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The reduction and mitigation of organic pollutants and photochemical smog: A review

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ABSTRACT

There has been a growing perception of organic pollutants as a threat to the environment. Because of their high persistence in the soil and significant toxicity at extremely low levels of exposure, organic contaminants pose a constant threat in the ecosystem. The most prevalent categories of organic pollutants found in the environment are pesticides, dye pollutants, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, dichlorodiphenyltrichloroethane etc. However, researchers have gathered a great deal of knowledge about the source, pathways of contamination to the environment, interactions with constituents, impact on soil microbes and degradability by plants, uptake by plants, and contamination of food. The multifaceted effects on the ecosystem include contaminated food, water, and air, decreased soil enzyme activity that disrupts nutrient transformation processes, decreased biodiversity, and mutagenicity in microorganisms, among other things. Nonetheless, the review covered the origins, effects, and eventual disposal of organic pollutants within the ecosystem.

***Keywords*:** Toxicity, ecosystem, organic pollutants, smog, prevention

1. INTRODUCTION

The release of dangerous substances into the environment is known as pollution. We refer to these dangerous substances as contaminants. Some pollutants are naturally occurring, like volcanic ash. Human action can also produce them, as in the case of factory runoff or waste.

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Air, water, and land quality are all harmed by pollutants (Ruan et al., 2023).Pollution is caused by several items that humans find useful. For instance, vehicles' exhaust pipes spew forth pollution. The air is contaminated when coal is burned to generate energy. The sewage and trash produced by households and businesses can contaminate the land and water. Animals are harmed by pesticides, which are chemical poisons that are used to eradicate weeds and insects and seep into streams. Air and water on Earth are essential to all living things, including single-celled organisms and blue whales. The contamination of these resources poses a threat to all living species.

Pollution is carried by water and air currents. However, marine contaminants are transported great distances by migratory fish and ocean currents. Radioactive material that has been unintentionally released from a nuclear reactor can be picked up by winds and dispersed all over the world. One nation's manufacturing smoke permeates another nation. Thus, pollution can travel to isolated locations where no one lives, even though urban areas are typically more polluted than rural ones. For instance, the Antarctic ice sheet has been shown to contain chemicals and pesticides. The Great Pacific Garbage Patch is a massive aggregation of tiny plastic particles in the middle of the northern Pacific Ocean (Aslam et al., 2023). However, pollution can be controlled by creating awareness on the dangers of pollution among individuals.

2. TYPES OF POLLUTION

The three major types of pollution are air pollution, water pollution, and land pollution.

2. 1. Air Pollution

Air pollution is typically invisible. However, at times, air pollution can be seen. For example, the exhaust pipes of huge trucks or factories can be seen to spew dark smoke. Even when contaminants are undetectable, the air they contaminate can still be hazardous. People may experience breathing difficulties and eye burns. Additionally, it may make lung cancer more likely (Ran et al., 2023). Air pollution can sometimes kill people quickly. A lethal gas was discharged into the atmosphere in 1984 due to an accident at a pesticide facility in Bhopal, India. Within days, at least 8,000 people perished. Many hundreds of thousands more suffered lifelong injuries (Anandan et al., 2020). The figure below shows the source in which air can be contaminated.

Rapid increases in air pollution can also be brought on by natural disasters. Gases and volcanic ash are released into the atmosphere during a volcano eruption. Monthly sky discolourations can result from volcanic ash. Sulfur dioxide is one of the volcanic gasses that can kill locals and render the soil unusable for years. The Italian volcano Mount Vesuvius is well-known for its 79 eruption, which claimed hundreds of lives in the surrounding towns of Pompeii and Herculaneum. The majority of Vesuvius casualties did not die via landslides or lava flows brought on by the eruption but are asphyxiated, or strangled, by lethal volcanic gasses (Fu et al., 2021). In 1986, a poisonous fog formed over Cameroon's Lake Nyos. Lake Nyos is situated within a volcanic crater. The volcano sent volcanic gasses into the lake even though it did not erupt. The hot gases seeped through the lake's water and gathered into a cloud that moved down the volcano's slopes and into neighboring regions. Birds and other creatures in their natural habitat perished as a result of the poisonous fog spreading across the countryside. Up to 1,700 people and thousands of cattle were also killed by this air pollution (Jones, 2021).

