.362	36.2	4.794	11.73	0.001
Iron welding machines						
0 meters						
Machine Age (year)	0.744	0.554	55.4	2.325	53.4	0.000
Machine Age (year), Capacity (W)	0.806	0.633	63.3	2.085	11.44	0.002
10 meters						
Machine Age (year)	0.540	0.291	29.1	3.166	17.68	0.000
Machine Age (year), Capacity (W)	0.631	0.398	39.8	2.952	7.46	0.009
20 meters						
Machine Age (year)	0.601	0.362	36.2	4.443	24.37	0.000
Machine Age (year), Capacity (W)	0.705	0.497	49.7	3.989	11.34	0.002
Food Grinding machines						
0 meters						
Machine Age (year)	0.368	0.136	13.6	5.401	5.800	0.0021
10 meters						
Machine Capacity (W)	0.662	0.439	43.9	2.684	28.93	0.0001
Machine Capacity (W), Age (year)	0.723	0.522	52.2	2.511	19.67	0.0001
20 meters						
Machine Capacity (W)	0.750	0.563	56.3	2.351	47.70	0.0001
Machine Capacity (W) , Age (year)	0.834	0.696	69.6	1.988	41.22	0.0001

On daily basis, about 60 percent of the workers were exposed to machine noise for 5 – 9 hours and another 25 percent for upward of 10 hours. Furthermore, almost 40 percent of the workers have worked as machine operators between 5 – 20 years. Exposure to noise above 85 dB(A) for 8 hours in the workplace has been linked to serious health effects in exposed humans (Smith *et al*. 2005). The exposure of a quarter of the machine operators to high noise levels for many years portends severe negative health implications for the machine operators and their apprentices.

Table 8: Assessment of noise level, exposure and impacts by the machine operators

Machine operators' assessment of noise	No. of respondents	Percent
Workshop area is noisy	67	84.8
Machine operation as source of noise	61	77.2
Exposure to noise affects health	45	56.9
Experienced hearing impairment	13	16.5
Ailment reported to hospital	3	3.8
Used self-medication for care	11	13.9
Daily exposure to machine noise		
< 5 hrs	12	15.2
5 – 9 hrs	47	59.5
10 hrs and more	20	25.3
Years of exposure on the job		
< 5 yrs	47	59.5
5 – 10 yrs	23	29.1
11 - 20 yrs	7	8.9
Other noise sources in the area		
Vehicular traffic	25	31.7
Use of power generators	17	21.5
Nearby markets	8	10.1
Block moulding machine	5	6.3

In spite of exposure of the machine operators to noise pollution generated by the studied machines, only 18 percent claimed the use of some sort of Personal Protective Equipment (PPE). Generally, 72 percent showed willingness to use PPE if provided, so as to minimize their exposure to noise pollution (Table 9). About 30 percent of the workers willing to change their jobs attributed this desire to many reasons, with only 6 percent mentioning the desire to avoid exposure to noise pollution from the machines. In cases where hazards associated with the jobs are practically difficult to be eliminated, PPE are used to minimize their impacts on the exposed workers (hear.it.org, 2012).

The specific ailments frequently suffered by the workers included stress (32%), dizziness (30%), tinnitus (24%) and sleep disturbance (22%). Frequent occurrence of these noise pollution-induced heath impacts points to the hazardous nature of these small-scale enterprises in the study area and other similar areas in Nigeria. Beyond mere coincidence, authors have indicated that these health problems have been found predominantly among people that are exposed to noise pollution (Fields, 1998; Kierman, 1997). Among block-moulder operators studied by Oguntoke *et al.* (2012a), more than 70 percent of them experienced the ailments mentioned above. Little surprise therefore, that hearing disorders are prevalent in low and medium income countries (Nelson *et al*. 2005; WHO, 2012b) where exposure to noise pollution is frequent.

