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Atmospheric pollution from the major mobile telecommunication companies in Tanzania

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Air pollution from five mobile telephone companies in Tanzania was investigated. Results show **maximum noise level of 83 dB and a minimum of 61.4 dB, above a permissible 45 dB. Concentrations of NOx ranged from 0.135 mg/m^3(NO) to 0.18 mg/m^3(NO_2), above a permissible level of 250 mg/m^3. The applied Gaussian model estimated the contribution of the BS generators to the atmosphere, to be between 0.0006 µg/m^3 and 0.001 µg/m^3 at 300 m from the source to 0.35 and 0.014 µg/m^3 10 m from the source for both NO and NO_2 respectively while the measured values ranged from 0µg/m^3 to 10 µg/m^3 for both (NO) and (NO_2) at 2.5 m from the source. The levels of $PM_{2.5}$ ranged from 0.04 to 0.25 mg/m^3, compared to standard of 0.1 mg/m^3. It can be concluded that there are high levels of noise and particulate emissions at varying degrees. At least 15 m should be maintained between the base stations and the closest residence for permissible noise levels.**

Key words: Atmosphere, base stations, mobile telephone, noise, particulates.

INTRODUCTION

The past decade has witnessed a number of mobile telephone companies have being operational in Tanzania (TCRA, 2009). These companies have installed Base Stations (BSs) that use diesel power generators especially during times of power cuts. Currently, eight mobile telephone companies are in place, expanding the number of their installations, consequently creating environmental problems as mentioned by Lingwala (2003) and Samuelssen et al. (2009). These include the elevated sound levels and air bone emissions coming from numerous generators that power the industry, as well as potential for groundwater pollution due to spills of oil used to fuel generators. There is also lack of personnel (for instance Sasatel, tIGO and Zantel) specifically charged to deal with environmental issues. This study therefore aims at assessing the performance of these BSs in meeting local and international atmospheric discharge standards.

MATERIALS AND METHODS

Site description

The study was conducted in Dar es Salaam city, the largest commercial city in Tanzania. Dar es Salaam is located on the eastern region of Tanzania and lies in the coast of the Indian Ocean. The sampling areas that is, Tandale Manzese and Magomeni are shown in Figure 1.

Questionnaires to local community

The sampling was conducted in Magomeni, Manzese and Tandale Wards, with about 170 households. The area also features a total of 15 mobile telephone BSs. The area is selected on the basis of documented complaints from the community to the environmental

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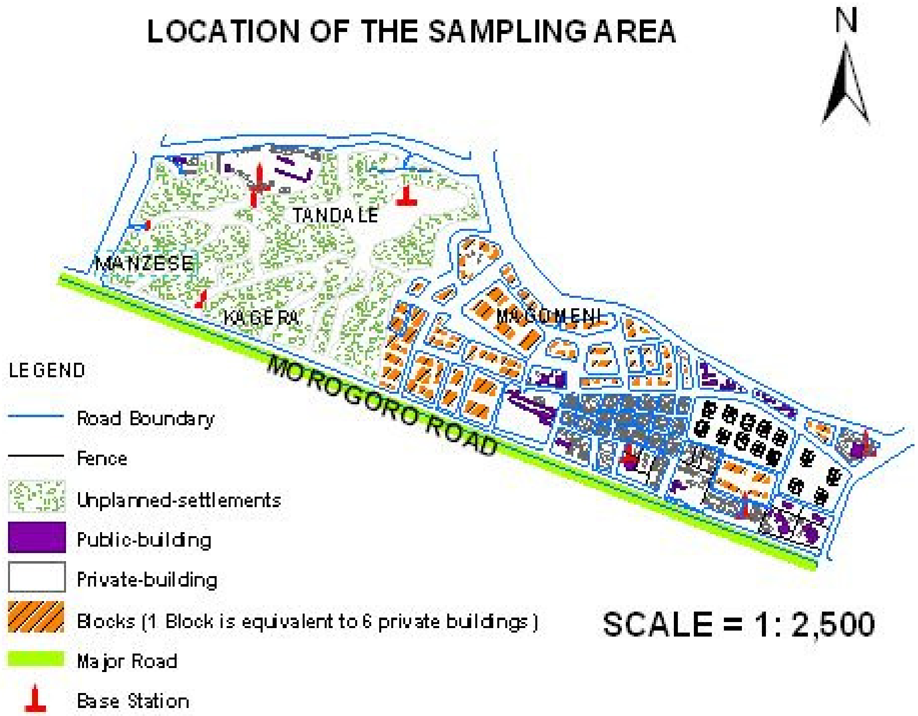

Figure 1. Location of the study area.

regulatory authorities regarding elevated levels of noise, smoke emissions from the generators and the fear of the radio frequency radiations from the transmission antenna. Questionnaire survey was conducted for chosen four closest households (about 1 to 3 m) to 14 of the base stations, making a total of 56 questionnaires.

Questionnaires to the regulatory authority

Some questionnaires were administered to the National Environment Management Council so as to crosscheck the information provided by the residents and the mobile telecommunication companies including the areas where the most complaints come from and the decisions made about the complaints.

Reconnaissance survey

The measurements were done at the 10 identified BSs in the area. A survey of the surrounding area was done prior to measurements to identify the potential areas for the measurements to be taken.

Noise level measurements

The selection of the measurement sites were based on the information rich cases (the ones providing the answer to research question and accessibility to the research data. In Table 1, various sites are chosen with respect to this criterion and the explanations of the functions are given.

The noise level was measured using Integrating-averaging sound level meter, Bruel and Kjaer Type 2240. This device used records the maximum noise level reached during the measurement procedure (the L_{max}) equivalent continuous sound level in seconds ($_{Leq}$) and the peak sound levels($_{Lpeak}$). The meter was calibrated by placing a portable acoustic calibrator, which in this case was a sound level calibrator, directly over the microphone so that it can calibrate the meter. The sound level meter calibration was done before and after each measurement session of 3 h. The sound levels were recorded in a 2 (two) meter interval from the boundary wall of the BSs to the nearest household. A total distance of 10 m was used to record the noise from the source of noise in this case the generators. Therefore a total of 5 readings were taken for each noise measurement practice.

Measurement of stack exhausts gas concentration

The instrument used for these measurements was the manual dragger pump Accuro® Pump. A manual pump using dragger tubes was used. The Dräger-Tubes® 2/c used can measure up to 200 ppm of the NO and NO_2 concentration in air in a single pump stroke). The measured volume of gas removed from the generator as an exhaust gas was drawn through a tube which contains chemicals which change in colour in response to the presence of target gas that is, NO and NO_2. The measurement period was 10 (ten) minutes for ten strokes and the concentrations of the NO_x gases was recorded for an hour average by recording in the first 10 min and in the last 10 min that is from the 50^{th} to the 60^{th} minute.

Measurement of stack exhausts gas exit velocity

The instrument used for these measurements was the Alnor® Velometer Series 6000P fitted with the metallic pitot probe that is used to detect the velocity of the exiting gases and the results being displayed in the analog display of the meter. The meter was held with the pitot probe direct and normal to the stack. The stack

Table 1. Sites Prone to noise pollution in the sampling area.

Measurement site	Function
House holds	Living, resting and socializing
Schools	Learning
Health centres	Providing and acquiring health services
Hotels	Resting, conferencing, working and socializing

velocity was then measured by the meter in the selected range that is, 0 to 50 m/s. 10 readings were taken in the half hour average every three minutes and the average value taken.

Measurement of particulate matter in the exhaust gases

The instrument used to measure particulate matter was the micro dust analyzer that is, MICRODUST pro 880 nm fitted with filters containing probe. The device takes measurements by sensing technique of forward light scattering (12° to 20°) using 880 nm infrared range of 0.001 to 2500 mg/m^3. By this narrow range of scatter the instrument sensitivity to variations in the refractive index and the colour of measured particulate is reduced.

Calibration of the instrument was done by attaching the purge to the probe purge inlet and inserting the calibration filter in the filter position and the bulb of the purge below was squeezed rapidly 6 times. An allowance of few seconds (3 to 5 s) was given for auto-ranging and for the reading to stabilize. The squeezing was repeated whenever the readings did not stabilize. On entering these results the device would set the reading to zero.

Measurements from the mentioned points were done by orienting the probe and allowing the dust particles to be detected and filtered as it passes through the filter hole in the probe. The readings in the amount of the dust scattered therefore detected, was recorded and eventually retrieved using the WINDDUST pro Application software.