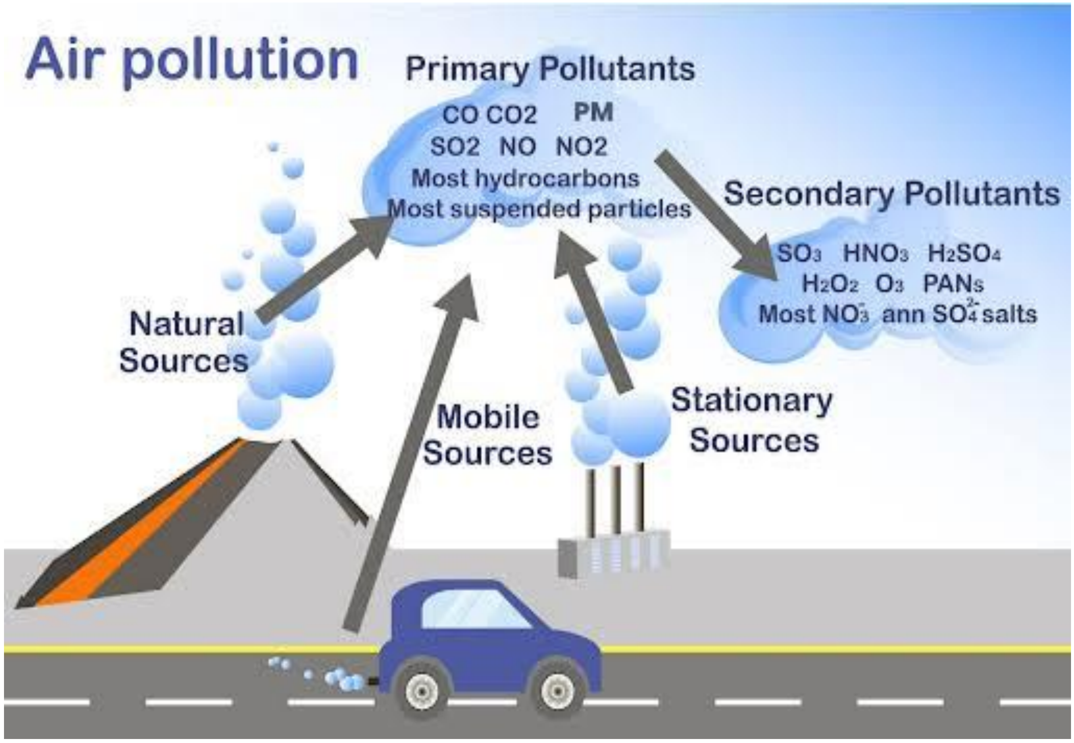

Figure 1. Source of air pollution **(**Chen et al., 2020**)**

However, most air pollution is not caused by nature. Burning fossil fuels like coal, oil, and natural gas produces it. Carbon monoxide is an odourless, colourless gas that is produced when gasoline is burned to power automobiles and trucks. When the gas concentration is high, it becomes hazardous. Carbon monoxide produced by city traffic is extremely concentrated. Other typical pollutants produced by companies and cars include hydrocarbons, sulfur dioxide, and nitrogen oxide. These substances react with sunlight to create a haze of air pollution, smog, or heavy fog. In Linfen, China, the haze is so dense that it is rare for residents to see the sun. Depending on the kind of pollutants present, smog might have a brown or grayish blue colour (Titchou et al., 2021). Breathing becomes difficult in smog, especially for elderly and young people. Extreme smog-prone cities may warn residents about air pollution. For instance, when the fog is particularly heavy, the Hong Kong authorities would issue warnings to the public not to go outside or perform physically demanding activities like swimming or running.

