International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 9, Issue 4 [April. 2020] PP: 09-14

Generators' Harmful Exhaust Emissions in Buildings: Effects on Humans and Preventive Strategy

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ABSTRACT
The generators, both diesel and gasoline types are designed to produce harmful exhaust emissions such as; carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC), particulate matter and sulfur dioxide (SO_x). These harmful exhaust emissions spread in buildings were generators are used due to human errors and atmospheric conditions. The health hazards associated with high concentration or even lower levels of some of these emissions in air are numerous and therefore, cannot be ignored. This paper presents a research conducted on generators harmful exhaust emissions, their spread in buildings, effects on humans and preventive strategy. It first presents the different types and nature of the harmful exhaust emissions and further discussed their sources in buildings. The effects of the harmful exhaust emissions on humans such as health disorders (Cancer, respiratory tract infection, carbon monoxide poisoning, fatigue, headache, bleeding and depression, lowered immune system) were also highlighted and analyzed. The preventive strategy which includes; implementing safe practices, proper use and maintenance of generators, and piping the exhaust emission away from buildings was finally presented.

KEYWORDS: *Generators, Harmful Exhaust Emissions, Health Disorders, Buildings, Preventive Strategy.*

Date of Submıssıon: 13-05-2020 Date of Acceptance: 26-05-2020

I. INTRODUCTION

The generators in general, are not perfect and they produce emissions through their exhaust pipes or other system. These emissions are produced as a result of the combustion of fuels, natural gas, gasoline, petrol (Omidvarborna et al., 2014).The major products of the complete combustion of petroleum-based fuels in generators and other internal combustion engine are carbon dioxide, water and nitrogen from air comprising highest percentage. A very small portion of the nitrogen is converted to nitrogen oxides and some nitrated hydrocarbons. Carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x), particulate matter and sulfur dioxide are other generators' exhaust emissions and they are harmful to humans. Some excess oxygen may be emitted which may be dependent on the operating conditions of the generator's engine.

Furthermore, the emission of generator exhaust contributes greatly to air pollution and are part of the major causes of health disorders and deaths in buildings in Nigeria (Bola, 2018; Yinka, 2017; Onoiribholo, 2018). The harmful exhausts emissions from generators are usually spread in buildings as a result of human errors and atmospheric conditions. Therefore, there is the need to reduce to minimum health hazards associated with the generator exhaust emissions in buildings. For health hazards to be minimized, the concentration of generator exhaust emissions in buildings should be reduced.

Moreover, these emissions can be reduced via maintenance and proper usage of generators (Dahlgren, 2014) and safe practices since the concentration of a chemical species in generator engine exhaust is a function of several factors, including engine type, engine operating conditions, fuel and lubricating oil composition and emission control system (Johnson, 1988; Elias et al., 2009).

The main objective of this paper is to identify and analyze the harmful exhaust emissions from generators in buildings, their effects on human health and to suggest preventive strategy.

GENERATOR EXHAUST EMISSIONS

Emissions from gasoline generator exhaust and other spark-ignition engines that run on unleaded gasoline are qualitatively similar to the emissions from diesel engines (Alsberg et al., 1984).

Diesel Generator Exhaust Emissions

Diesel engines (generators) emit compounds containing a complex mixture of gases, vapors, liquid aerosols and particulate substances or particles. These substances are the products of combustion. The exhaust emissions from diesel generators are usually more visible than those emitted from petrol engines because they

contain over ten times more soot (HSE, 2012). Diesel engines generally produce less carbon monoxide than petrol engines but more oxides of nitrogen, sulphur oxides, aldehydes and particulate matter (table 1).
The main chemical constituents of diesel generator exhaust emissions are carbon (soot), nitrogen (N_2), water (H_2O), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), of sulphur oxides (sulphur dioxide (SO_2), aldehydes, ketones, alcohols, polycyclic aromatic and various hydrocarbons (PAHs).
The composition and quantity of diesel generator exhaust emissions depend on the following;
(a) The engine type (non-turbocharged, turbocharged diesel engine),
(b) The engine condition,
(c) Specification of the fuel used,
(d) Workload demand on the engine, and
(e) Engine temperature

Gasoline generator exhaust Emissions
Emissions from gasoline generator exhaust are quiet similar in terms of quality to the emissions from diesel engines and they are shown in table 1.

