IMPACT OF DIESEL FUEL GENERATORS ON SOIL HEAVY METALS

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Abstract: Heavy metals are ubiquitous and are released into the atmosphere/ environment by a variety of natural processes, but their quantities have been greatly augmented by anthropogenic activities. This study investigated the concentration of heavy metals Iron (Fe), Arsenic (As), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Manganese (Mn) and Lead (Pb) in the soil around the power plant obtained at the old power plant, new power plant and a far-away point from the plants which served as the control. In each location, two samples were obtained top layer and bottom layer of soil. Standard laboratory methods were employed for all the analyses. High concentration was obtained for the selected heavy metals in the soil at both the old and the new power plants with Arsenic having an average of 0.67 mg/kg and 0.40 mg/kg, Lead having an average of 2.63 mg/kg and 1.67 mg/kg, Iron having 1.25 mg/kg and 0.95 mg/kg, Chromium having 1.08 mg/kg and 0.67 mg/kg, Cadmium having 1.46 mg/kg and 0.54 mg/kg, Manganese having 1.97 mg/kg and 1.86 mg/kg and Zinc having 2.43 mg/kg and 0.86 mg/kg at the old and new site respectively. All the obtained concentration levels are above the permissible limit of the United States, United Kingdom, Europe and WHO. It is expedient that necessary measures be put in place to control the emissions from the plants to reduce the contaminating impact of the soil around the power plant as well as moving some human intakes far from the locations.

Keywords: impact, heavy metals, soil, environment, diesel fuel

1. INTRODUCTION

It is no doubt that no economy can thrive in the absence of energy. Energy is key in every stratum of development, including industry, environment, agriculture and the socio-economic system as a whole. In developing countries like Nigeria, a good number of homes and industries rely on generators as an alternative or substitute to the power source. Despite the immense natural resources bestowed on Nigeria in the form of natural gas, oil and coal, the country is still unable to give a long-term solution to the country's power problem [1]. There is an approved license for energy generation to the tune of 26000 MW as of 2015 and the current available capacity is more than 6000 MW of the installed generation capacity of about 12000 MW. An average of about 4000 MW is what gets distributed to the populace partly due to the constraint on the transmission and the

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distribution network, however, the manufacturing industries demand stands in excess of 13000 MW. Decentralized generation in line with some of the windows of opportunity provided by the National Electric Regulatory Commission will allow for the supply of the excess generated energy to the manufacturing industries and higher institutions of learning and encourage the generation of full capacity and commissioning of a new plant with the provision of conducive environment.

Over the years, the pollution of soil with heavy metals has received great attention as a global environmental issue [2, 3]. There are several sources from which heavy metals got introduced to the soil, some of the sources are industrial activities, municipal solid waste disposal, vehicle emissions, mining operations, fertilizers and pesticide usage, coal and fuel burning, and other wastes [2-4]. Potentially dangerous heavy metals, particulate matter and fly ash are released from the combustion of fuels and Coal, these bye products are harmful to both wildlife and humans [5]. The most common emitter of toxic metals and acid gases are power plants in the United States [6]. According to the United States Environmental Protection Agency (USEPA) 62 % of As, 28 % of Ni, 50 % of Hg, 22 % of Cr, 13 % of NOx, and 60 % of SO_2, which are toxic air pollutants, come from power plants [7]. Assessment of risks to the environment and human health as well as ecological risks to water and soil by emissions of heavy metals from thermal power plants and diesel generators have been investigated by several researchers [6, 8-12]. The heavy metals received over the period in plant tissues via the soil are taken by humans. The activities of endocrine and immune systems, nerves, normal cellular metabolism etc., are affected by heavy metals stored in fatty tissues [13].

The use of generators has been a substitute for the serious load shedding of power supply from the national grid. The working fluid of these generating sets/ generators are fossil fuels like gasoline and Diesel. Fossil fuels come with their attendant issues like the emission of dangerous gasses. Generators run on the principle of combustion, it is a form of Internal combustion engines, where chemical energy of the working fluid (e.g. gasoline and diesel) are used to transform the mechanical energy of the generator to do mechanical work, which is the power generated. Asides from the PAHs that get to the ambient air to pollute the environment, heavy metals from these combustions also settle in the soil and excess heavy metal accumulation in soils is toxic to humans and other animals. Chemically speaking, heavy metal refers to metals and metalloids that possess an atomic mass greater than 20 and a specific gravity greater than 5, such as cadmium (Cd), mercury (Hg), copper (Cu), arsenic (As), lead (Pb), chromium (Cr), nickel (Ni), and zinc (Zn). “Heavy” describes a series of metals, in some cases metalloids, that even in low concentrations can be toxic for plants and animals according to biological view [12].