The Gaussian dispersion model

The Gaussian dispersion model (Cooper and Alley, 1994) was used to model the concentration of the gaseous pollutants. The general equation is provided by Equation 1.

$$C = \frac{Q}{2\pi * U * \delta y * \delta z} Exp\left(-\frac{1}{2}\frac{Y^2}{\delta y^2}\right) * \left[-\frac{1}{2}\frac{(Z-H)^2}{\delta z^2} + Exp - \frac{1}{2}\frac{(Z+H)^2}{\delta z^2}\right] \quad (1)$$

Where: U =Wind speed at stack height (m/s); Y = Horizontal distance from plume center line (m); Q = Emission rate (g/s); C = Steady state concentration at a point (x, y, z) g/m^3; H = Effective stack height (m), δz, δy = Standard deviations of concentration in respect to direction measured (m), these are functions of distance x and atmospheric stability; Z = Height above the ground level (m).

The Gaussian model for determination of downwind concentration of emitted pollutants is explained in Equation 2;

$$C(x,0,0,H) = \frac{Q}{\pi * U * \delta y * \delta z} Exp - \frac{1}{2}\frac{H^2}{\delta z^2} \quad (2)$$

Where:

H = Effective stack height (m); Q = Emission rate (g/s), δz, δy =Standard deviations of concentration in respect to direction measured (m), these are functions of distance x and atmospheric stability, C = Downwind concentration (g/m^3).

From the stability class and the receptor position, δz and δy may not be obtained directly from the Pasquill-Gifford curves since, the lowest values indicated in the curves is 100 m. The formula used to calculate δz and δy are obtained using Equations 3 and 4:

$$\delta z = cx^d + f \quad (3)$$

$$\delta y = ax^b \ldots \quad (4)$$

Where: a, b, c, d and f are constant that are dependent on the stability class, x is distance in km.

The mentioned values can be read in Table 2 Where: a, b, c, d and f are constant that are dependent on the stability class, x is distance in km. The mentioned values can be read in Table 2.

Wind velocity calculations

The stack gas exit velocity data at site were collected at various positions from the ground level, this needed to be corrected to 10 m above the ground so that the stability classes could be determined. The mean wind speed is frequently represented empirically as a power law function of height and can be calculated using Equation 4.

$$\frac{u_2}{u_1} = \left(\frac{Z_2}{Z_1}\right)^P \quad (5)$$

Where;
u_2, u_1 = wind velocities at higher and lower elevation respectively (m/s), Z_2, Z_1 = higher and lower elevation (m), P = function of stability (≅ 0.5 for very stable conditions and ≅ 0.15 for very unstable conditions).

The exponent p varies with atmospheric stability class and with surface roughness. Table 3 below shows various values for exponent p for various stability classes. The values of the exponent chosen are based on the rough surfaces since all the measurements were done in urban environment. For flat, open country and lakes and seas, there is less variation between the surface wind and geotrophic wind.

Estimation of Pasquill stability classes

Stability classification is designated by letters A to F. Stability class A, the most unstable, has the greatest dispersion potential stability, the most stable class which represents conditions that dampen turbulence, thereby reducing dispersion. Class A to C are limited to

Table 2. Values of curve-fit constants for calculating dispersion coefficients as a function of downwind distance and atmospheric stability.

Stability class	x<1 km					x> 1 km		
	a	b*	c	d	f	c	D	F
A	213		440.8	1.941	9.27	459.7	2.094	-9.6
B	156		106.6	1.149	3.3	108.2	1.098	2.0
C	104		61.0	0.911	0	61.0	0.911	0
D	68		33.2	0.725	-1.7	44.5	0.516	-13.0
E	50.5		22.8	0.678	-1.3	55.4	0.305	-34.0
F	34		14.35	0.740	-0.35	62.6	0.180	-48.6

b*=0.894 for all stability classes and values of x (Cooper and Alley, 1976).

Table 3. Exponents for wind profile (power law) model for rough surfaces.

Stability class	Exponent (p)
A	0.15
B	0.15
C	0.20
D	0.25
E	0.40
F	0.60

Source: Cooper and Alley (1994).

daytime whereas E to F are night time conditions only. A neutral stability classification D can occur during the day or during night time periods. Table 4 gives various stability classes with respect to sky condition. Therefore the wind speed at the stack height is obtained by Equation 6 as given below;

$$4 = u_1\left(\frac{10}{Z_1}\right)^P \tag{6}$$

Control of exhaust gases

Plume rise prediction

The analytical methods for predicting the concentration of stacks effluents involve the location of a virtual or equivalent origin. Elevation H of the virtual origin is obtained by adding, the plume rise Δh to the actual height of the stack (h). There are numerous methods for calculating Δh, basically three sets of parameters control the phenomenon of a gaseous plume injected into the atmosphere from a stack. These are stack characteristics, meteorological conditions and the physical and chemical nature of the effluent. In this study the plume rise was calculated using Moses and Carson for unstable condition equation provided in equation 7 (Cooper and Alley, 1994), other equations that is, equations 8 and 9 are used to determine the mass flux and the area of the stack. The equations were chosen for Wind speed between 3 to 5; the surface is rough urban and the equations involved;

$$\Delta h = 3.47\left(\frac{Vsd}{U}\right) + 5.15\frac{(Q_h)^{0.5}}{U} \tag{7}$$

$$Q_h = \dot{m} C_p (T_s - T_a) \tag{8}$$

$$m = \delta_a VsA \tag{9}$$

$$A = \frac{\pi d^2}{4}$$

Whereby;

δ_a - density of air at 32°C= 1.165 kg/m^3 (Engineering Toolbox, 2005); C_p - pressure constant specific heat capacity of air = 1.016 kJ/Kg°K (Engineering toolbox, 2005); Vs -Stack exit velocity (m/s); d- diameter of the stack (m); Ts- Temperature of the exit gases (°K); Ta- Ambient temperature (°K); Q_h- is the heat emission rate(KJ/s); Δh- plume rise (m).

RESULTS AND DISCUSSION

Questionnaire survey

Questionnaire survey and analysis conducted in the visited companies and the sampling areas indicated that out of the total of (4170) base stations, Environmental Impact Assessment has been conducted for only 11%, equivalent to 458 stations in Dar es Salaam. The survey also indicate that 86% of the respondents experience noise and smoke emission while the rest 25% responded that they experience noise only while the rest explains that they do not experience those effects as shown in Table 5. Moreover the questionnaire survey revealed that, 100% of the interviewed residents do not have generators for power back up. This means that the noise from the generators talked about come from the operating BSs. It was also noted that, 20% of the interviewed residents although they do not have power

Table 4. Pasquill stability classes.

Surface Wind at 10 m above the ground	Day incoming solar radiation			Night cloudiness	
	Strong	Moderate	Slight	$\geq 4/8$	$\leq 3/8$
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Source: Seinfeld (1986) A: extremely unstable, B: moderately unstable, C: slight unstable D: neutral, E: slightly stable, F: moderately stable.

Table 5. Environmental Management related issues in the visited companies.

Company	Zain/Airtel	Tigo	Sasatel	Zantel	Vodacom
No. of B.S in Tanzania	1250	1000	20	600	1300
No. of B.S in DSM	143	400	20	98	390
No. of B.S with EIA	68	200	20	14	24
Complaints due to operations	Yes	Yes	-	Yes	Yes
Major complaints	-Noise -Smoke	-Noise -Smoke -Fear of radiation	-	-Noise -Smoke	-Noise -Smoke

generator, they live close to other sources of noises such as flour milling machines or timber cutting machines. This makes it difficult to determine whether the noise come only from the BS operating generators or these other sources. Out of the interviewed residents 7% are from the houses surrounding the BS which EIA was done prior to project commencement.

Noise measurement results from the base stations

The noise levels measured from the boundary wall of the Cell sites as proposed in the EIA revealed the margin of failure in the implementation of the levels proposed in the Environmental Impact Assessment or addressed in the Environmental Management Plan.

Zain BSs

The first and second Zain BS with tower ID 10 and 464 respectively shows that the generators produce noise levels with the deviation from the noise levels value of 45 dB (in residential houses) and 70 dB (in industrial areas). The magnitude of this deviation has been of average of about 26 dB. This case is shown in Figure 2. According to these findings, a minimum distance of about 22 m is required above which the proposed noise level of 45 dB can be attained.