Table 1: Generator Exhaust Emissions

Generator exhaust emissions	**% of total**	
Compound	**Petrol**	**Diesel**
Nitrogen	71	67
Carbon dioxide	14	12
Water vapor	13	11
Oxygen		10
Trace elements	< 0.6	~ 0.3
Nitrogen oxides	< 0.25	< 0.15
Carbon monoxide	1 - 2	< 0.045
Particulate matter		< 0.045
Hydrocarbons	< 0.25	< 0.03
Sulfur dioxide	possible traces	< 0.03

(Source: ADUI, 2000)
All figures in table 1 are approximate values.

GENERATORS' HARMFUL EXHAUST EMISSIONS
Generally, internal combustion engines are not perfect. Even most modern, technologically advanced generators and other internal combustion engines still naturallyly produce some level of harmful emission output. This is because several conditions in the combustion chamber prevent complete combustion and causes unwanted chemical reactions leading to harmful emissions.
The harmful emissions from generators and their causes are:

Carbon monoxide (CO) Emission
Carbon monoxide is a byproduct of incomplete combustion. The air and fuel mixture in the engine will not burn completely when it does not have enough oxygen present during combustion because there is insufficient oxygen present to fully oxidize the carbon atoms into carbon dioxide. As a results this, carbon atom bond with only one oxygen atom thereby forming carbon monoxide (Yamaki et al., 1986). The carbon monoxide, CO usually formed is colorless, tasteless, and odourless, but highly toxic and combustible gas.

Hydrocarbon (HC) Emission
Hydrocarbons are raw fuels of organic compounds that are made up of only hydrogen and carbon atoms. The amount of hydrocarbons emitted from combustion chamber when combustion does not take place at all as a result of misfire is high (Pulkrabek, 2004). Misfire occurs due to fuel delivery, ignition or air induction problems. Partial misfire occurs when there is poor mixing of fuel and air as a result of excessive intake of air and low temperature. The harmful hydrocarbons emitted are benzene (C_6H_6) and Polycyclic Aromatic Hydrocarbons (PAHs) among others.

Oxides of Nitrogen (NO_x) Emission
According to Zaebst et al. (1988), high engine cylinder temperature and pressure which occur during the combustion process can cause nitrogen to react with oxygen to form Oxides of Nitrogen -NO_x. Lean air/fuel mixture, extreme temperature intake air and overheated engines are the common causes of excessive NO_x.

Sulfur dioxide

Sulfur dioxide is emitted as the result of fuel combustion and in very small concentration in diesel engine as shown in table 1. Sulfur dioxide is an invisible gas and has a nasty, sharp smell. It reacts easily with other substances to form harmful compounds, such as sulfuric acid, sulfurous acid and sulfate particles.

Particulate matter

Particulate matter is made up of all solid and liquid particles (includes both organic and inorganic particles, such as dust, soot, smoke, and liquid droplets) suspended in air.

The particulate matter emitted by generator contains 60–80% of elemental carbon (Zaebst et al., 1988), 2–7% sulfuric acid (Pierson & Brachaczek, 1983) and some metallic species, e.g., iron from the engine and exhaust system (Lang et al., 1981), barium from fuel (Hampton et al., 1983) and zinc from lubricating oil (Hare & Baines, 1979), and adsorbed organic compounds (National Research Council, 1982).

THE SPREAD OF GENERATORS' HARMFUL EXHAUST EMISSIONS IN BUILDINGS

The generator engines are designed to push exhaust gases in a given direction. At the end of the exhaust pipe, the speed is about 7 m/s which enables emissions to be directed away from the body of the generator. In addition, wind plays an important role in the movement of these gases. The generators' harmful exhaust emissions can spread in buildings through the following means:

i. Directing exhaust pipe towards the building as shown figure 1.