Acids are created when air pollutants like sulfur dioxide and nitrogen oxide combine with moisture. Then, as acid rain, they return to Earth. Acid rain is frequently carried far from the source of pollution by wind. Acid rain can occur in Norway as a result of pollutants released by Spanish companies and power stations. A forest's trees can all be destroyed by acid rain. It can destroy streams, lakes, and other bodies of water as well. Fish cannot live in lakes that get too acidic. Acid rain in Sweden has left thousands of "dead lakes" empty of fish. Stones other than marble are also eroded by acid rain. Numerous old structures and monuments have been damaged, and gravestones have had their words removed. In the past, the TajMahal in Agra, India, was brilliant white. It's pale from years of exposure to acid rain (Song et al., 2024).

An additional cause of air pollution is greenhouse gas emissions. Methane and carbon dioxide are examples of greenhouse gases that naturally exist in the atmosphere. They really are essential to life as we know it on Earth. They stop sunlight from escaping into space by absorbing it as it is reflected off of Earth. They maintain Earth's temperature just right for human habitation by retaining heat in the atmosphere. We refer to this as the greenhouse effect (Wang et al., 2024).

However, human actions like the combustion of fossil fuels and the destruction of forests have increased the atmospheric concentration of greenhouse gases. As a result, the greenhouse effect has intensified and global average temperatures are rising. The warmest decade on record started in the year 2000. Global warming refers to this rise in average global temperatures that is partially due to human activity. Glaciers and ice sheets are melting as a result of global warming. Sea levels are rising at a pace of two millimeters (0.09 inches) each year due to the melting ice. Low-lying coastal areas will eventually be inundated by the rising seas. The Maldives islands and other entire nations are at risk due to climate change (Devendrapandi et al., 2024).

Ocean acidification is another process that is influenced by global warming. The process of ocean waters absorbing more carbon dioxide from the atmosphere is known as ocean acidification. In warmer, less salinized waters, fewer creatures can thrive. Due to the inability of marine life, including coral, to adapt to increasingly acidic waters, the ocean food chain is in danger. According to scientific predictions, there will be a rise in severe storms due to global warming. Additionally, it will result in more flooding in certain areas and more droughts in others (Jabbar et al., 2023). Certain habitats, or the areas where plants and animals naturally reside, are already becoming smaller due to the change in average temperatures. In the Arctic, polar bears use sea ice to hunt seals. Polar bear populations are declining as a result of having to go farther in search of food due to the melting ice (Ran et al., 2023).

2. 2. Water Pollution

Certain dirty water has floating trash, a muddy appearance, and an unpleasant scent. Certain dirty water also appears clear, but it contains dangerous substances that are invisible to the naked eye or nose. It is dangerous to swim or drink contaminated water. Some individuals who consume contaminated water may be exposed to dangerous substances that cause illness years later. Others eat disease-causing germs and other microscopic water critters. According to united nation estimates, drinking contaminated water causes 4,000 deaths in children every day (Lu et al., 2020). Trash dumped in a river reduced the socio-economic activities in the river as evidence shown the figure below.

Sometimes people are harmed indirectly by contaminated water. They become ill because it is dangerous to consume fish that reside in contaminated water. Their flesh contains an excessive amount of contaminants. Water contamination can come from a few natural causes. For instance, naturally occurring subterranean sources can leak natural gas and oil into lakes and oceans. We refer to these locations as petroleum seeps. The Coal Oil Point Seep, located off the coast of the US state of California, is the largest petroleum seep in the world (Chen et al., 2020). Tar balls wash up on neighboring beaches as a result of the Coal Oil Point Seep's massive oil leak. Tar balls are tiny, sticky waste particles that break down in the ocean over time. Water pollution is also caused by human activity.

Factory oils and chemicals are occasionally poured into rivers or leak into them. We refer to these substances as runoff. Aquatic life may find itself in a harmful environment due to chemicals in runoff. Runoff has the potential to foster a favourable habitat for blue-green algae, or cyanobacteria. A toxic algal bloom is produced by the fast reproduction of cyanobacteria. The presence of harmful algal blooms keeps fish and other marine life from thriving. They are linked to "dead zones" in the lakes and rivers of the world, which are areas with minimal life below the surface of the water (Anandan et al., 2020).