Tigo BSs

The two TIGO BS with tower ID Dar 147 and Dar 035 respectively also show the deviation from the noise levels value of 45 dB (in residential houses) as provided in the EMP as shown in Figures 3 and 4. The magnitude of this deviation has been about 27 and 37.8 dB respectively. The two stations have different types of generators of different ages and therefore the results show the difference in the noise levels. According to this an estimated minimum distance of 15 and 20 m for each generator respectively is required to achieve the recommended noise level in the EMP.

Sasatel BSs

Results from the Sasatel BS show elevated levels of noise compared to that proposed in the EMP. The noise levels measured from two BSs with ID number Dar 18 and Dar 17 and similar making showed the levels of noises to have increased by about 25 dB from the proposed 45 dB, as shown by Figure 5. Again a distance of 20 m is required to achieve the proposed noise level in the EMP.

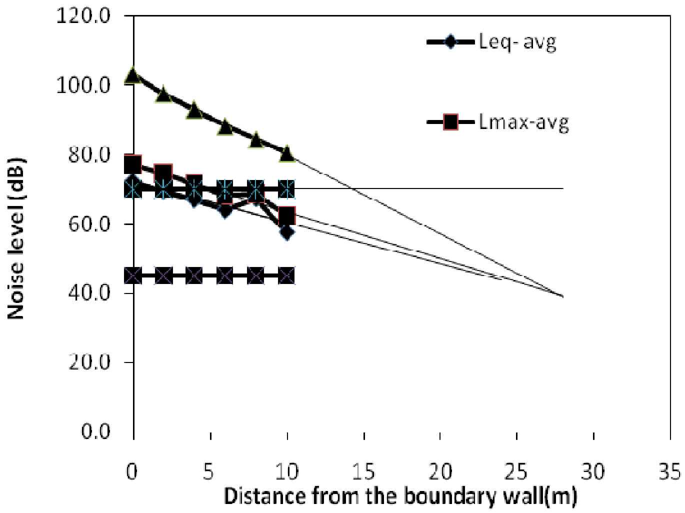

Figure 2. Variation of noise level with distance for Zain BS.

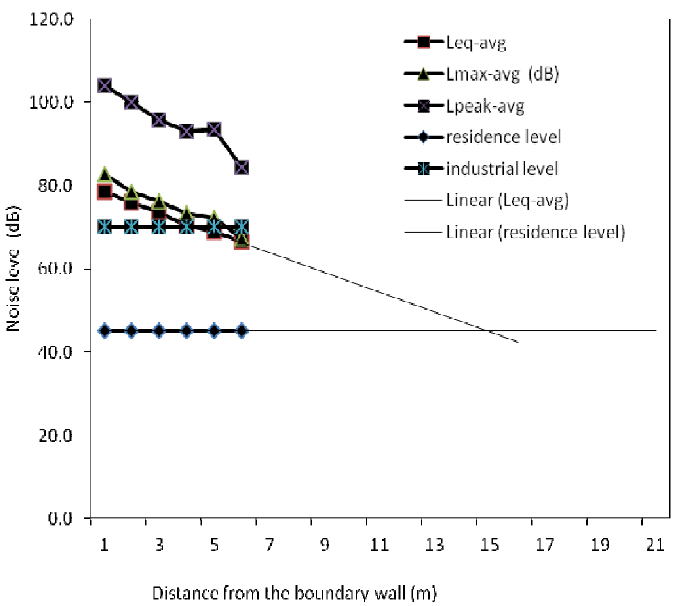

Figure 3. Variation of noise level with distance for TIGO BS 1.

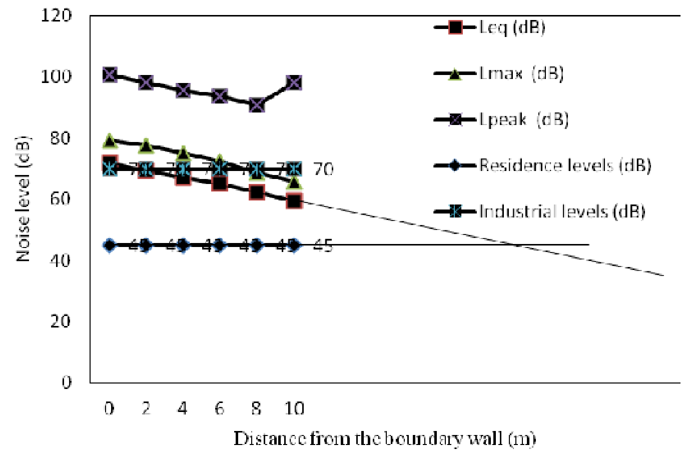

Figure 4. Variation of noise level with distance for TIGO BS 2.

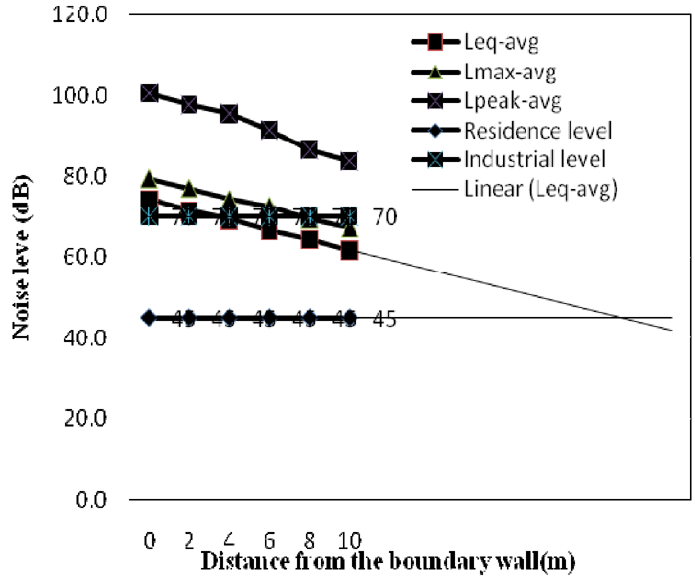

Figure 5. Variation of Noise level with distance from the Sasatel BS boundary wall.

Vodacom BSs

Results from the Vodacom BSs generators show elevated levels of noise compared to that proposed in the EMP. Even though the deviations from the proposed EMP noise level in residential levels is a bit higher in average that is by 16.4 dB compared to the other companies BSs sampled, the noise level proposed in the Noise level Management Plan in the company (that is 65 dB) is slightly lower than that in the EMP for industrial level. As shown in Figure 6, this is ok for the industrial areas even though is still higher than that for the residential areas especially in the case study areas where the distance from the boundary wall to the nearest households is hardly 2 m, in other critical cases the boundary wall of the BSs is in close contact about 0.5 m to the wall of the households' bedroom. In this case a minimum distance of 18 m from the boundary wall is required so that the proposed noise level can be attained.

Zantel BSs

Results from the Zantel BSs, as well shows the high levels of noise compared to that proposed in the EMP. The noise levels measured from two BSs generator with

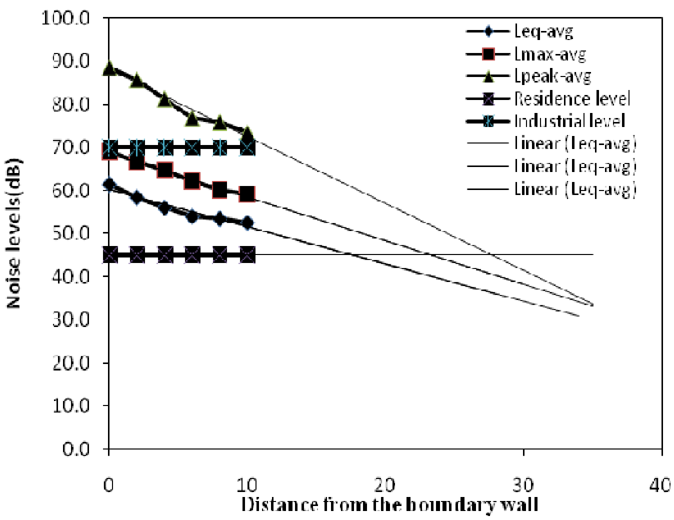

Figure 6. Variation of Noise level with distance from the Vodacom BS boundary wall.

