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REVIEW ARTICLE

A review on indoor air pollution from lightning sources in developing countries—The pollutants, the prevention and the latest technologies for control

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ABSTRACT

Currently, developing nations around the world rely heavily on the use of biomass and fossil fuels for cooking, lighting, and warmth due to a lack of access to clean fuels and constant electricity supply. Unfortunately, the use of these materials has the side effect of emitting of harmful pollutants into the air. Constant exposure to some of these emissions has led to the death of millions of people around the world, with women and children disproportionately affected due to greater amounts of time spent indoors. The work focused on indoor air pollution from lightning sources in developing countries and the negative impacts of cases of ill-health and mortality. The techniques adopted for the research comprised extensive and intensive review of literature on lightning sources. Resources used encompassed internet materials, current reports and recent publications by researchers of note. The findings show that there are associated pollutants, the prevention and the latest technologies for control the pollutants. It was concluded that the dearth of research in lighting sources as sources of indoor air pollution is needed to be addressed by researchers. Also, policy implications to improve electricity deficits should be embarked upon by governments to discourage the use of fossils and biomass for lighting indoors.

Keywords: pollution; air pollution; indoor environment; indoor air pollutants; prevention; control

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1. Introduction

An estimated 85 million Nigerians—a typical developing country, which amounts to about 43% of the country's population, have no access to the nation's power grid system, making the country to have one of the largest energy access deficits on the planet[1]. This consistent lack of electricity acts as a major constraint to businesses, consumers, and the general welfare of its citizens, thereby driving the shift to alternative energy and lighting sources such as generators and inverters for middle to upper-class citizens, and solar-powered lamps, candles, and lanterns for lower-class citizens. According to the Access to Energy Institute report of June 2019, the collective capacity of Nigerian gasoline generators amounts to about 42 Gigawatts which is eight times the current capacity of the nation's power grid. The staggering difference between these two sectors further accentuates the severity of the nation's current power generation deficit and the increasing need for Nigerians to resort to the burning of fossil fuels for power generation and lighting. A study conducted by Okedere et al.[2], showed that backup power generation accounts for an estimated 60%

of the yearly CO_2 emissions produced by the country's energy sector. Considering the fact that the majority of the 22 to 65 million backup power generators currently in service are situated right next to residential areas and office buildings, an inquiry into the current state of indoor air quality is of paramount importance[3].

Although, death tolls associated with indoor air pollution around sub-saharan Africa have seen significant dips over the decades, it is still one of the leading risk factors for mortality and the largest risk factor at lower incomes[4,5]. Deaths associated with indoor air pollution disproportionately affect women and children due to greater amounts of time spent at home, especially in developing countries[6]. This is backed by data that shows as high as 6000 indoor air pollution-related mortalities in middle-aged people which pales in comparison to the over 40,000 recorded deaths in children aged 5 and below in 2017 alone[7]. The higher infant mortality rate can also be attributed to the generally-higher resting metabolic rates and oxygen consumption when compared to adults, as well as narrower airways making them more susceptible to the effects of indoor air pollution[8].

About 3.8 million deaths a year are caused by illnesses attributable to household air pollution and are mostly caused by the use of inefficient solid fuels and kerosene for lighting and cooking. Studies show that the release of these pollutants in households tends to cause health complications such as pneumonia, bronchitis, heart disease, and lung cancer[6]. Research by Sofoluwe[9] in 1968 which studied exposure in nearly a hundred different Nigerian homes showed the presence of high concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), and benzene (C_6H_6) which according to him, were responsible for illnesses observed in several children. CO in particular is one of the most lethal of the pollutants and is produced as a result of incomplete combustion of fuels in generators, cars, and wood-burning among other sources[10]. As many as 1500 deaths a year are caused by direct inhalation of carbon monoxide in generator smoke which induces complications such as asphyxia, dizziness, edema, and death[11].

This review focused on the pollutants from indoor pollution current strategies for mitigating indoor air pollution and the current technologies for control.

2. Metodology

The techniques adopted for the research comprised extensive and intensive review of literature on lightning sources. Resources used encompassed internet materials, current reports and recent publications by researchers of note, indoor air pollution from lightning sources, the associated pollutants, the prevention and the technologies for control.