Figure 2. Water contaminated with trash (Devendrapandi et al., 2024)

Water pollution can also be caused by drilling and mining. One of the main causes of river and stream contamination close to coal mines is acid mine drainage. Miners use acid to help them separate coal from the nearby rocks. After being carried into rivers and streams, the acid reacts with the sand and rocks there. It causes a river that is abundant in sulfuric acid by releasing chemical sulfur from the rocks and sand. Fish and other aquatic life are toxic to sulfuric acid. People can be poisoned by sulfuric acid, which makes rivers contaminated with acid mine drainage unsafe places to drink and use for personal hygiene (Fu et al., 2021).

Another cause of water pollution is oil spills. Oil leaked from the ocean floor when the Deepwater Horizon oil rig collapsed in the Gulf of Mexico in April 2010. Hundreds of millions of gallons of oil leaked into the gulf seas in the months that followed. Large oil plumes under the water and an oil slick covering up to 24,000 square kilometers (9,100 square miles) were the results of the incident. Wetlands in the American states of Louisiana and Mississippi were covered in an oil slick, which killed aquatic life including fish and crabs as well as marsh plants. Oil covered birds, like pelicans, made it impossible for them to fly or get food. The Deepwater Horizon oil leak claimed the lives of around two million animals (Tchinsa et al., 2021).

Moreover, buried chemical waste might contaminate water sources. People disposed of chemical wastes carelessly for a long time without comprehending the risks. Residents of Niagara Falls, New York's Love Canal neighborhood saw exceptionally high incidences of cancer and birth abnormalities in the 1970s. It was found that the water in the vicinity was contaminated by a chemical waste dump. Eight hundred Love Canal households were forced to leave their houses in 1978 (Jones 2021). Radioactive waste from nuclear power stations can leak into the environment if it is not properly disposed of. Radioactive waste can contaminate water and endanger living beings.

Water pollution is frequently caused by improperly treated sewage. Sewage treatment plants and sewage networks are often in bad condition in many places worldwide. In India, the capital city of Delhi is home to around 21 million people. The Yamuna River receives more than half of the city's sewage and other garbage disposal. The river is unsafe to use as a source of water for drinking or personal hygiene because of this contamination. Additionally, it diminishes the river's fishing, which means that the neighborhood will have less food. According to some estimation, this waste patch is Texas's size (Yao et al., 2021). Fish and seabirds are at risk from the waste because they mistake the plastic for food.

2. 3. Land Pollution

Numerous contaminants that contaminate water also have negative effects on land. Hazardous chemical contamination of the soil can occasionally result from mining. The wind carries fertilizer and pesticides from agricultural areas. They may cause harm to people, animals, or plants. Certain fruits and vegetables take up the pesticides used to aid in their growth. Pesticides enter people's bodies when they eat fruits and vegetables. A few chemicals have been linked to cancer and other illnesses (Titchou et al., 2021).

Dichlorodiphenyltrichloroethane was a pesticide that was previously widely employed to eradicate insects, particularly mosquitoes. A million people die from malaria each year, a disease spread by mosquitoes in many regions of the world. Paul Hermann Muller, a Swiss chemist, won the Nobel Prize for his discovery of how dichlorodiphenyltrichloroethane suppresses insects and other pests. Malaria has decreased in areas like Taiwan and Sri Lanka because to dichlorodiphenyltrichloroethane (Song et al., 2024).

The hazards of dichlorodiphenyltrichloroethane were described in the 1962 book Silent Spring by American biologist Rachel Carson. She maintained that it might be a factor in human cancer. She also described how it was killing bird eggs, which in turn was causing a decline in bald eagles, brown pelicans, and ospreys. The United States outlawed the use of dichlorodiphenyltrichloroethane in 1972. Many other nations have outlawed it as well. However, dichlorodiphenyltrichloroethane did not completely vanish. As long as dichlorodiphenyltrichloroethane is still the most effective strategy to prevent malaria, many governments now favor its usage (Lü et al., 2024).

Hawaii's cities are covered in plastic bottles and bags that the tide carries in. The rubbish lowers local economic activity and poses a threat to marine life. Hawaiian tourism is the state's main industry. Tourists are deterred from spending money on the area's lodging, dining, and entertainment options by dirty beaches. Some cities burn their waste in an incinerator. Trash can be destroyed via incineration; however doing so may release hazardous chemicals and heavy metals into the atmosphere. Hence, even though waste incinerators can reduce land pollution, occasionally they exacerbate air pollution.