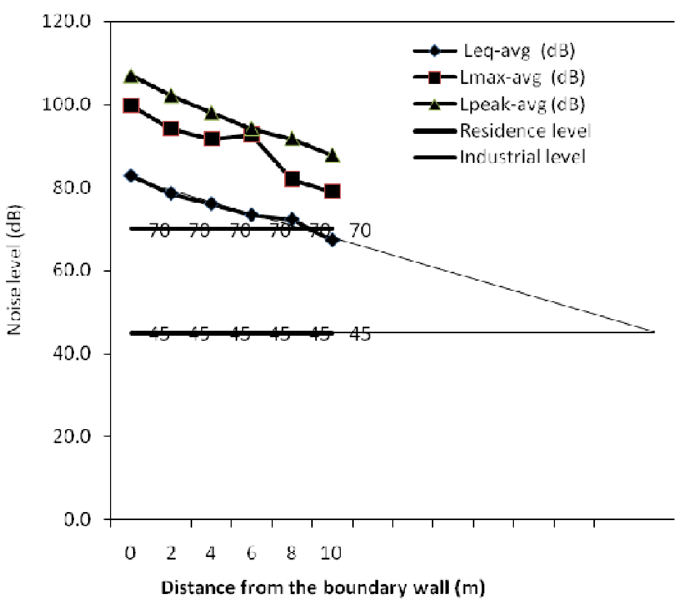

Figure 7. Variation of Noise level with distance from the Zantel BS boundary wall.

similar making showed an increment in the noise levels, by an average of about 37.8 dB from the proposed 45 dB, shown in Figure 7. From the analysis it is shown that a distance of about 26 m from the boundary wall is required from which the residents wouldn't be affected by the elevated noise, in which case the standard for the noise levels proposed in the EMP would be achieved.

Summary of the noise level measurement

A minimum of 15 m from the BSs from the site wall is

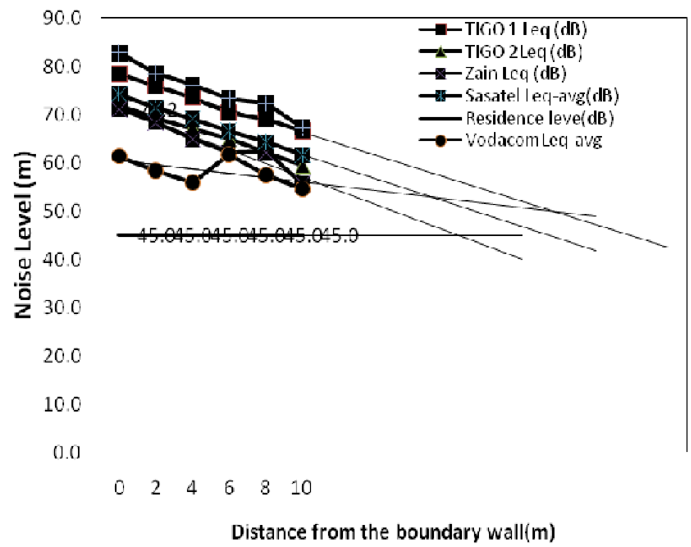

Figure 8. Noise level with distance from the boundary wall for the visited companies BSs.

required above which the effects of noise to the residents would be negligible as indicated in Figure 8.

Concentration results from the base stations

The results from the measurements of the gaseous pollutant concentration show that the gases of interests in this project were below the permissible standards for the emissions from the stacks.

NOx

Levels of NOx in base stations were low with the maximum hourly mean of 0.13 mg/m^3 for NO (Zantel BS) and 0.08 mg/m^3 for NO_2 (Zantel BS) compared to the permissible stack emission standard of 250 mg/m^3 (Figures 9a, 9b, 10a and 10b). It was also noted that older generator emitted more the noxious gas emission with an exception of the Zantel generators.

Orientation of the generator' stack

60% of the surveyed generators complied with the requirements of EMP while the rest did not comply with this mitigation measure as the proposed measure in the EMP states that the stacks should be vertical and with the appropriate height to enhance effective dispersion of contaminants (particularly noxious gases and particulate matter). The Gaussian Model indicates that a sufficiently tall and vertical stack has better dispersion so that the concentration of the emitted pollutant reaching the receptor is very low.

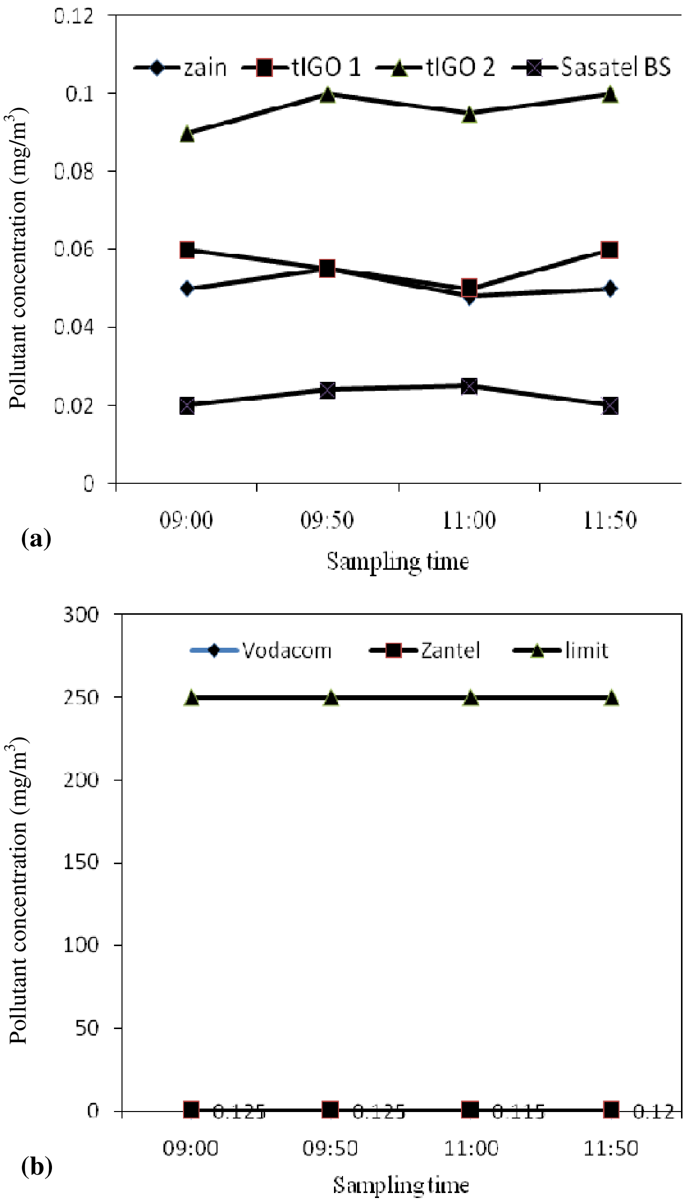

Figure 9. (a) Stack NO emissions for different generator stacks (b) NO concentration against the stack emission standard of 250 mg/m^3.

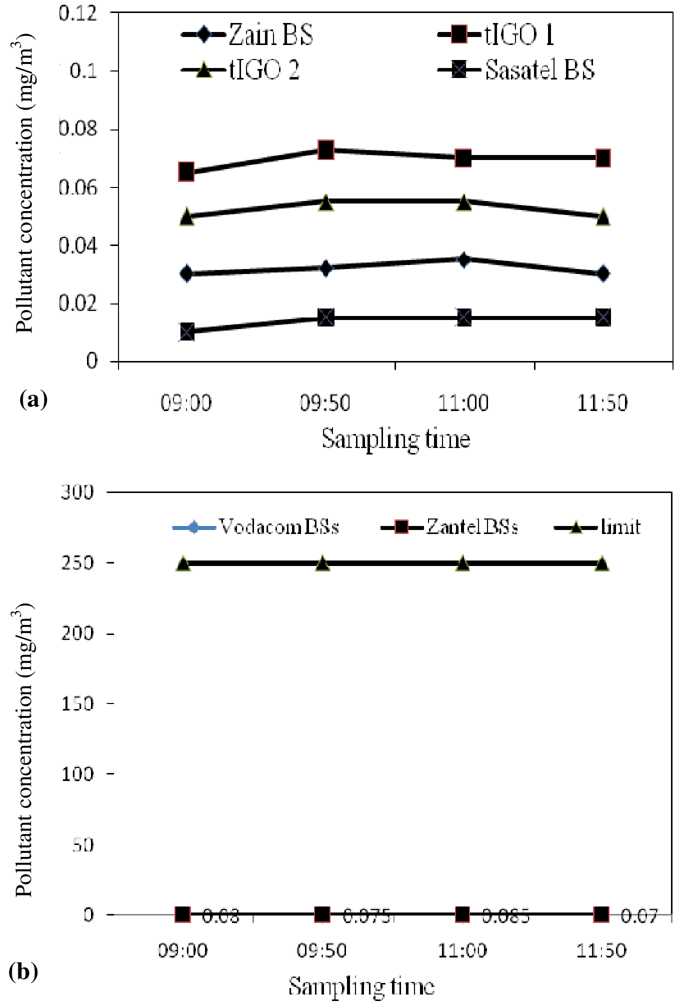

Figure 10. (a) Stack NO_2 emissions for different generator (b) NO_2 concentration against the stack emission standard 250 mg/m^3.