Table 9: Use of PPE and Occurrence of Ailments among Machine Operator

Use of PPE	No. of respondents	Percent
Willing to use PPE	57	72.2
PPE not provided	43	54.4
PPE not necessary	22	27.8
Workers using PPE	14	17.7
Willing to change job	24	30.4
Change of job due to noise	5	6.3
Frequently experienced ailments		
Headache	15	19.0
Dizziness	24	30.4
Annoyance	13	16.5
Stress	25	31.6
Sleep disturbance	17	21.5
Tinnitus	19	24.1
Speech interference	17	21.5
Possibility of noise reduction	18	22.8

CONCLUSION

In this study, iron welding, aluminium slitting and food grinding machines used on commercial basis emit noise at levels above the permissible limits. The levels of noise emitted by these machines were within acceptable limit only at 20 m away from the machine workshops.

The machine operators, apprentices and nearby residents stand the risk of exposure to undesirable health consequences such as auditory and non-auditory (tinnitus, stress, dizziness and sleep disturbance) ailments.

The non-use of personal protective gadgets which would have minimized the impact of noise on workers and nearby residents was a serious issue. Non-provision of PPE was an issue in this regard, that is in cases where the appropriate ones are known to the people. These may include hear-muff, ear-plug and other hearing organs protection.

The spatial preference of the small scale enterprises for residential area portends more serious danger due to the exposure of the nearby residents who have no idea about noise control and hazard prevention mechanisms.

RECOMMENDATIONS

The policy implications of this study are that; spatial seclusion of seeming harmless (non-hazardous) small-scale economic activities from predominantly residential areas is pertinent. Secondly, workers at these workshops should be mandated to wear PPE in order to safeguard their health. Finally, the Environmental and Sanitation officers saddled with task of regulation and compliance monitoring at the local levels should include small and medium scale enterprises for regular inspection.

REFERENCES

Abel, S.M. 1990. The extra-auditory effects of noise and annoyance: an overview of research. *Journal of Otolaryngology,* 19(1), 1-13.
Akinrinola O.O. 2011. Informal economy, economic growth and poverty in Nigeria: a macro-economic analysis. Accessed from http://www.hsbremen.de/internet/studium/stg/isvw /conferenc/impactonafrica on July 19 2011.

CCOHS – Canadian Centre for Occupational Health and Safety 2016. Noise – Occupational Exposure Limits in Canada. Accessed from https://www.ccohs.ca/oshanswers/phys_agents/ exposure_can.html on July 28 2016.

Egunjobi, L. 1983. Perception of environmental Problems, Pilot Study centred on the City of Ibadan, Research Report, NISER, Ibadan.

Evans, G.W., Lepore, S.J. 1993. Non-auditory effects of noise on children; a critical review. *Children's Environments,* 10:31-51.

Evans, G.W., Lercher P., Meis M., Ising H., Kofler W.W. 2001. Community noise exposure and stress in children. *Journal of Acoustic Society of America*, 109 (3):1023-1027.

Evans, G.W., Maxwell L. 1997. Chronic noise exposure and reading deficits: The mediating effects of language acquisition. *Environment and Behaviour*, 29: 638-656

Fields, J.M. 1998. Reactions to environmental noise in an ambient noise context in residential areas. *Journal of the Acoustical Society of America,* 104: 2245-2260.

Gibson, T., van der Vaart H. J. 2008. Defining SMEs: A Less Imperfect Way of Defining Small and Medium Enterprises in Developing Countries. Publication of Brooking Global Economy and Development. Accessed from http://www.brookings.edu/~/media/research/files/papers/2008/9/development%20gibson.pdf on November 27 2015.

Hear-it.org 2012. The global burden of noise induced hearing loss. Accessed from http://www.press.hear-it.org on July 30 2012.

Kabir, G., Madugu, A.I. 2010. Assessment of environmental impact on air quality by cement industry and mitigating measures: a case study. *Environmental Monitoring and Assessment*, 160(1–4): 91–99.