Rapid development in agriculture and industry, as well as disturbance of the natural ecosystem due to the ever-increasing growth in world population, has led to massive contamination with heavy metals and has become a great threat to the environment and food security [13]. Heavy metals can migrate from surface soil to subsoil and contaminate ground water [14]. Heavy metals unlike organic pollutants, is covert, irreversible and persistent pollutants that poses a great threat to the health and well-being of organisms and human beings as well as degrade the quality of water bodies, the atmosphere, and food crops [15]. Studies have been conducted to investigate the presence of PAHs in Nigerian soils [14, 16-18]. The presence of high level of Cadmium (Cd) and other heavy metals in soil affects the plants visibly with a symptomatic show of growth inhibition, chlorosis, browning of root tips and eventual [19]. Cd and other heavy metals poisoning on cellular molecules have caused oxidant-antioxidant imbalance, leading to exposure of varieties of dangerous effects. Cd, as well as some other heavy metals, has also been related to the pathogenesis of several diseases like cancers, hypertension, diabetic nephropathy, myocardial infraction and peripheral artery disease [20].

Nigeria as a nation is seriously battling with an epileptic power supply, most industries, as well as government parastatals, are spending a lot on accumulated via expenses incurred in the purchase of diesel to power their operations. Meanwhile issues of environmental challenges, as well as human health, is on the high increase in the country. Some health challenges earlier mentioned as a result of the emission of harmful gases and soil heavy metals are very rampart in the country, which invariably is adding to the reduction in average life expectancy in the country. Lack of proper maintenance culture contributes to the problem realized from the use of generators and this definitely increases the percentage of PAHs and heavy metals that affect the environment and human health. Also, cost of maintenance of these generators are not friendly, so many users cut cost and all these affect the end product of combustion in the generators thereby also increasing the percentage of these poisonous gases and heavy metals in the soil. The aim of this work centers on an area that several other researchers are yet to investigate, which is the impact of the generator on the soil heavy metals within the university communities.

2. EXPERIMENTAL SETUP

2.1. The study area and determination of sampling point

The study site is Osun State University Osogbo campus. Osogbo southwestern Nigerian with geographical location of latitude 07°45'34.46" and longitude 04°36'00.02" university (Osun State University, Osogbo campus). The university has two generator houses, one is installed close to the senate building and the other one is installed close to mechanical workshop.

2.2. Soil sampling

Soil samples were collected using a stainless-steel hand auger. The samples were collected from two points (0-30 cm depth) at each soil sampling location. The soil samples were collected on the old generator house and new generator house considering instances such as: neighboring farmland, neighboring office and pathway. The soil samples were collected from different points in the old and new generator houses. Ten (10) soil samples were taken from the new generator house while twelve (12) soil samples were taken from the old generator house. Twenty-two soil samples were collected in all. At each sampling point, topsoil was collected from 0-15 cm and bottom soil from 15-30 cm. A Global Positioning System (GPS) was used to record the geographical coordinates of the sampling points. The samples were collected into clean polythene bags, stored in an ice-chest and transported to the laboratory for analysis.

2.3. Soil Preparation and Analysis

The soil samples were air dried and homogenized, after which unwanted matter (stones, plant materials etc.) was removed. The soil samples were sieved through a 2 mm sieve and the smaller particle size were used for the various analyses.

2.4. Soil Sample Digestion

ASTM method D 3974 – 99 was applied in the sample preparation and determination of the heavy metals. 5 g of the sieved sample was weighed into a 250 mL beaker and an empty beaker was set up to represent the reagent/glassware blank. In each beaker, 100 mL of distilled water was added; 1.0 mL of concentrated HNO_3 and 10 mL of concentrated HCl were added respectively. The beakers were covered with ribbed watch glasses and heated at 95 °C on a hot plate to avoid splattering during the heating process to ensure that the analyses were as quantitative as possible. The beakers were removed from the hotplate when the remaining solution is between 10 and 15 mL. The contents were allowed to cool to room temperature then each solution was filtered and quantitatively transferred into a 50 mL volumetric flask and diluted to volume with distilled water.