3. Indoor pollutants

3.1. Particulate matter

Particle pollution, commonly known as particulate matter (PM), consists mostly of microscopic particles; either solid or liquid in the air. These particles could contain soot, dirt, smoke, and liquid drops. Some particles are large enough (or appear dark enough) to be seen—for example, smoke in the air is frequently visible. Others are so little that they are invisible in the air[12]. Particulate matter can be inhaled, which could potentially cause major health issues and complications. Particles with diameters as small as 10 micrometers can enter the human lungs, and possibly invade the bloodstream. Meanwhile, particles with diameters of 2.5 micrometers and below are the most dangerous having the greatest health impacts.

Particulate matter and nitrogen dioxide are prevalent indoor and outdoor air contaminants. Tobacco smoking, the use of machines that run on gas, kerosene, wood, or coal, and, to a lesser extent, cleaning and repair operations can all contribute to indoor pollution. Biomass fuel (wood, charcoal, fossil fuel-based generators, and so on) is commonly burned in households in underdeveloped countries, either in open flames or inefficient stoves. As a result of incomplete combustion, a substantial amount of hazardous compounds, such as particulate matter, carbon monoxide, and nitrogen oxides, are produced in large quantities and can be classified in three ways: by mass concentrations, carbonaceous fractions, or individual chemical constituents[13].

Particulate matter sources

Indoor air pollution emanates from a variety of sources in homes, schools, office buildings and many more. The emission of these pollutants are mostly caused by common daily routine activities like cooking using solid fuels, or incomplete combustion of fuels in cars from adjoining garages. As a result, the quality of indoor air significantly decreases and leads to a consistent exposure to contaminants such as carbon monoxide (CO), Ozone O_3, nitrogen oxides ($NO_{x)}$ and volatile organic compounds (VOC) such as xylenes, toluene, and naphthalene[14]. Different pollutants affect the human body in a myriad of ways causing diseases ranging from headaches and nausea to cancer. For this reason, these pollutants will be discussed in greater detail in the subsequent paragraphs.

3.2. Carbon monoxide (CO)

Carbon monoxide is a deadly gas emitted as a result of the incomplete combustion of a wide variety of fuels. faulty cooking, tobacco smoke and heating devices, fires, and car gases from adjoining garages, as well as outdoor air exchange in crowded traffic regions or highly industrialized areas, are the main indoor sources of CO. The compound is a chemically simple molecule made up of one carbon atom and one oxygen atom linked together. Though both carbon and oxygen are necessary for human life in various forms, they combine to generate carbon monoxide, which is a dangerous combination. Carbon monoxide is particularly dangerous because it causes red blood cells to absorb it while rejecting oxygen. As a result, the human body experiences oxygen deprivation, which leads to cellular death. The affected individuals will eventually suffocate if this occurs at high enough concentrations[15].

3.3. Nitrogen oxides (NOx)

High-temperature combustion produces nitrogen monoxide (NO) and nitrogen dioxide (NO_2), which are gases created by nitrogen and oxygen reactions. The reactions can involve both nitrogen in the fuel and nitrogen in the air. In the atmosphere, NO can be formed and then oxidized to produce NO_2, which is the most poisonous of the nitrogen oxides (often referred to as NO_x) and is extremely harmful to human health. Emissions of nitrogen oxides have usually grown, resulting in a plethora of studies on nitrogen oxide exposure, notably in the last 15 years[16]. The major source of nitrogen dioxide emissions is from road traffic. Tobacco smoke and gas, wood, oil, kerosene, and coal-burning equipment such as stoves, ovens, water heaters, and fireplaces, mostly poorly maintained units, are the most significant indoor sources[17]. Outdoor air infiltration has a significant impact on indoor levels, particularly near highways or high-density industrial areas. Inhaled NO_2 is converted to nitric acid in the lungs, causing cellular and immune system damage. When other pathologies are present, inhalation can cause respiratory dysfunction (limit for protection of asthmatic of 200 g/m^3 1-h average; 2000 g/m^3 impact normal individuals). Direct contact with NO_2 can also cause eye irritation[18].