Figure 3. A land polluted by refuse (Li et al., 2023)

3. ORGANIC POLLUTANTS

Organic substances that are resistant to breakdown by chemical, biological, and photolytic processes are known as persistent organic pollutants. They are poisonous and have a negative impact on the environment and human health globally (Devendrapandi et al., 2024). Since most Persistent Organic Pollutants produced in one nation can travel great distances by wind and water, they have the potential to impact people and wildlife far beyond their point of usage and release.

At the 2001 Stockholm Convention on Persistent Organic Pollutants, the worldwide community deliberated on the impact of persistent organic pollutants on human and environmental health, with the goal of either completely banning or severely restricting their production. Pesticides and insecticides make up the majority of persistent organic pollutants, yet some are also solvents, medications, and industrial chemicals (Li et al., 2024). While some Persistent Organic Pollutants are produced naturally, including by volcanoes, the majority are created by humans.

Aldrin, chlordane, dieldrin, endrin, heptachlor, mirex, toxaphene, Polychlorinated biphenyls, dichlorodiphenyltrichloroethane, dioxins, and polychlorinated dibenzofurans are among the "dirty dozen" persistent organic pollutants that were named by the Stockholm Convention (Ruan et al., 2023). But since then, a large number of additional Persistent Organic Pollutants have been added, such as polyfluoroalkyl substances. Being halogenated organic compounds, persistent organic pollutants have a high solubility in lipids, they bioaccumulate in fatty tissues as a result (Krishnan et al., 2024).

The high stability of halogenated compounds can be attributed to the C-Cl bonds' resistance to hydrolysis and photolysis. Polyhalogenated organic compounds are especially concerning since the stability and lipophilicity of organic compounds are frequently correlated with their halogen concentration (Xu et al., 2024). Long range transport, which enables them to travel far from their source, and bioaccumulation, which reconcentrates these chemical compounds to potentially dangerous amounts are the two methods by which they negatively impact the environment.

The substances that comprise persistent organic pollutants are also categorized as toxic organic micro pollutants or persistent, bioaccumulative, and toxic (Miyah et al., 2024). Exposure to persistent organic pollutants may result in death, chronic illnesses, and developmental abnormalities. Numerous have the ability to alter endocrine functions in the immune system, central nervous system, or reproductive system. Persistent organic pollutants are mostly exposed to humans and animals through food, work, or development in the womb (Pan et al., 2024). Due to bioaccumulation in adipose tissues and bioaccumulation along the food chain, foods containing animal products account for over 90% of human exposure to persistent organic pollutants in situations where exposure is not accidental or occupational. Persistent organic pollutants serum levels often rise with age and are typically higher in women than in men (Xu et al., 2024).

Research has looked into the relationship between low-level persistent organic pollutants exposure and a number of illnesses. Thus, Governmental organizations may create a human health risk assessment that considers the pollutants' dose-response relationships and bioavailability in order to evaluate the illness risk associated with persistent organic pollutants in a specific area.

3. 1. Polycyclic Aromatic Hydrocarbons

Natural sources of polycyclic aromatic hydrocarbons include coal, crude oil, and gasoline. Burning coal, oil, gas, wood, trash, and tobacco also produces them. These sources produce polycyclic aromatic hydrocarbons that can attach to or combine with tiny airborne particles. Meat and other foods will produce polycyclic aromatic hydrocarbons when they are cooked at a high temperature. One polycyclic aromatic hydrocarbon that is commercially produced in the US is naphthalene, which is used to generate mothballs and other compounds. Numerous polycyclic aromatic hydrocarbons are found in cigarette smoke. Humans frequently come into contact with polycyclic aromatic hydrocarbon mixes. Exposure commonly happens through breathing in air contaminated by pollutants from asphalt roads, cigarette smoke, wood smoke, and exhaust from motor vehicles. When people consume foods that have been exposed to airborne polycyclic aromatic hydrocarbons particles, such as grilled or charred meats, they are consuming polycyclic aromatic hydrocarbons. The body breaks down polycyclic aromatic hydrocarbons into breakdown products termed metabolites, which are expelled from the body through the urine and feces after being consumed, breathed in, or in certain cases, transmitted through the skin (Song et al., 2024).