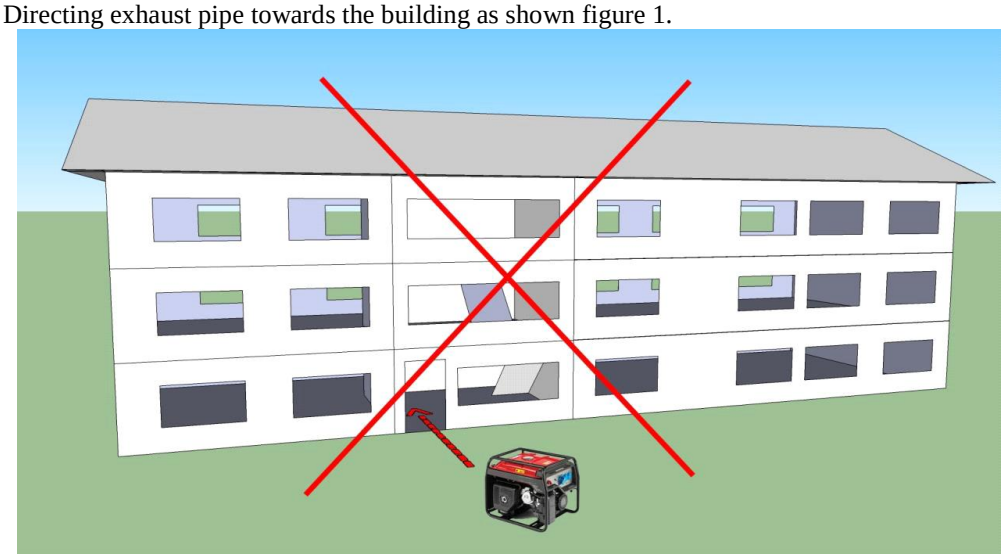

Figure 1: Wrong direction of generator's exhaust pipe (Source: CTIF. 2014)

ii. Keeping generator in room, corridor, gang way, stair case and passage among many others.

Figure 2: Generator in a corridor

iii. Keeping generator less than 7m away from a building. In this position, the concentration of emissions from generator in a building increase faster to a level that endanger human life.

Figure 3: Generator in close proximity to house

iv. Positioning of generator's harmful exhaust pipe due west in the tropics. The wind is usually from the east and to the west (American Meteorological Society, 2009) through most of the tropics and positioning of generator's harmful exhaust pipe due west will cause emissions to be blown in the opposite direction which may be towards building.

v. Fast blowing wind. Wind blowing faster than 1 m/s especially during harmattan, can redirect exhaust emissions; towards opposite direction of the right setting of generator in building environment (i.e. towards the building). In this case generators' harmful exhaust emissions can spread inside windows and doors when opened even when the distance is more than 7 m.

EFFECTS OF HARMFUL EXHAUST EMISSIONS ON HUMAN HEALTH

The effects of harmful exhaust emissions on human health are numerous and are stated and analyzed below;

Health Effect of CO

Carbon Monoxide is a product of incomplete combustion (oxidation) of fossil fuels or hydrocarbons. The binding of carbon monoxide (CO) with haemoglobin to form carboxy-haemoglobin (HBCO) reduces the capacity of blood to carry oxygen, and the binding with other haem proteins is directly related to changes in the functions of affected organs, such as the brain, cardiovascular system, exercising skeletal muscle and the developing foetus.Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries (Omaye, 2002). Poisoning is more serious with higher concentration, longer exposure and more intense physical activity.

Health Effect of NO_x

Mono-nitrogen oxides NO and NO_2 (NOx) react with ammonia, moisture, and other compounds that form nitric acid vapor and related particles. When these particles in excess get into the lung tissue, they can cause damage to it, leading to premature death in extreme cases. According to Turner et al. (2017), the inhalation of NO species increases the risk of lung cancer and colorectal cancer. Also, they may cause respiratory diseases such as emphysema and bronchitis and heart disease (EPA, 2013).