3.4. Benzene

Benzene is a widely used VOC in industry and is commonly emitted indoors from indoor sources such as building materials, cookers, furniture, and garages and as a result of various human activities[18]. Exposure to high concentrations of the compound has been observed to cause abnormalities in cell activities. It can, for example, cause the bone marrow in the body to significantly reduce its production of cells which could result in anaemia. Benzene also has the effect of altering antibody levels in the body there by weakening the immune system and causing white blood cell loss.

The severity of the effects of benzene exposure is heavily dependent on length of exposure, as well as its concentration in the air[12]. Acceptable levels of benzene exposure ranges from 1 ppm for long term exposure, to 5 ppm for short term[19].

3.5. Formaldehyde

Formaldehyde is a pungent and colorless gas commonly used in the production of building materials and household products such as pressed-wood products, plywood, insulation materials, adhesives and glues. The presence of formaldehyde in indoor air has been linked with a variety of health complications such as nausea, wheezing, coughing and increased difficulty breathing. High enough exposure to the compound can also lead to cancer. The health effects associated with formaldehyde exposure is heavily dependent on length of exposure and general susceptibility[20].

Formaldehyde, a colorless, pungent-smelling gas, has been linked to watery eyes, burning sensations in the eyes and throat, nausea, and difficulty breathing in some people who have been exposed to high levels (above 0.1 parts per million). Asthmatics may experience attacks if the concentrations are too high. Some people can develop a sensitivity to formaldehyde, according to research. It has also been shown in animal studies to cause cancer and may cause cancer in humans. Eye, nose, and throat irritation; wheezing and coughing; fatigue; skin rash; and severe allergic reactions are all possible side effects[21].

3.6. Toluene

Toluene is one of the most common VOCs found in indoor air. The compound is mostly released as a gas at room temperature and is usually added to gasoline which when combusted is one of the major sources of toluene in indoor air. Other major sources of the pollutant include paints, resins, cosmetics, gasoline and a wide variety of home goods[22–25].

The health effects of toluene vary significantly from person to person. It is heavily dependent on factors such as the concentration of the compound in the air, length of exposure, and the sensitivity of an individual to it. Studies show that toluene; when exposed to a significant amount of it, can cause major health issues such as headaches, dizziness and a variety of respiratory and neurological diseases[26]. The highest concentrations of toluene were discovered to be in shopping malls (15–164 g/m^3), followed by workplaces (6–32 g/m^3) and houses (3–20 g/m^3). High toluene levels can also be observed in new buildings due to its abundance in construction material[25,27–30].

3.7. Xylene

Xylene is a colorless, sweet-smelling liquid which is widely used in medical technology and industries as a solvent. The compound is commonly produced indoors by the combustion of organic materials like coal, wood or fossil fuels[31]. High levels of exposure to xylene can cause headaches, nausea and throat discomfort. Long-term exposure on the other hand has been linked with health issues such as respiratory, lung, kidney and heart diseases[32]. Shopping districts, with levels ranging from 1.3 to 74 g/m^3, and workplaces, with levels ranging from 2.2 to 16 g/m^3, are among the most contaminated. At houses and schools, maximum xylene concentrations of 3.1 and 0.3 g/m^3 have been measured[28–30,33]. Acceptable xylene exposure limits range from 100 ppm to 150 ppm over an 8-hour period.

3.8. Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are formed when organic material is incompletely burned. Except for a few medications and industrial activities, most PAHs have no recognized use. Benzo (a) pyrene has received the most attention and is one of the most poisonous of all PAHs. Because there is minimal information on human exposure to any one, pure PAH, it is frequently employed as an indication, or marker, for this category of contaminants. PAHs can irritate the eyes, skin, and respiratory system, and at high concentrations, they can induce headaches, nausea, vomiting, and stomach discomfort. A variety of PAHs have been linked to cancer in humans. Benzo (a) pyrene is linked to lung cancer, and the risk increases in the presence of other chemicals, such as cigarette smoke[34].