The Gaussian air dispersion model results and discussion

Determination of downwind concentration of measured pollutants

Gaussian dispersion model was used to predict the average concentration of NOx downwind for hourly average based on the Equation 2 where:

H = Average effective stack height (m)
U = Average wind speed at 10 m, 4.0 m
C = Downwind concentration mg/m^3

Model results Tigo

The model results from the TIGO BSs showed peak NOx concentration of 0.35 μg/m^3(NO) and 0.014 μg/m^3(NO_2) at 10 m from the source. Also the measured concentration was found to be 5 and 2.5 μg/m^3 for both NO and NO_2 respectively at 2.5 m from the source. The results both measured and modeled are shown in Figure 11.

Model results for the Sasatel

The model results from the Sasatel showed the peak concentration of NOx of to be 0.0033 μg/m^3(NO) and 0.0056 μg/m^3(NO_2) at 10 m from the source. However the measured concentration did not show any detection possibly because of the instrument detection limit. The results of modeled concentration are shown in Figure 12.

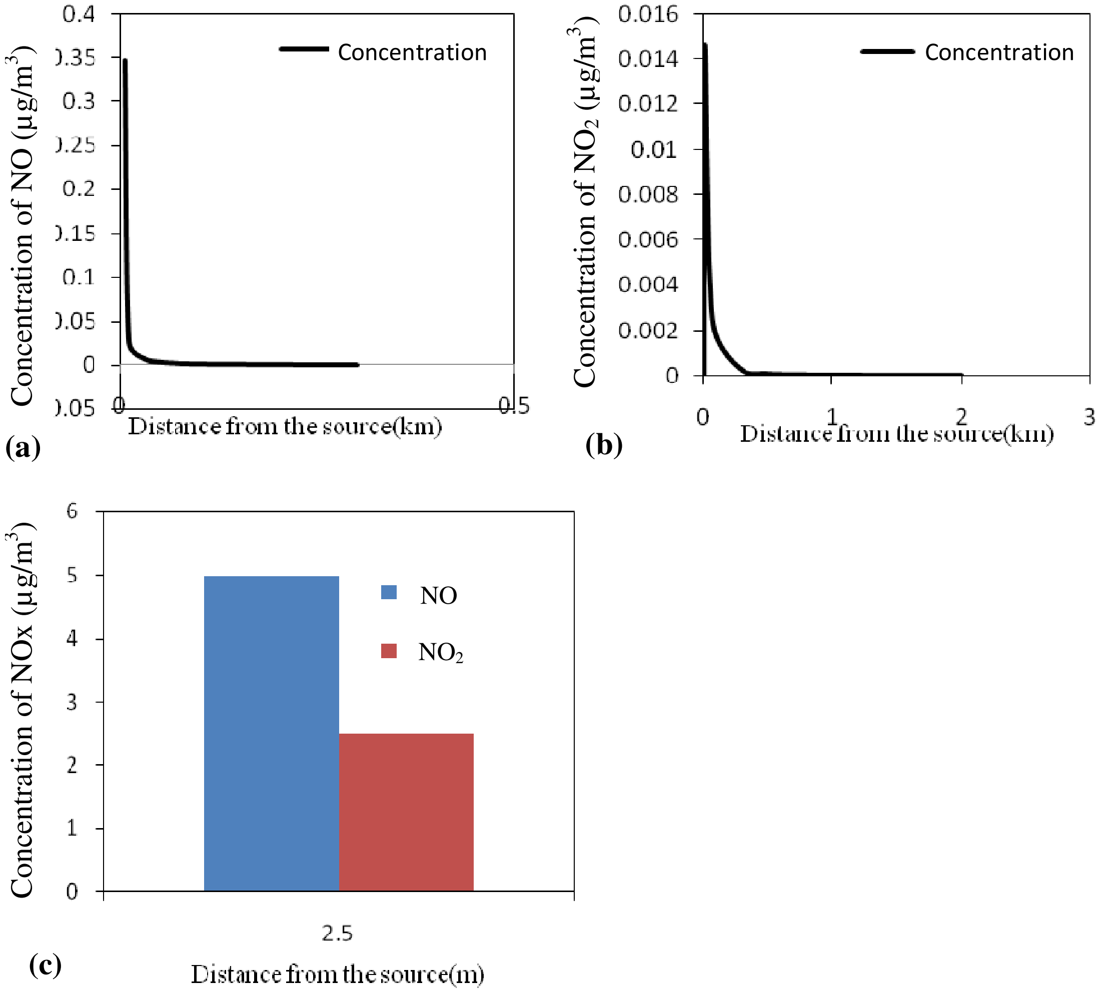

Figure 11. (a) The modeled NO conc. with distance (b) the modeled NO_2 conc. with distance (c) the measured NOx concentration with distance.

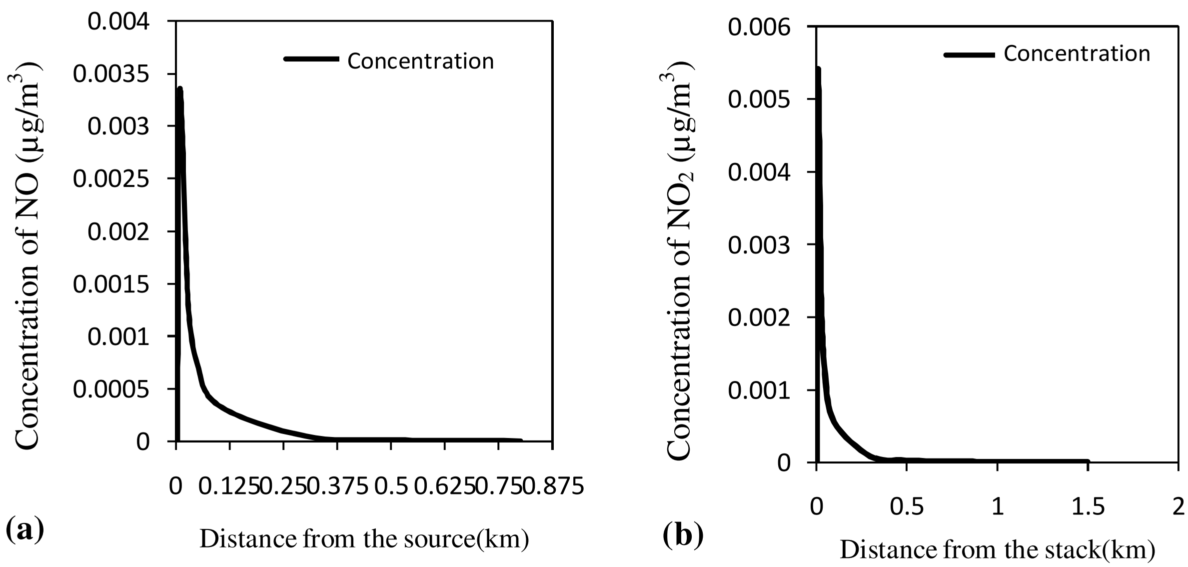

Figure 12. (a) Modeled NO concentration for Sasatel tower (b) Modeled NO_2 conc. for Sasatel tower.