Health Effect of Particulate matter (PM_{10} and $PM_{2.5}$)

Inhalation of airborne particulate matter can cause asthma and cardiovascular issues. Due to the size of the particles, they can infiltrate the deepest part of the lungs (Babadjouni et al., 2017) and cause lung cancer (Hamra et al., 2015). Inhalation of airborne particulate matter can also cause premature death (Kurt et al., 2016; Bourdrel et al., 2017).

Health Effect of Hydrocarbons

Long-term exposure to benzene (C_6H_6) can lead to damage of bone marrow; can cause excessive bleeding and upset the immune system, increasing the chances of infection. C_6H_6 in the blood causes leukemia and also other blood cancers and pre-cancers of the blood (Automobile Association Developments Limited, 2012). On the other hand, several Polycyclic Aromatic Hydrocarbons (PAHs) are carcinogenic (IARC, 1983; IARC, 1987)

Health Effect of Sulfur dioxide

Inhalation of sulfur dioxide causes constriction of air passages, creating problems for people with asthma and for young children whose small lungs need to work harder than adults' lungs (Dahlgren, 2014).

Health Effect of Ozone

Though ozone is beneficial in the upper atmosphere, it reacts with lung tissue in the body. It can inflame and cause harmful changes in breathing passages, decrease the lungs' working ability and cause coughing and chest pains (EPA, 2016). Even healthy people are found to be affected by ozone.

PREVENTIVE STRATEGY

The preventive strategy involves both reduction of the emission rate and prevention of spread of emissions in buildings and is discussed below.

Reduction of Emission Rate

The exhaust emissions depend on the engine combustion design and operating conditions, the fuel grade and lubricant and the state of maintenance (Elias et al., 2009). Reduction of emission rate therefore, involves the following:

1. Use of more fuel-efficient or lower emission generator where possible. This may cause higher engine injection pressures to reduce particulates and fitting exhaust gas recirculation systems to reduce gaseous oxide emissions;
2. Proper maintenance of generator. Generator pollutes the least amount when they are brand new. Over time, the emission control systems of the generator degrade and pollution increases. Keeping your generator well-maintained with regular tune-ups will prolong the efficiency of your engine and its emission control systems. Generator owner's manual has a suggested maintenance schedule that can help generators operate efficiently. Maintenance also involves using high grade fuel (cleaner fuels such as low sulphur diesel fuels) and lubricant in running generators.
3. Using generators in good operating conditions.
4. Using generators without exceeding the load capacity as specified by the manufacturer.

Prevention of Exhaust Emissions from Spreading in Buildings

The following are ways exhaust emissions can be prevented from spreading in buildings:

1. Keeping generator at least 7m away from a building especially when operated in the open. Keeping generators in this position reduces emissions volume that enters building at a level that is less harmful to life.
2. Directing exhaust pipe away from the building.
3. Avoiding keeping generators in corridor, room, gang way, stair case, deepened parts of buildings and passage among many others.
4. Closing windows and doors when running generators in open environment.
5. Piping exhaust emissions away from buildings especially when used in corridor, stair case, passage, gang way, and deepened parts of buildings among many others.
6. Piping exhausts emissions above 10m when used around bungalows (Ezetoha et al., 2014). When emissions are 10m and above, they will spread in air above windows and doors level in bungalows. In addition, the emissions (gases) such as CO, is lighter than air and therefore cannot spread through windows and doors.
7. Positioning of generator's harmful exhaust pipe due east in the tropics. This will cause emissions to be blown in the direction of the wind and this is away from the building.
8. Use of electronic detectors/monitors for monitoring exhaust emissions in buildings. The personal dosimeter is an example of such device for the detection of carbon monoxide (CO).

II. CONCLUSION

This work has shown that generators produce emissions that spread in buildings due to human errors. The harmful exhaust emissions cause health problems such as fatigue, headache, respiratory tract infection, carbon monoxide poisoning, bleeding and depression, lowered immune system and cancer among many others.

The study also established that the volume of emission and the associated health problems can be prevented by reducing the emission rate and preventing harmful emissions from spreading in buildings. The preventive strategy therefore includes implementation of safe practices, proper use and maintenance of generators, and piping of exhaust emission away from buildings. It is therefore advised that the preventive

strategy presented herein be adopted by anybody using generator in building in order to prevent health disorderliness associated with its exhaust emissions.