3.9. Naphthalene

Naphthalene is a toxic air pollutant that is widely present in ambient and indoor air as a result of emissions from the chemical and primary metals industries, biomass burning, gasoline and oil combustion, tobacco smoking, the use of mothballs, fumigants, and deodorizers, and a variety of other sources. It is a common intermediary in the manufacture of phthalic anhydride (66,000 metric tons in the United States in 2000), surfactants (27,000 tons), and insecticides (14,000 tons)[35]. Although accidental eating of mothballs has been observed, inhalation is the primary mode of naphthalene consumption in people. Acute naphthalene poisoning can result in hemolytic anemia and cataracts. There have been no reports of long-term adverse health consequences or evidence of human carcinogenicity or genotoxicity[14,24].

3.10. Trichloroethylene

Trichloroethylene is a colorless, nonflammable liquid that is used as a solvent to remove grease from metal components. Adhesives, paint removers, varnishes, lubricants, and spot removers all contain the compound. It is not uncommon to find low amounts of Trichloroethylene (TCE) in indoor air. The Massachusetts Department of Environmental Protection considers TCE levels in indoor air of up to 0.4 micrograms per cubic meter (g/m^3) to be normal[36]. Humans are exposed to this VOC through skin absorption, ingestion, and inhalation. TCE exposure is frequently sporadic since the goods containing this pollutant are not always utilized. At concentrations of 270 mg/m^3, acute TCE exposure affects the central nervous system, resulting in decreased sensory ability. TCE is a carcinogenic substance when exposed for an extended period of time. Extended exposure can lead to cancer, liver failure and even kidney failure. Its carcinogenic properties make exposure to the compound in any quantity undesirable[25].

4. Indoor air pollution prevention

A wide variety of methods currently exist and are extensively used for improving indoor air quality; the most common of which is ventilation. It is the simplest and most effective method for reducing pollutant concentrations in the air, except in situations where outdoor pollutant concentrations are high. For example, areas with intense traffic or with high industrial activity would have a much higher than average pollutant concentration in the outdoor air making ventilation far less effective. Mechanical ventilation systems draw in outside air, thereby causing a significant reduction in pollutant concentration, which is far more effective than simply opening windows or other more natural ventilation methods. Other potentially hazardous pollutant sources include building materials such as asbestos and other insulation fibers. These can be removed professionally to avoid health risks associated with prolonged exposure. Smoking restrictions in public spaces has also proven to be an effective method of indoor air pollution abatement. Cigarettes release a variety of contaminants such as carbon dioxide and methane that significantly decrease air quality, which makes indoor smoking regulation absolutely essential.

Finally, properly monitoring the relative humidity and temperature indoors is crucial for reducing organic pollutant emissions indoors. High relative humidity indoors can cause the growth of molds and mildew which could lead to a wide variety of health complications. On the other hand, low relative humidity also has the effect of causing skin irritation, dry eyes and the death of mucosal membranes which could increase the susceptibility of individuals to respiratory illnesses. Air conditioning systems and thermostats play a major role in reducing these pollution sources by maintaining both the humidity and temperatures of a room at safe levels based on current air conditions or inhabitant activities[14]. The continued use of cooking stoves and firewood, which is more rampant in developing nations, introduces pollutants into the air such as particulate matters (PM), benzene, toluene, ethylbenzene and xylene, CO, and NOx. These compounds are produced during the combustion of fuels and general use of combustion devices which must therefore be properly maintained to avoid malfunctioning and exposure to high concentrations of pollutants.

The use of kerosene and biomass as pollutants release toxins into ambient air at high concentrations which necessitates the need for the use of cleaner and more efficient fuels such as electricity and natural gas[14]. This is backed by research into kitchens in Nepal where PM2.5 emissions from various fuels were tested. When comparing emissions from the combustion of wood and rice husk to that of electricity and natural gas, the emissions from the latter were measured to be about 8 times less than that of the wood and rice husk[37]. Furthermore, better cooking stoves have been shown to lower PM and CO emissions[38–40]. Other sources of combustion, such as candles or fragrant incense, may also contribute to poor indoor air quality (IAQ)[24].

In most situations, ample ventilation in indoor spaces has proven to be one of the most effective methods in improving indoor air quality through the indoor-outdoor exchange of air; more so in situations where there are no continuous emissions of contaminants. Not only is ventilation considered to be one of the most efficient methods of improving air quality, but also the most cost-effective. To significantly reduce indoor emissions, it is important to identify and adequately maintain potential air pollution sources some of which include paints, building materials, and cooking stoves[14].