2.5. Heavy Metals Analyses

The Flame Atomic Absorption Spectrophotometer (FAAS), GBC Avanta PM type, was calibrated with prepared working standard solutions from stock solutions (1,000 mg/L Accu Standards Inc, USA) for each of the respective heavy metals to be analyzed. Soil extracts were aspirated into the flame atomizer through the capillary tube attached to the nebulizer unit of the FAAS. Air-acetylene flame was applied, at flow rates of 2 L/min for the fuel and 10 L/min for the oxidant. The instrument settings and conditions must be in line with the manufacturer’s specifications. A prepared working solution of 1 mg/L of each element was introduced after every three samples run to monitor instrument deviation which served as a quality check procedure. Triplicate analysis of each sample was carried out and the mean concentrations were reported. Tables 1 and 2 show the EU (Europe), UK (United Kingdom), US (United States), and WHO (World health organization) Standards for maximum permissible limits of heavy metals in soil.

Table 1. Maximum permissible limits for heavy metals in soil [21] .

Heavy metals	Maximum concentration (mg/kg)			
	EU STD	UK standard	US standard	WHO standard
Arsenic	0.30	0.30	0.30	0.30
Lead	0.30	0.07	0.30	0.30
Iron	0.45	0.40	0.40	0.50
Chromium	0.18	0.20	0.25	0.20
Cadmium	0.30	0.15	0.15	0.50
Manganese	0.50	0.55	0.50	0.65
Zinc	0.30	0.20	0.20	1.20

Table 2. Interval of contamination/pollution index of heavy metals in soil and its significance [22].

Limit (mg/kg)	Significance
<0.1	Very slight contamination
0.10 – 0.25	Slight contamination
0.26 – 0.50	Moderate contamination
0.51 – 0.75	Severe contamination
0.76 – 1.00	Very severe contamination
1.10 – 2.00	Slight pollution
2.10 – 4.00	Moderate pollution
4.10 – 8.00	Severe pollution
8.10 – 16.00	Very severe pollution
>16.00	Excessive pollution

3. RESULTS AND DISCUSSION

3.1. Heavy Metals Concentration

The results obtained from the laboratory tests done to determine the concentration of heavy metals in soil at the control site, old power plant and new power plant area of the university were presented using graphs and charts for proper description.

3.2. Arsenic Salt

In Figure 1, the concentration of Arsenic salt at the top and bottom soil of the control site, old power plant and new power plant of the university were shown. It was observed that the soil obtained at the old power plant has the highest concentration of Arsenic salt at both top soil and the deep soil with a value of 0.67 mg/kg and 0.44 mg/kg at the top and bottom respectively. This was followed by the new power plant with 0.40 mg/kg at both top and the deep soil. The values obtained at the control site is within the limits specified by EU, UK, US and WHO standard but the old and the new power plant has a concentration above the permissible limits by all the relevant standards. Moreover, the old site is severely contaminated while the new site is moderately contaminated. This shows that the emission from the plant has negative impact on the concentration of Arsenic salt at the university.

3.3. Lead salt

Figure 2 shows the comparison of Lead salt concentration at the control site, old site and a new site at both the top and bottom soil. The result shows that the soil obtained from the old power plant has the highest average concentration of Lead salt at both top and the bottom soil. Moreover, the relevant standards reveal that all the sites (including the control site) have lead salt concentrations higher than the permissible limits with the control site having the lowest concentration. The significance of the concentrations shows that the control site is severely contaminated while the old and the new site are moderately polluted and slightly polluted respectively. This implies that the emissions from the power plant increase the concentration of the soil even though some other areas may be polluted by other factors.

3.4. Iron salt

Figure 3 shows the result of the concentration of iron salt at the top and bottom soil of the sites. Just like the previously discussed heavy metals, the highest concentration was obtained at the old site with 1.25 mg/kg at the top and 0.87 mg/kg at the bottom. The pollution index reveals that the old site is slightly polluted while the new site is very severely contaminated. Moreover, the concentrations obtained at the power plants are higher than the permissible limits specified by all the standards stated in Table 1.