REFERENCES

[1]. American Meteorological Society. (2009). Trade winds, Glossary of Meteorology. Archived from the original on 2008-12-11. Retrieved 2008-09-08.

[2]. Alsberg, T., Westerholm, R., Stenberg, U., Strandell, M., & Jansson, B. (1984). Particle associated organic halides in exhausts from gasoline and diesel fueled vehicles. In: Cooke, M. & Dennis, A.J., eds, Polynuclear Aromatic Hydrocarbons, 8th International Symposium: Mechanisms, Methods and Metabolism, Columbus, OH, Battelle, pp. 87–97.

[3]. AUDI. (2000). Self-Study Programme 230: Motor Vehicle Exhaust Emissions (PDF). Retrieved 23 March 2012.

[4]. Automobile Association Developments Limited. (2012). Exhaust emissions: What comes out of your car's exhaust? Retrieved from http://www.theaa.com/driving-advice/fuels-environment/emissions

[5]. Babadjouni, R. M., Hodis, D. M., Radwanski, R., Durazo, R., Patel, A., Liu, Q., & Mack, W.J. (2017). Clinical effects of air pollution on the central nervous system; a review. Journal of Clinical Neuroscience, 43, 16–24. doi:10.1016/j.jocn.2017.04.028. PMC 5544553. PMID 28528896.

[6]. Bola, B. (2018). Generator fumes kill three family members in Osogbo. Retrieved from https://www.pressreader.com/nigeria/the-punch/20181130/281582356693191

[7]. Bourdrel, T., Bind, M. A., Béjot, Y., Morel, O., & Argacha, J. F. (2017). Cardiovascular effects of air pollution. Archives of Cardiovascular Diseases, 110 (11), 634–642. doi:10.1016/j.acvd.2017.05.003. PMC 5963518. PMID 28735838.

[8]. CTIF. (2014). Dangers concerning the production of carbon monoxide by generators and other internal combustion engines Version 1. CTIF Fire Prevention Commission. Retrieved from https://www.ctif.org › sites › files › library › files › coproposed_document

[9]. Dahlgren, T. (2014). Health Effects from Automobile Emissions. Emission Check. Retrieved from https://fortress.wa.gov › ecy › publications › publications

[10]. Elias, V., Leonidas, N., Panayiotis, P., Zissis, S., Loukia, C., Constantini, S., Chrysi, P., Petros, S., & George, S. (2009). An investigation on the physical, chemical and ecotoxicological characteristics of particulate matter emitted from light-duty vehicles. Environmental Pollution, 157, 2320–2327.

[11]. EPA. (2013). Nitrogen Dioxide. United States Environmental Protection Agency (EPA). Retrieved from https://www.epa.gov/environmental-topics/air-topics

[12]. EPA. (2016). Ozone-Pollution**.** Rtrieved from www.epa.gov/ozone-pollution**.**

[13]. Ezetoha, F. C, Nwokeke, A. O, Ohaneme, L. C., & Onyemaobim, I. (2014). Health Hazards in Substandard Computer Centres. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 3(7):1-13.

[14]. Hampton, C. V., Pierson, W. R., Schuetzle, D., & Harvey T. M. (1983). Hydrocarbon gases emitted from vehicles on the road. 2. Determination of emission rates from diesel and spark-ignition vehicles. Environ. Sci. Technol, 17: 699–708.

[15]. Hamra, G. B., Laden, F., Cohen, A. J., Raaschou-Nielsen, O., Brauer, M., & Loomis, D. (2015). Lung Cancer and Exposure to Nitrogen Dioxide and Traffic: A Systematic Review and Meta-Analysis. Environmental Health Perspectives, 123 (11):1107–12. doi:10.1289/ehp.1408882. PMC 4629738. PMID 25870974.

[16]. Hare, C. T., & Baines, T. M. (1979) Characterization of Particulate and Gaseous Emissions from Two Diesel Automobiles as Functions of Fuel and Driving Cycle (Technical Paper Series 790424), Warrendale, PA, Society of Automotive Engineers.