5. Current technologies for iap control

Indoor air pollution is an important issue plaguing mostly developing countries and causing the death of millions around the world. The lack of access to clean cooking fuels and adequate power supply has encouraged the use of biomass and solid fuels which significantly reduces the quality of air. Over the years, deaths as a result of indoor air pollution have seen a significant decline worldwide owing to the spread of cleaner cooking fuels and greater awareness of the effects of exposure to pollutants. Although there have been improvements in the quality of indoor air over the years, a lot of work still needs to be done to further decrease the death tolls associated with it.

In some situations, it is not possible to improve the quality of air by taking cost-effective measures such as ventilation. For this reason, the use of indoor air pollution abatement technologies is necessary to reduce the risk of exposure to contaminants. Increasing the quality of indoor air is commonly achieved using a wide variety of technologies such as air filters or ozonizers which are usually part of the ventilation systems in buildings or as portable units[41]. The performance of these devices can be significantly improved by the use of sensors. They monitor current air properties such as temperature, humidity, major pollutant concentrations and make necessary adjustments to correct any deviation from what is considered to be normal.

5.1. Adsorption technology

Activated carbon, which is a major component of air filters, includes a wide range of carbon-based materials which exhibit a high degree of porosity and extended inter-particulate surface area. These properties of carbon make it excellent for use in filtration and purification (**Figure 1**). Carbon air filters work by using millions of micro pores to create a large surface area ideal for capturing pollutants in the air by adsorption. It is the process by which a solid holds molecules of a liquid, gas, or solute as a thin film on its surface.

The efficiency of these air filters can significantly affect the relative humidity or fluctuation in pollutant concentrations in the air. Furthermore, the adsorption of one pollutant by the filter may inhibit the ability of the filter to adsorb other pollutants. These systems also tend to accumulate germs which could be harmful to human health. For this reason, adsorptive materials used in indoor air purifications must be properly maintained and periodically changed or cleaned[42], adsorption technologies are considered to be one of the best technologies for VOC removal from air.

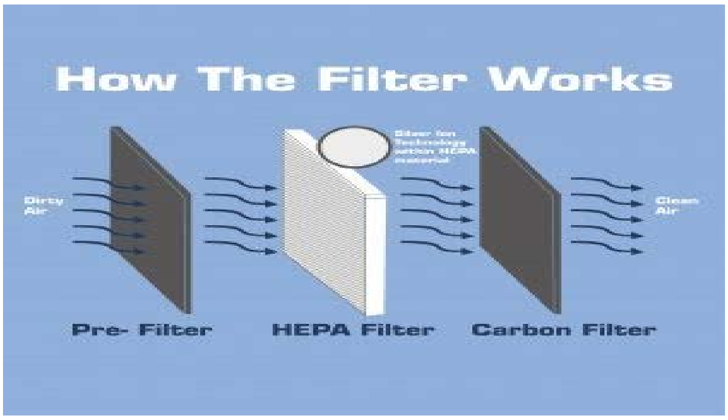

Figure 1. How air filters work[43].

5.2. UV photolysis

UV photolysis relies on ultraviolet light to degrade VOCs, bacteria, fungus, and viruses. Indeed, this technique is an efficient way of sterilizing at room temperature and pressure This method of indoor air pollution abatement involves the use of ultraviolet light to destroy bacteria, fungi, VOCs, and other contaminants in the air. It is an efficient and effective method for air treatment at room temperatures and pressure[44]. Although the UV photolysis method is able to remove contaminants in the air, constant exposure of humans to ultraviolet light can be harmful to humans when considering long-term effects. The high cost of lamp acquisition and intensive energy consumption are also disadvantages of the use of the technology. Furthermore, due to the non-specific action of UV light on contaminants in the air, the formation of undesirable compounds like ozone is usually an issue[42].