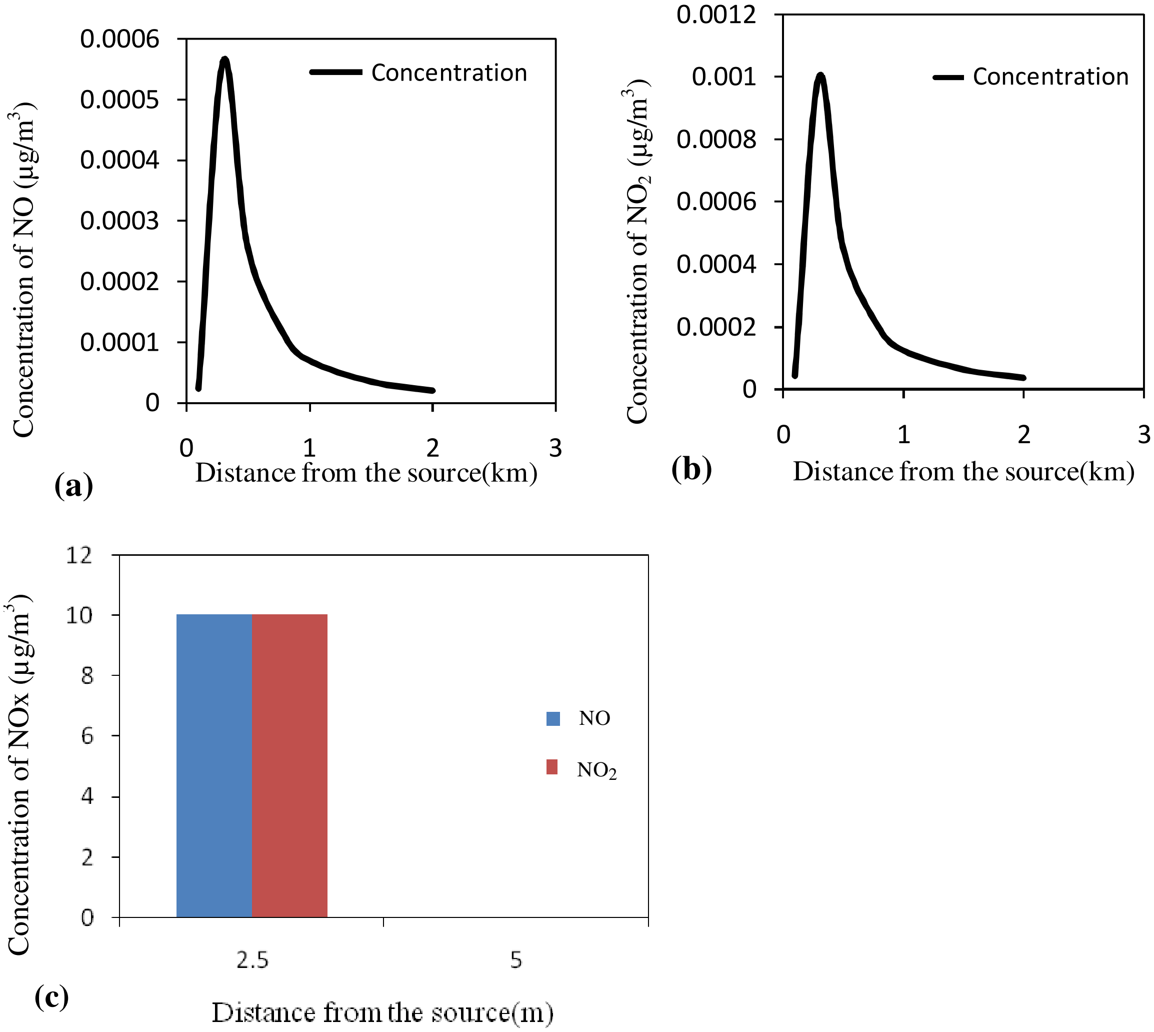

Figure 13. (a) Modeled concentration of NO for Vodacom (b) Modeled concentration of NO_2 for Vodacom BS (c) The measured NOx concentration with distance.

Model results for Vodacom

The model results from the Vodacom BSs showed peak NOx concentration of 0.0006 µg/m^3(NO) and 0.001 µg/m^3(NO_2) at 300 m from the source. However the measured concentration showed a peak concentration of 10 µg/m^3 at 2.5 m. The measured concentration was higher possibly due to contribution of other sources such as motor vehicles. Both measured and modeled concentration results are shown in Figure 13.

Model results for Zantel

The model results from the Zantel BSs showed peak NOx concentration of of 0.017 µg/m^3(NO) and 0.012 µg/m^3(NO_2) at 300 m from the source. The measured concentration was below the instrument's detection limit. The model output is shown in Figure 14.

Model results for Zain

The model results from the Zain BSs showed peak NOx concentration of of 0.013 µg/m^3(NO) and 0.008 µg/m^3(NO_2) at 10 m from the source. The measured concentration showed a peak concentration of 10 and 7 µg/m^3 for NO and NO_2 respectively, at 2.5 m. The measured concentration was higher compared to the modeled, first, due to the difference in positions of the measured and modeled concentration given the method of measurement, but also possibly due to contribution of other sources such as motor vehicles, since these sites are located close to the street or main roads. The results of both measured and modeled peak concentrations are shown in Figure 15.

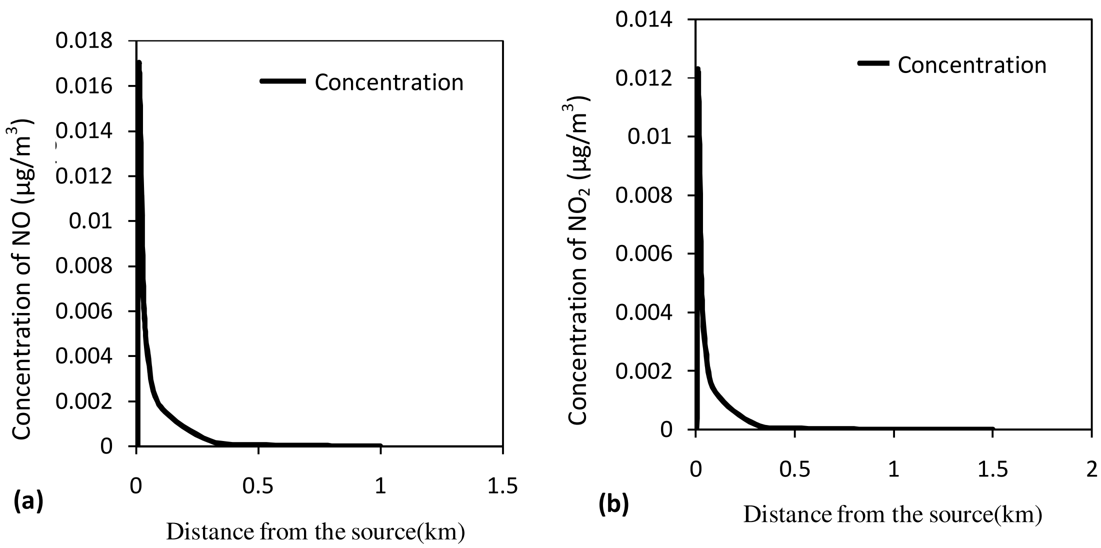

Figure 14. (a) Modeled conc. of NO for Zantel (b) Modeled conc. of NO_2 for Zantel.