[17]. HSE, (2012). Control of diesel engine exhaust emissions in the workplace, (3RD ED.). Health and Safety Executive, UK, 1-22.

[18]. IARC. (1983). IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, Vol 32, Polynuclear Aromatic Compounds, Part 1, Chemical, Environmental and Experimental Data, Lyon.

[19]. IARC. (1987). IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, Vol. 42, Silica and Some Silicates, Lyon, pp. 39–143.

[20]. Johnson, J. (1988). Automotive emissions. In: Watson, A.Y., Bates, R.R. & Kennedy, D., eds, Air Pollution, the Automobile, and Public Health, Washington DC, National Academy Press.

[21]. Kurt, O. K., Zhang, J., & Pinkerton, K. E. (2016). Pulmonary health effects of air pollution. Current Opinion in Pulmonary Medicine, 22 (2), 138–43. doi:10.1097/MCP.0000000000000248. PMC 4776742. PMID 26761628.

[22]. Lang, J. M., Snow, L., Carlson, R., Black, F., Zweidinger, R., & Tejada, S. (1981). Characterization of Particulate Emissions from In-use Gasoline-fuelled Motor Vehicles (Technical Paper Series No. 811186), Warrendale, PA, Society of Automotive Engineers.

[23]. National Research Council. (1982). Diesel Technology — Impacts of Diesel-powered Light-duty Vehicles. Washington DC, National Academy of Sciences.

[24]. Omaye, S. T. (2002). Metabolic modulation of carbon monoxide toxicity. Toxicology. 180 (2): 139–150. doi:10.1016/S0300-483X(02)00387-6. PMID 12324190.

[25]. Omidvarborna., et al. (2014). Characterization of particulate matter emitted from transit buses fueled with B20 in idle modes. Journal of Environmental Chemical Engineering. 2 (4): 2335–2342. doi:10.1016/j.jece.2014.09.020.

[26]. Onoiribholo, F. (2018). Six Family Members Die, One Survives Death From Generator Fumes In Benin. Retrieved from https://www.independent.ng/six-family-members-die-one-survives-death-from-generator-fumes-in-benin/

[27]. Pierson, W. R., & Brachaczek, W. W. (1983). Particulate matter associated with vehicles on the road. II. Aerosol Sci. Technol.: 2:1–40.

[28]. Pulkrabek, W.W. (2004). Engineering Fundamentals of the Internal Combustion Engine. Pearson Prentice Hall, New Jersey

[29]. Turner, M. C., Krewski, D., Diver, W. R., Pope, C. A., Burnett, R. T., Jerrett, M., Marshall, J. D., & Gapstur, S. M. (2017). Ambient Air Pollution and Cancer Mortality in the Cancer Prevention Study II. Environmental Health Perspectives, 125 (8), 087013. doi:10.1289/EHP1249. PMC 5783657. PMID 28886601.

[30]. Yamaki, N., Kohno, T., Ishiwata, S., Matsushita, H., Yoshihara, K., Iida, Y., Mizoguchi, T., Okuzawa, S., Sakamoto, K., Kachi, H., Goto, S., Sakamoto, T., & Daishima, S. (1986). The state of the art on the chemical characterization of diesel particulates in Japan. In: Ishinishi, N., Koizumi, A., McClellan, R.O. & Stöber, W., eds, Carcinogenic and Mutagenic Effects of Diesel Engine Exhaust, Amsterdam, Elsevier, pp. 17–40.

[31]. Yinka, O. (2017). Generator fumes disaster: Mother, 5 children dead; father in coma. Retrieved fromhttps://www.tribuneonlineng.com/105080/

[32]. Zaebst, D. D., Blade, L. M., Morris, J. A., Schuetzle, D., & Butler, J. (1988). Elemental carbon as a surrogate index of diesel exhaust exposure. In: Proceedings of the American Industrial Hygiene Conference, 15–20 May 1988, San Francisco, CA, Cincinnati, OH, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluation and Field Studies.