5.3. Photocatalytic oxidation

Photocatalytic oxidation (PCO) employs catalytic semiconductors to generate reactive radicals from ambient oxygen and UV rays, which then react with indoor contaminants. Because of its low cost, non-toxicity, and efficacy, TiO_2 is the most widely used catalyst. The process of photocatalytic oxidation utilizes ultraviolet rays along with a catalyst which results in the production of reactive radicals from ambient oxygen that react with indoor air contaminants to form water, detritus, and carbon dioxide. Titanium dioxide is the most commonly used catalyst due to its low non-toxicity and low cost. Other metal oxides including ZnO, SnO_2 and CdS can also be employed[45].

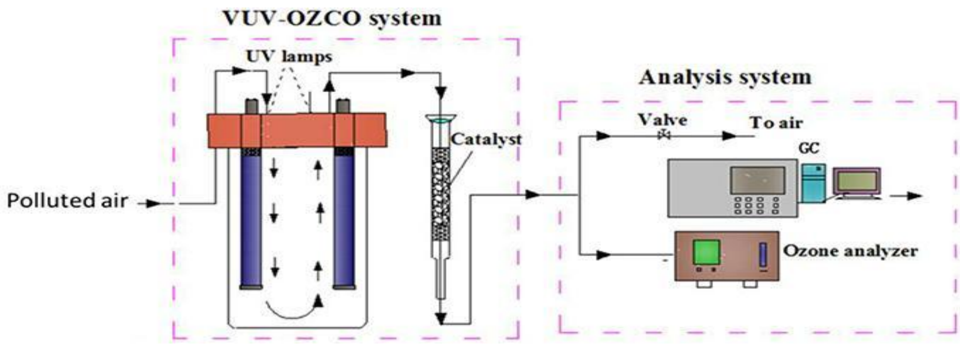

Figure 2. Photocatalytic oxidation illustration[46].

The air purification process by photocatalytic oxidation begins with ambient air being pulled through an existing air conditioning unit which then passes through a chamber containing the titanium catalyst and UV light. As the contaminated air passes through the chamber, VOCs along with microbes are attacked by free hydroxyl radicals, which in turn break down the contaminants into water, carbon dioxide, and detritus. **Figure 2** shows an illustration of the photocatalytic oxidation process.

5.4. Non-thermal plasma

Matter can exist in different phases which include gaseous, liquid, and solid states. Although these phases of matter are the most common phases which are observed in everyday life, there exists another phase of matter which is known as plasma. Plasma is a state of matter which is typically formed at extremely high temperatures which causes a significant increase in the velocity of electrons. This increase in velocity causes the particles in the atom to break free of their bonds and move about freely. It contains oxidants, positive ions and free radicals which may destroy organic contaminants and kill microorganisms contained in the air[41]. Plasma can also be produced at room temperatures when exposed to strong electric fields. The non-thermal plasma technology works by utilizing two cathodes. One of which is pipe-shaped, with the other having the shape of a wire running through the pipe and separated by glass beads or some other suitable dielectric material as shown in **Figure 3**. As the polluted air passes through the pipe, the voltage between the two electrodes becomes high enough to overcome the insulating effects of the glass beads causing millions of micro discharges. The formation of these discharges ionizes pollutants in the air causing the production of free radicals which are highly reactive. They recombine with other molecules in the air forming less harmful compounds, which reduces contaminants in the air.

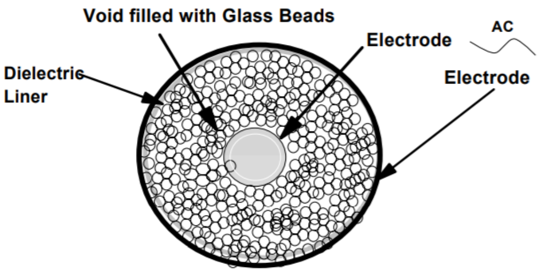

Figure 3. Non-thermal plasma reactor[41].