3.5. Chromium

Figure 4 shows that chromium also follows the same trend as the previously discussed heavy metals with the highest concentration at the old site at both top and the deep soil. The highest concentration obtained was 1.08 mg/kg at the top soil in the old power plant and this is followed by the bottom soil at the old power plant. Also, the concentration obtained at the top soil of the new power plant is 0.67 mg/kg and 0.48 mg/kg at the deep soil. Only the control site has the chromium concentration within the permissible limits as presented in Table 1. The old site is slightly polluted while the new site is severely contaminated.

3.6. Cadmium

In Figure 5, the result of the concentration of Cadmium at the top and bottom soil of the three sites was presented in a bar chart. The highest concentration was obtained for the old power plant with a value of 1.46 mg/kg at the top and 1.13 mg/kg at the bottom. Also, at the new power plant, a value of 0.67 mg/kg was obtained at the top and 0.48 mg/kg at the bottom. The control site has an average concentration of 0.06 mg/kg at the top and 0.01 mg/kg at the bottom. It was observed that the concentrations at the old power plant is above the limit recommended by all the standards agencies and it is slightly polluted while the new power plant is above the limits specified by EU, UK and US but falls within the recommended value by WHO.

3.7. Manganese

Figure 6 shows that the emission from the old and the new power plants has increased the concentration of manganese in the soil around the plant as the concentrations obtained are very high compared to the control site. At the old site, a concentration of 1.97 mg/kg and 1.66 mg/kg were obtained at the top and bottom of the soil respectively. The same trend but a lower value was observed for the new power plant with 1.86 mg/kg and 1.50 mg/kg for the top and the bottom soil respectively. The concentration at the old and the new power plant is above the permissible limits recommended by the EU, UK, US and WHO. The concentration at both the old and the new site implies slight pollution as presented in Table 1.

3.8. Zinc

Figure 7 shows the variation in the concentration of Zinc at the top and bottom of the sites. It was observed that the highest concentration was obtained at the old site and this was followed by the new site. Also, the concentration obtained at the old power plant exceeds the limits specified by the EU, UK, US and WHO. However, the concentration at the new power plant is within the limit specified by WHO for both the top and the bottom soil. Moreover, the concentration at the old power plant implies moderate pollution, which will have less impact on the environment and staff. Meanwhile, the new power plant that is associated with much dangerous impact is situated far away from staff and students of the institution.

The toxic effects of heavy metals on human health, vegetation, soil and ground water have been reported in several works of literature. In this case, only the soil heavy metals were examined and the possibility of human exposure through dermal contact exists. Although, dermal samples of workers around the power plants were not collected, previous authors had reported significant levels of some heavy metals in the dermal samples of workers at e-waste recycling sites [23]. Lu et al. also reported significant health risks from exposure to soil heavy metals in China [24]. Due to human activities in the present study area, the possibility of dermal exposure also exists.

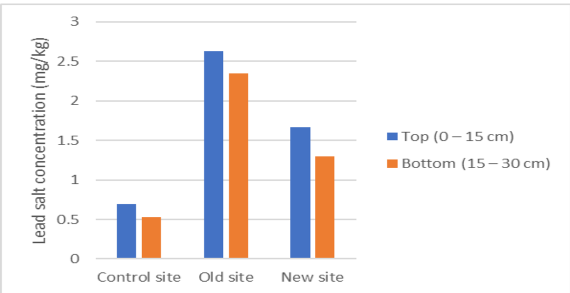

Fig. 1. Arsenic salt concentration.

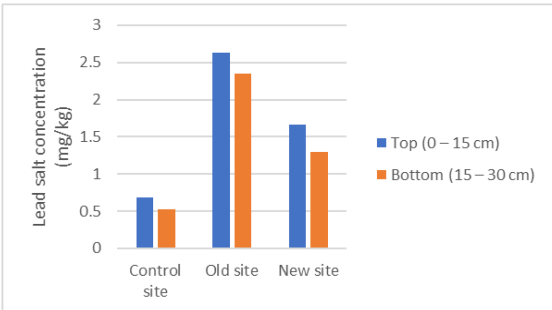

Fig. 2. Lead salt concentration.