It is unknown how low amounts of polycyclic aromatic hydrocarbon exposure in the environment may affect human health. Breathing passages and eyes can get irritated by high airborne naphthalene concentrations. Blood and liver problems have been reported in workers who have been exposed to high concentrations of naphthalene through inhaling vaporized naphthalene and skin contact with liquid form. Many polycyclic aromatic hydrocarbons and some combinations of polycyclic aromatic hydrocarbons are thought to be carcinogenic substances (Naghdi et al., 2023).

3. 2. Polychlorinated Biphenyls

Polychlorinated biphenyls are a class of synthetic compounds. They are greasy liquids or solids that lack flavour or smell and range in color from clear to yellow. Polychlorinated biphenyls are extremely stable combinations that can withstand high pressure and temperatures. Polychlorinated biphenyls were frequently utilized in transformers and other electrical equipment. They were also utilized in plasticizers, lubricants, hydraulic fluids, and heat transfer fluids. Since exposure to polychlorinated biphenyls might have negative health effects, commercial manufacture of polychlorinated biphenyls ceased in 1977. Although the use of polychlorinated biphenyls was outlawed by the US Environmental Protection Agency in 1979, numerous products manufactured prior to that year still contain polychlorinated biphenyls (Kanakaraju et al., 2023). Unsuitable disposal and storage practices, spills, and leaks from electrical and other equipment have all resulted in the release of polychlorinated biphenyls into the environment. More than half of the polychlorinated biphenyls created are thought to have been discharged into the environment. Polychlorinated biphenyls tend to be persistent in the environment because they may travel great distances and have a significant binding affinity for soil and sediment. All across the planet, they have been discovered in the soil, water, air, and sediments. Since 1977, polychlorinated biphenyls have not been produced, so their concentrations in the environment and food chain have been dropping (Jabbar et al., 2023).

Polychlorinated biphenyls are ubiquitous in the environment, thus chances are good that everyone has come into contact with them. Through physical contact, inhaled air, or eating or drinking tainted food, polychlorinated biphenyls can enter the body. The body may readily absorb polychlorinated biphenyls and stores them in adipose tissue. Because polychlorinated biphenyls are not effectively removed from the body, they might build up there.

The majority of people come into contact with polychlorinated biphenyls through consuming tainted meat, seafood, and dairy products. Carp, buffalo fish, and catfish typically contain the greatest quantities of polychlorinated biphenyls. Since plants can only absorb very small amounts of polychlorinated biphenyls from the soil, grazing animals and dairy products often contain lower levels of polychlorinated biphenyls than fish. On the outside of fruits and vegetables, there may be dust contaminated with trace amounts of polychlorinated biphenyls. Since polychlorinated biphenyls are poorly soluble, exposure to them through water is typically not dangerous. Old submersible pumps that contain polychlorinated biphenyls oil may be used in certain private wells. Polychlorinated biphenyls have the potential to leach into the well and contaminate the drinking water if the pump seal fails. Transformers and ballasts from older fluorescent lights that are still in use in homes, workplaces, and schools can still contain polychlorinated biphenyls. Polychlorinated biphenyls have the potential to leak out and pollute exposed surfaces and the air if the ballasts fail. The amount of polychlorinated biphenyls detected in the air following a light ballast failure can be substantial. Exposure to polychlorinated biphenyls may also occur in the workplace (Ruan et al., 2023).

3. 3. Aldrin and Dieldrin

Insecticides, or products that kill insects, are quite comparable between aldrin and dieldrin. The white granules known as pure aldrin and dieldrin have a faint chemical smell.

They do not occur in the environment naturally. Dieldrin is produced in the body and the environment by the rapid breakdown of aldrin. From the 1950s until 1970, citrus fruits, corn, cotton, and other crops were frequently treated with aldrin and dieldrin as insecticides. Up until 1989, they were also employed to manage termites. After 1989, these substances were never again utilized as insecticides (Ruan et al., 2023).