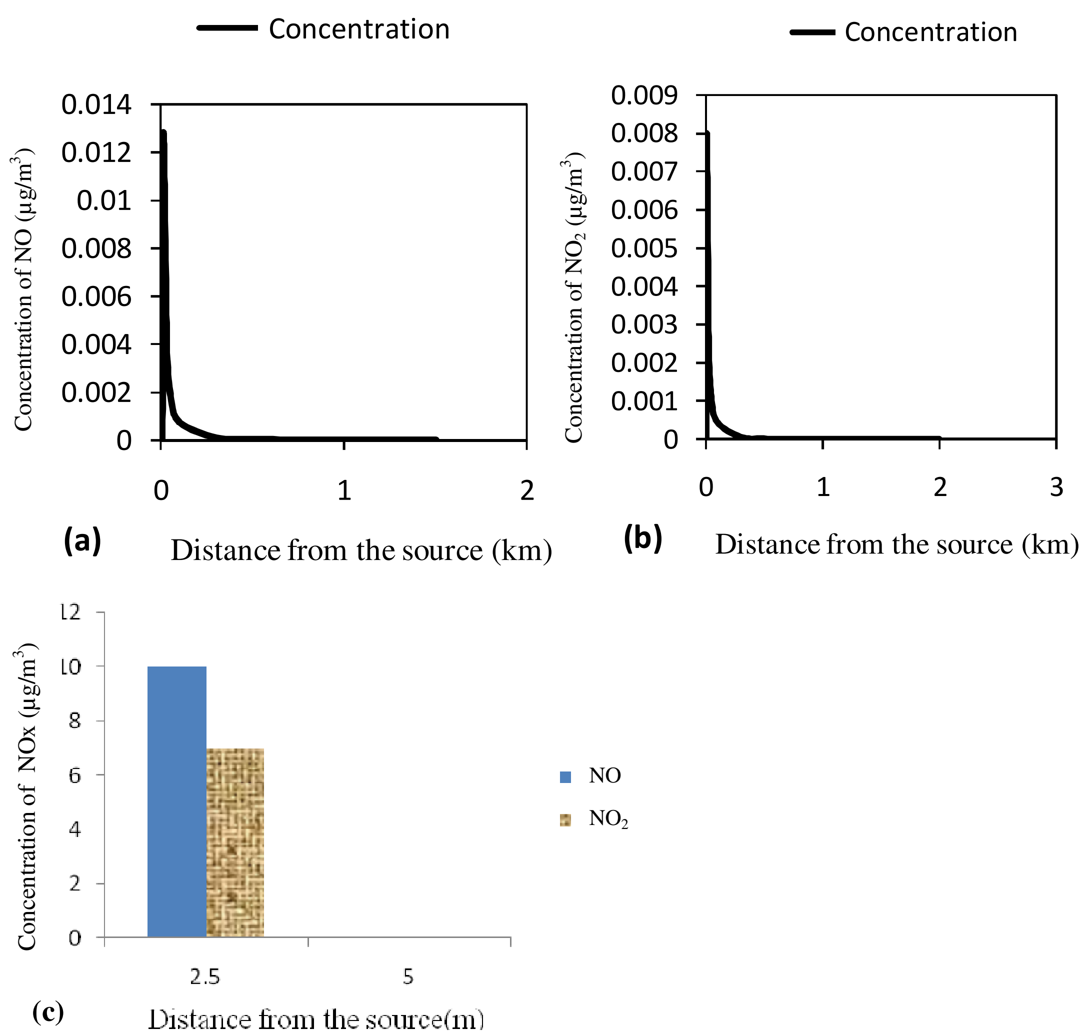

Figure 15. (a) Modeled concentration of NO for Zain tower (b) Modeled concentration of NO_2 for Zain BS (**c**) The measured NOx concentration with distance.

Particulate matter (PM) results

Tigo

The results of the stack particulate emissions for TIGO 1 and TIGO 2 BSs are as shown in Figure 16 and 17, while the ratios of the indoor to outdoor are given in Tables 1 and 2. According to the results PM concentration was found to be higher after the generators had been running for both the outside and the indoor environments. This might also be caused by the orientation of the generator stack being horizontal which caused unidirectional flow of stack smoke. The ratio of the indoor to outdoor concentration was 0.5 and 0.8, which shows that the indoor concentration was higher than the outdoor concentration for the same reason that the horizontal stacks may have influenced the concentrations in the indoor environment.

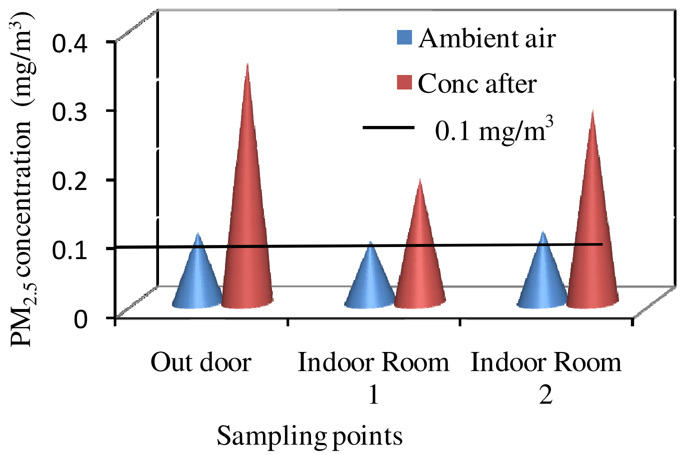

Figure 16. The PM concentration at Room 1 and 2 and outdoor.

Zantel

The results of the stack particulate emissions for Zantel BSs are as shown in Figure 18, while the ratios of the indoor to outdoor are given in Table 3. These results suggest that PM concentration was higher after the generators had been running for both the outside and the indoor environment. However the PM levels in the outside ambient air was greater than in the indoor which may have been caused by other PM sources such as the moving vehicles to and from the area, given that the place is close to the street road. The results and the ratio of the indoor to outdoor concentration was found to range between 0.53 to 0.98 for before and after sampling respectively, the closeness of the ratio to 1 during sampling might have been due to proper ventilation in the classroom.

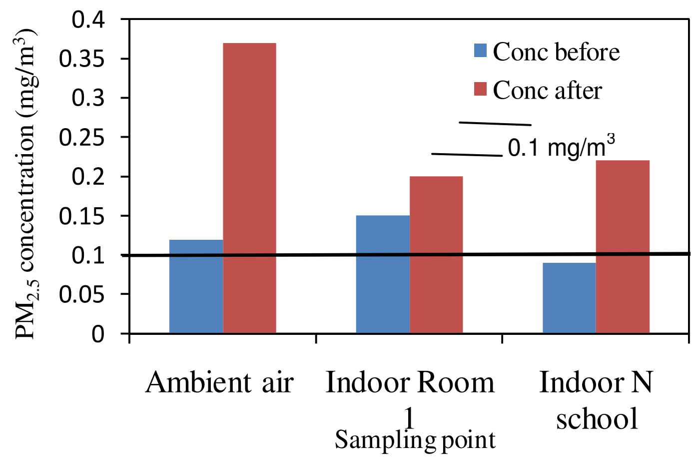

Figure 17. The PM concentration at Room 1& Nursery school class and outdoor.

Zain

The results of the stack particulate emissions in the sampled points for Zain BSs are shown in Figure 19. Similar to Zantel, PM concentration was found to be higher after the generators had been running for both the outside and the indoor household. The ratios of the indoor to outdoor PM concentrations were such that before the generator was on Household (HH) $PM_{2.5}$ were higher than ones after the generator running.

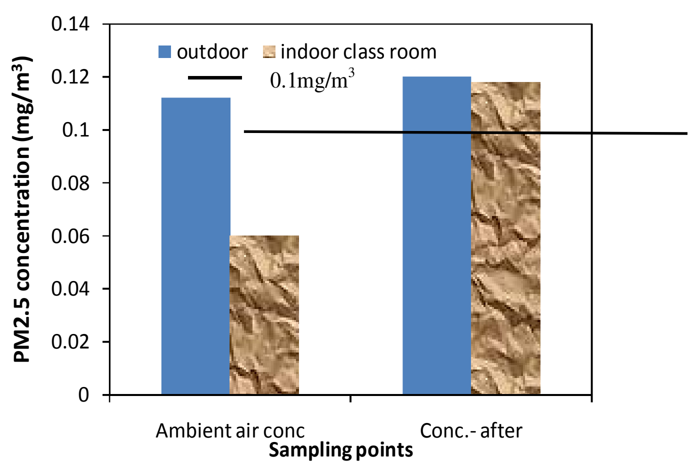

Figure 18. The PM concentration at outdoor and indoor in class room.

Vodacom

The results of the stack particulate emissions in the sampled points for Vodacom BSs are as shown in Figure 20, while the ratios of the indoor to outdoor are given in Table 5. PM concentration was found to be higher after the generators had been running for both the outside and

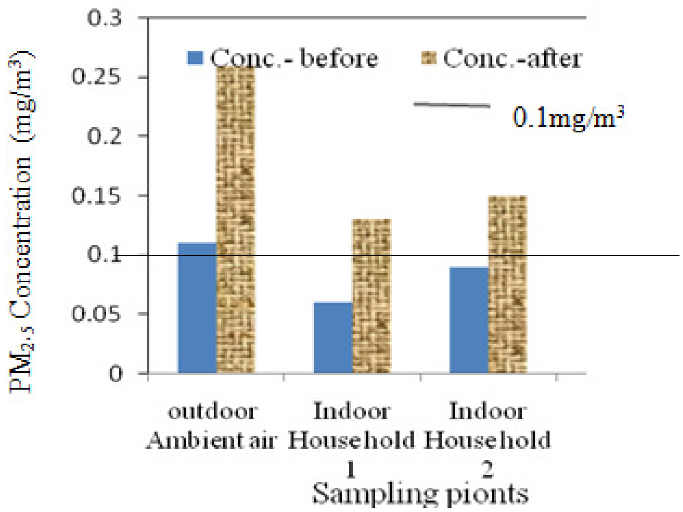

Figure 19. PM concentration at outdoor and indoor inside 2 households.