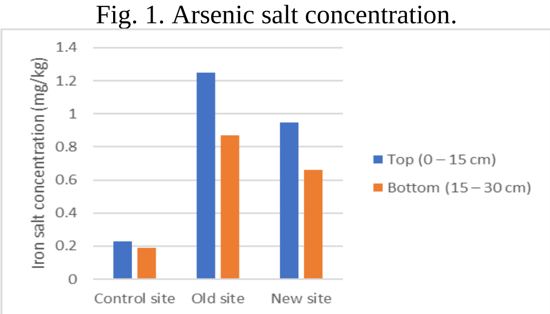

Fig. 3. Iron salt concentration.

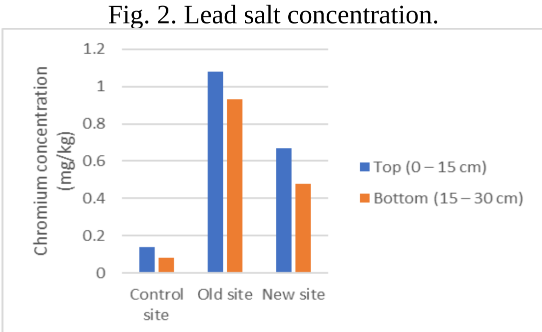

Fig. 4. Chromium concentration.

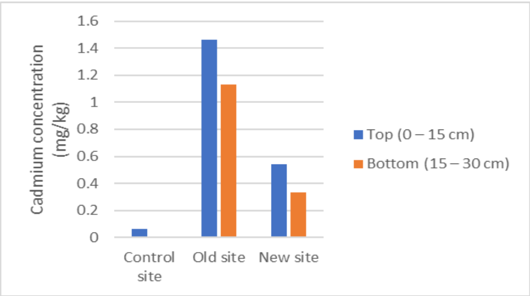

Fig. 5. Cadmium concentration.

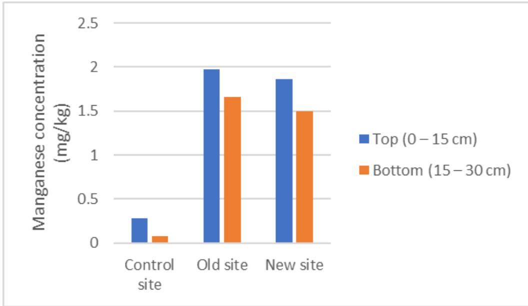

Fig. 6. Manganese concentration.

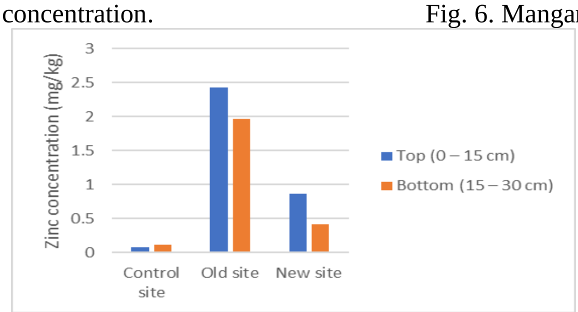

Fig. 7. Zinc concentration.

4. CONCLUSIONS

The impact of diesel fuel generators on soil heavy metals was examined at both old and new power plants (generator houses) of the Osun State University main campus in Osogbo, Nigeria. High concentration was obtained for the selected heavy metals in the soil at both the old and the new power plants with Arsenic having an average of 0.67 mg/kg and 0.40 mg/kg, Lead having an average of 2.63 mg/kg and 1.67 mg/kg, Iron having 1.25 mg/kg and 0.95 mg/kg, Chromium having 1.08 mg/kg and 0.67 mg/kg, Cadmium having 1.46 mg/kg and 0.54 mg/kg, Manganese having 1.97 mg/kg and 1.86 mg/kg and Zinc having 2.43 mg/kg and 0.86 mg/kg at the old and new site respectively.

The concentration of the heavy metals indicated that the soils of the power plants contained considerably high levels of heavy metals (Fe, Cr, Mn, Cd, Ar, Zn and Pb). The great variation between the means of the control and that of the power plants as observed from the coefficient of variation values suggest that the emission from the plants has contributed significantly to the levels of toxic metals in these soils and the values exceed the limits specified by EU, UK, US and WHO Standards. Proper education on the need to situate farmland, water sources and even offices not too close to these locations should be encouraged as this invariably can affect human health.

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