Surface water, groundwater, soil, and sediment have all been found to contain low concentrations of aldrin and dieldrin. Dieldrin is primarily found in the environment because aldrin is converted to dieldrin by sunlight and microorganisms. Dieldrin and aldrin attach firmly to soil and release oxygen gradually. Dieldrin degrades extremely slowly in water and soil. Aldrin and dieldrin are absorbed by and stored by plants from the soil.

Large doses of aldrin or dieldrin have caused convulsions in certain people, and some have even passed away. Employees who were exposed to these substances in smaller doses but for longer periods of time experienced headaches, lightheadedness, agitation, nausea, and uncontrollable muscle spasms (Yu et al., 2024), the workers recovered fast once they were not exposed to these substances. Even at lower exposure levels, these compounds have the potential to accumulate in the body and induce health problems over extended periods of time.

In experiments on animals, both high and low doses of aldrin or dieldrin caused seizures, tremors, impaired learning, liver damage, and issues with reproduction. Pregnant animals fed aldrin or dieldrin had a lower survival rate for their pups. If people experienced these same symptoms, it is unknown. Animals require far larger doses of aldrin or dieldrin than are present in the environment to have these effects (Ran et al., 2023).

3. 4. Chlordane

An organochlorine chemical known as chlordane or chlordan was once employed as a pesticide. Before it was outlawed in 1988, almost 30 million homes in the US were treated for termites using chlordane. Ten years prior, chlordane was prohibited for use on lawns and home gardens, as well as on food crops like corn and citrus (Tchinsa et al., 2021). Similar to other pesticides containing chlorinated cyclodiene, chlordane is categorized as an organic pollutant that poses a risk to human health. It quickly accumulates in the lipids of both humans and animals and is resistant to degradation in the environment and in humans and animals. The chemical has been connected to neurological conditions, diabetes, and malignancies (Titchou et al., 2021).

Chlordane was a widely used insecticide for citrus and corn crops between 1948 and 1988. It was also a frequent way to treat termites at home. Exposure to chlordane can occur through a variety of pathways, including eating crops cultivated in soil polluted with the chemical, breathing in air from residences treated with chlordane and from landfills, and consuming high-fat meals like dairy, pork, and fish, as chlordane accumulates in fatty tissue. More than 30 million homes were treated with technical chlordane or technical chlordane with heptachlor, according to a report by the US Environmental Protection Agency.

Indoor air levels of chlordane can still be orders of magnitude higher than the Minimal Risk Levels for chronic disease and cancer, depending on the location of home treatment. Chlordane is eliminated gradually through the feces, urine, and breast milk of nursing mothers. It can pass through the placenta and be absorbed by growing fetuses in expectant mothers (Wang et al., 2024). Oxychlordane, a metabolite that results from the breakdown of chlordane, builds up in adipose tissue and blood as people age.

3. 5. Dichlorodiphenyltrichloroethane

Dichlorodiphenyltrichloroethane is an organochloride that is a crystalline chemical compound that is tasteless, colourless, and practically odourless. It was first created as an insecticide, but its effects on the ecosystem led to its notoriety. Initially, Othmar Zeidler, an Austrian chemist, created dichlorodiphenyltrichloroethane in 1874. The Swiss chemist Paul Hermann Müller discovered the insecticidal properties of dichlorodiphenyltrichloroethane in 1939. During the latter half of World War II, dichlorodiphenyltrichloroethane was employed to stop the development of typhus and malaria among soldiers and civilians, two diseases carried by insects. In 1948, Müller received the Nobel Prize in Physiology or Medicine "for his discovery of the high efficiency of dichlorodiphenyltrichloroethane as a contact poison against several arthropods".