Kiernan, V. 1997. Noise pollution robs kids of languages skills. *New Scientist*, 10 (5): 120–126.

Mbuligwe, S. 2004. Levels and Influencing Factors of Noise Pollution from Small-Scale Industries (SSIs) in a Developing Country. *Environmental Management*, 33 (6): 830–839.

National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007.

Nelson, D.I., Nelson R.Y., Concha-Barrientos M. Fingerhut M. 2005. The Global Burden of Occupational Noise Induced Hearing Loss. *American Journal of Industrial Medicine*, 48(6): 400–408.

NIOSH, 1996. National occupational research agenda. National Institute of Occupational Safety and Health, (NIOSH) Pub. No. 96-115. Cincinnati, OH.

Oguntoke, O., Awanu, E.A., Annegarn J.H. 2012b. Impact of Cement factory operations on air quality and human health in Ewekoro Local Government Area, Southwestern Nigeria. *International Journal of Environmental Studies*, 69 (6): 934–945.

Oguntoke, O., Odeshi T., Annegarn, H. 2012a. Assessment of Noise Emitted by Vibrator-Block Factories and the Impact on Human Health and Urban Environment in Nigeria. *International Journal of Applied Environmental Sciences,* 7(1): 57–68.

Onuu, M.U. 2000. Road traffic noise in Nigeria: measurements, analysis and evaluation of nuisance. *Journal of Sound and Vibration* 233(3): 391–405.

Onyebueke, V. U. 2013. Policy implications of the spatial and structural relationships of the informal and formal business sectors in urban Nigeria: the case of Enugu (1990-2010). A PhD Thesis submitted to Stellenbosch University. Accessed from http://scholar.sun.ac.za/handle/10019.1/79889 on November 25 2015).

Scheider, F. 2002. Size and measurement of the informal economy in 110 Countries around the World. A paper presented at a workshop of the Australian National Tax Centre ANU Canberra, Australia. Accessed from http://www.economics.uni-linz.ac.at on May 17 2011.

Sexton, K., Gong, H., Bailar, J.C., Ford, J.G., Gold, D.R., Lambert, W.E., Utell, M.J. 1993. Air pollution health risks: Do class and race matter? *Toxicology and Industrial Health*, 9(5): 843–878.

Smith, RJH, Bale JFJ, White KR 2005. Sensorineural hearing loss in children. *Lancet* 365, 879–90.

Sonibare, J.A., Akeredolu, F.A., Latinwo I., Solomon B.O. 2004. Impact of tanneries on ambient noise levels in Kano, Nigeria. *African Journal of Environmental Assessment and Management* 8: 1–18.

Stansfeld, S.A., Matheson, M.P. 2003**.** Noise pollution: non-auditory effects on health. *British Medical Bulletin*, 68: 243–257.

Tajudeen, Y., Okpuzor, J. 2011. Variation in exposure to cement dust in relation to distance from Cement Company. *Research Journal of Environmental Toxicology*, 5(3): 203–212.

Tsepav, M.T., Oladipupo M.D., Ndanusa B. 2011. Assessment of the level of noise produced by sound generating machines in Lapai, Northern Nigeria. *Advances in Applied Science Research*, 2 (6): 520–531.

U.S. Department of Health and Human Services (US-DHHS) 1998 Criteria for a recommended standard, occupational noise exposure Revised Criteria 1998, Cincinnati, Ohio. 99p.

WHO (2001) WHO guideline on Community Noise (Ed.) Dietrich Schwela. TRB Session 391, WHO Geneva, Switzerland.

World Health Organization (2012a). Deafness and Hearing Impairment. Fact Sheet no 300, February 2012. Accessed from http://www.who.int/mediacentre/factsheets/fs300/en/index. html on July 30 2012)

WHO, 2012b. Occupational Health: A Manual for Primary Health Care Workers. Accessed from http://www.who.int/occupational_health/regions/en/oehemhealthcareworkers.pdf on November 19 2012).

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