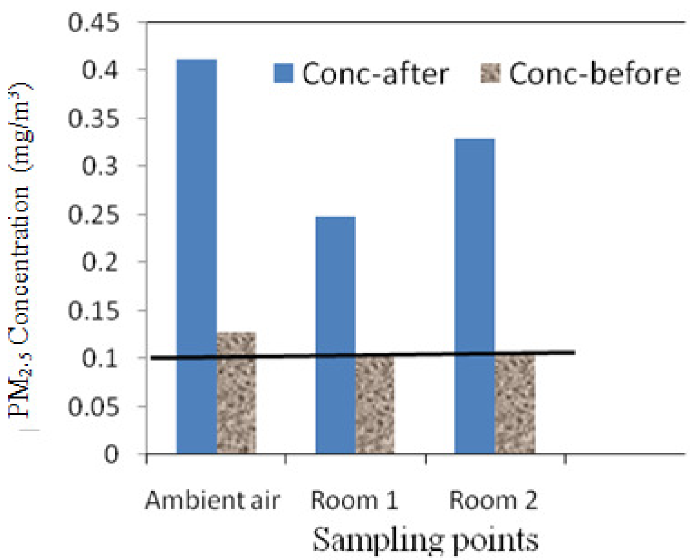

Figure 20. The PM concentration at outdoor and indoor inside class room.

the indoor environment. The ratio of the indoor to outdoor concentration was found to be 0.75 to 0.85 and 0.6 to 0.8 before and after running the generator for the two rooms, this shows that the outdoor concentration was higher than the indoor concentration in all cases which may have been contributed by the orientation of the generator stack being vertical so as to allow dispersion and the location of the rooms being a bit far from the source about 3 m.

Sasatel

The results of the stack particulate emissions at different

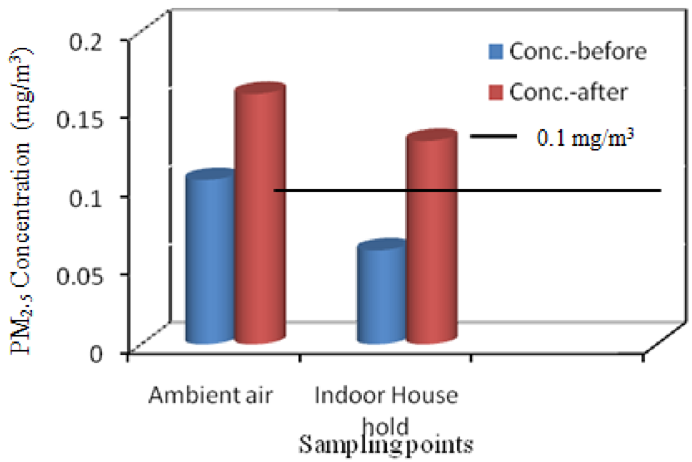

Figure 21. The PM concentration at outdoor and indoor inside class room**.**

sampling points for Sasatel BSs are as shown in Figure 21 while the ratios of the indoor to outdoor are given in Table 6. In this case the results of PM concentration were also found to be higher after the generators had been running in both the outside and the indoor environment. The ratio of the indoor to outdoor concentration showed that the outdoor concentration was higher than the indoor concentration which may also be contributed by the distance the rooms are located from the source and the stack being vertical so that dispersion was enhanced.

Comparison of the ambient $PM_{2.5}$ concentration between horizontal and vertical stacks

The results show that $PM_{2.5}$ concentration from the horizontal stacks cause a greater contribution in the increased ambient $PM_{2.5}$ level than those coming from vertical stack. This is shown in Figure 22.

Conclusions

The mobile telecommunication sector has played a pivotal role in the country's economic development, especially enhancing instant communication. This research was set to determine potentially adverse impacts to the environment by investigating how effective the EMPs and MPs are implemented with respect to the noise, particulate and the NOx gases pollution. Noise level was found to on the higher side compared to permissible levels. In addition, the released levels of the $PM_{2.5}$ caused a significant raise in PM level in the ambient air $PM_{2.5}$ concentration of the surrounding (indoor and outdoor) environments with the hourly average increase of about 0.25 mg/m^3 (Tigo BSs), 0.045 mg/m^3 (Zantel BSs), 0.08 mg/m^3 (Zain), 0.23 mg/m^3 (Vodacom BSs) and

Table 6. Ratios of PM concentrations (indoor and Outdoor) before and after the generator running.

Sampling point	Before		After	
	R1	R2	R1	R2
Indoor	0.09	0.104	0.18	0.28
Outdoor	0.102	0.102	0.35	0.35
Ratio In/Out	0.88	1.01	0.51	0.8

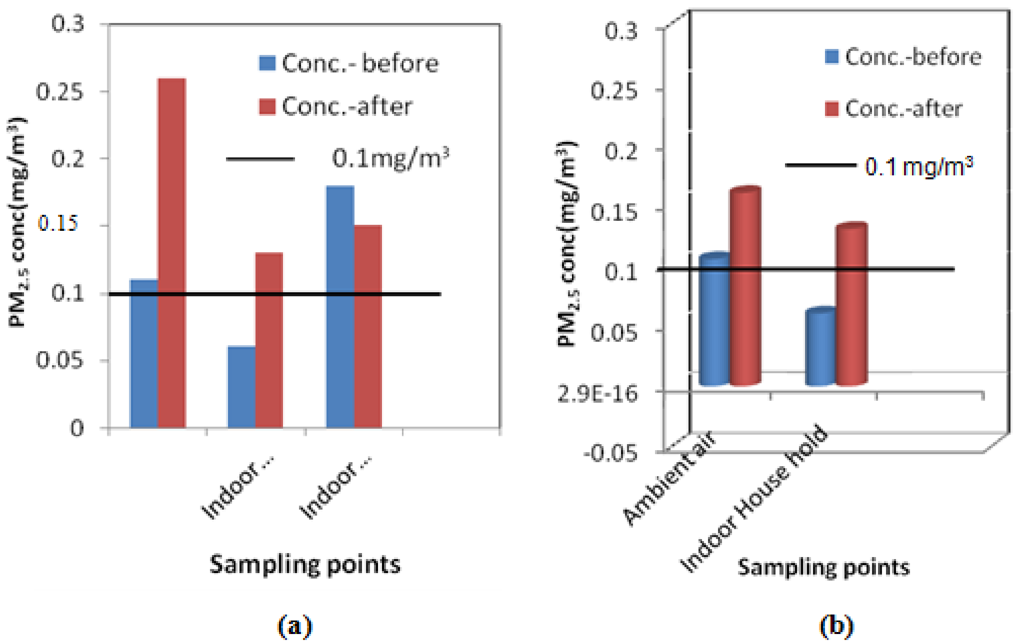

Figure 22. A comparison of the ambient $PM_{2.5}$ from the horizontal (a) and vertical (b) stacks.

0.04 mg/m^3 (Sasatel BSs) above the standard of 0.1 mg/m^3(TBS, 2007).

The EMPs do not propose the cut of values for gaseous NOx emissions however the levels of concentration at the stack exits are low with maximum hourly average of 0.18 mg/m^3(NO) and 0.135 mg/m^3(NO_2) compared with the permissible standard provided by the of <250 mg/m^3.

The Gaussian air pollutant plume model provided an approximation of the contribution of the BS generators to the atmosphere of maximum hourly concentration of NO and NO_2 respectively of about 0.35 µg/m^3 0.014 µg/m^{3}at 10 m from the source for Tigo BS, 0.0033 µg/m^3 and 0.0056 µg/m^3 at 10 m for Sasatel BSs, 0.0006 µg/m^3 and 0.001 µg/m^3 for Vodacom BSs at 300 m from the source, 0.017 µg/m^3 and 0.012 µg/m^3 for Zantel BSs at 10 m from the source and 0.013 µg/m^3 and 0.008 µg/m^3 for Zain BSs at 10 m from the source. The measured NOx values had hourly peak averages of NO and NO_2 respectively of about 5 µg/m^3 and 2.5µg/m^3 (Tigo BS), 10 µg/m^3 (Vodacom BS) and 10 µg/m^3 and 7 µg/m^3(Zain BS) at 2.5 m from the source.

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