5.5. Ozonizers

Ozonizers work by generating ozone molecules from atmospheric air being fed into them as shown in **Figure 4**. The molecules are formed by exposing oxygen molecules in air to an electric field or ultraviolet light which causes the diatomic oxygen molecules to temporarily split into individual oxygen atoms. These free oxygen atoms then combine with diatomic oxygen molecules to form ozone. Naturally, Ozone is a strong oxidant with the ability to react with common indoor air pollutants thereby increasing the quality of indoor air. Although pollutant quantities in the air are significantly reduced, the performance of these devices are still not superior when compared with other physical and chemical methods[41]. Although the use of ozone generators indoors has its advantages, the technology also comes with health risks. Some of the by-products from the reaction between ozone and VOCs, especially terpenes, could form harmful by-products which could be detrimental to the health of exposed individuals. Furthermore, the general increase in indoor concentrations of ozone could be another source of health issues[47]. They are generally not recommended as a solution to IAP.

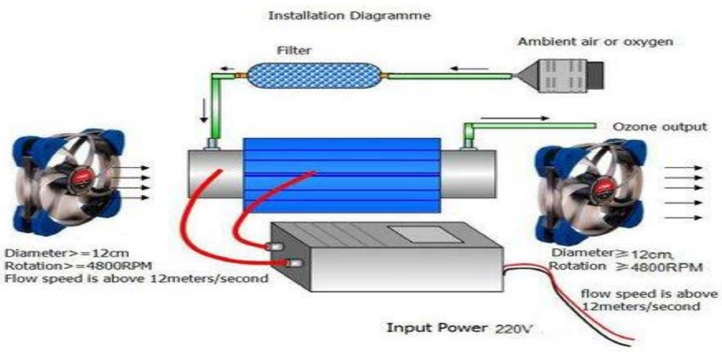

Figure 4. Ozonizer[48].

6. Discussion

This review critically explored indoor air pollution and its general effects on the health of individuals exposed to unsafe quantities of the emitted pollutants caused by activities such as cooking, and the increasing use of fossil fuel-powered generators; especially in developing nations. Methods for preventing the emission of these indoor pollutants as well as current technologies being utilized for significantly reducing their concentrations were also thoroughly discussed.

The absence of the emission of pollutants in the daily routine of the populace is practically impossible considering the varied sources from which these pollutants emanate. This in turn causes the deaths of millions of people around the world; with the vast majority of the death toll being observed in developing nations. Nigeria for example currently has a population of about 200 million and only about 57 percent of the country's population have access to the nation's power grid. The shortcomings of the electricity sector in the country have forced businesses and homeowners to resort to alternative sources for lighting and warmth, which primarily involves the use of fossil fuel-powered backup generators. The consistent rise in the purchases and use of these generators has caused a significant rise in pollutant levels in residential buildings and offices majorly due to the release of carbon monoxide which is produced as a result of the incomplete combustion of fossil fuels. These generators can be considered to be one of the primary sources of indoor air pollutants in the country. Another main source of these pollutants can be observed in the continued use of solid fuels and kerosene for lighting and cooking which can also be attributed to the nation's poor electricity distribution.

Considering the issues highlighted, it is quite clear that an improvement in the power generation and distribution in the nation would be extremely helpful in the abatement of the release of these pollutants. The sustained availability of electricity to the populace would be instrumental in decent-vising the use of backup generators as well as the use of solid fuels for cooking and lighting. Another simple yet effective method for indoor air pollution is ventilation. As simple as it may sound, it is one of the most effective methods for reducing the concentrations of pollutants in the air. Proper ventilation along with the use of technologies listed in this paper such as the use of air filters, UV photolysis, and photocatalytic oxidation has the potential to drastically improve indoor air quality and reduce the death tolls associated with it.

7. Conclusion

On average, modern people live and work indoors 90% of the time which makes indoor air quality an important aspect in staying healthy. Indoor pollution causes a variety of respiratory and cardiovascular health problems, ranging from minor symptoms to the onset of serious diseases. In a particular environment, many contaminants may interact, raising the risk of future illnesses. Understanding the negative consequences of indoor air pollution will aid in the implementation of necessary precautions to decrease the potential for health problems. Additionally, the incorporation of indoor air quality sensors and control devices will further aid in combating indoor pollution and its associated issues. The dearth of research in lighting sources as sources of indoor air pollution is needed to be addressed by researchers. Also, policy implications to improve electricity deficits should be embarked upon by governments to discourage the use of fossils and biomass for lighting indoors.

Conflict of interest

The authors declare no conflict of interest.

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