The World Health Organization used a lot of dichlorodiphenyltrichloroethane in their 1950s and 60s anti-malaria effort, and the results looked good, yet subsequently there was a rebound in poorer nations. Dichlorodiphenyltrichloroethane is available in a variety of formulations, such as charges for vaporizers and lotions, emulsifiable concentrates, powders that are water-wettable, granules, aerosols, smoke candles, and solutions in xylene or petroleum distillates. More than 40,000 tonnes of dichlorodiphenyltrichloroethane were used annually in agriculture between 1950 and 1980; during the 1940s, an estimated 1.8 million tonnes of dichlorodiphenyltrichloroethane have been generated worldwide. About fifteen businesses, including Monsanto, Ciba, Montrose Chemical Company, Pennwalt, and Velsicol Chemical Corporation, manufactured it in the United States. The annual production peaked in 1963 at 82,000 tons. Prior to the prohibition in 1972, the United States applied more than 600,000 tons (1.35 billion pounds). Usage peaked in 1959 at about 36,000 tonnes. China ceased production in 2007, leaving India the only country still manufacturing dichlorodiphenyltrichloroethane; it is the largest consumer. In 2009, 3,314 tonnes were produced for malaria control and visceral leishmaniasis. In recent years, in addition to India, just seven other countries, all in Africa, are still using dichlorodiphenyltrichloroethane (Yu et al., 2024).

3. 6. Endrin

Endrin is an organochlorine compound with the chemical formula $C_{12}H_8Cl_6O$ that was first produced in 1950 by Shell and Velsicol Chemical Corporation. It was primarily used as an insecticide, as well as a rodenticide and piscicide. It is a colourless, odourless solid, although commercial samples are often off-white (Xia et al., 2021). Endrin was manufactured as an emulsifiable solution known commercially as Endrex. The compound became infamous as a persistent organic pollutant and for this reason it is banned in many countries.

In the environment endrin exists as either endrinaldehyde or endrinketone and can be found mainly in bottom sediments of bodies of water. Exposure to endrin can occur by inhalation, ingestion of substances containing the compound, or skin contact. Upon entering the body, it can be stored in body fats and can act as a neurotoxin. China stopped producing Dichlorodiphenyltrichloroethane in 2007. However, India is the only nation that continues to produce the chemical and is also its biggest buyer. 3,314 tons were produced in 2009 to combat visceral leishmaniasis and malaria (Wang et al., 2024). Only seven other African nations, including India, have been known to continue using Dichlorodiphenyltrichloroethane in recent times. Despite not being categorized as a human carcinogen or a mutagen at this time, endrin is nevertheless a hazardous substance that has negative side effects on central neurological system, which may result in seizures, convulsions, or even fatalities (Wang et al., 2023). By 1991, the manufacturers had discontinued the use of endrin in the United States due to these harmful consequences. Concerns about food imports have been brought up because endrin may still be used as a pesticide in some nations.

3. 7. Mirex

Mirex is an organochloride that was commercialized as an insecticide and later banned because of its impact on the environment. This white crystalline odourless solid is a derivative of cyclopentadiene. It was popularized to control fire ants but by virtue of its chemical robustness and lipophilicity it was recognized as a bioaccumulative pollutant. The spread of the red imported fire ant was encouraged by the use of mirex, which also kills native ants that are highly competitive with the fire ants. The United States Environmental Protection Agency prohibited its use in 1976. It is prohibited by the Stockholm Convention on Persistent Organic Pollutants (Song et al., 2024).

3. 8. Heptachlor

Heptachlor is an organochlorine compound that was used as an insecticide. Usually sold as a white or tan powder, heptachlor is one of the cyclodiene insecticides. In 1962, Rachel Carson's Silent Spring questioned the safety of heptachlor and other chlorinated insecticides. Due to its highly stable structure, heptachlor can persist in the environment for decades. In the United States, the Environmental Protection Agency has limited the sale of heptachlor products to the specific application of fire ant control in underground transformers. The amount that can be present in different foods is regulated. Heptachlor is a persistent organic pollutant. It has a half-life of ~1.3-4.2 days (air), ~0.03-0.11 years (water), and ~0.11-0.34 years (soil) (Pan et al., 2024). One study described its half-life to be 2 years and claimed that its residues could be found in soil 14 years after its initial application. Like other persistent organic pollutants, heptachlor is lipophilic and poorly soluble in water (0.056 mg/L at 25 °C), thus it tends to accumulate in the body fat of humans and animals (Li et al., 2023).

3. 9. Hexachlorobenzene

Hexachlorobenzene is formed as a byproduct during the manufacture of other chemicals. It was widely used as a pesticide until 1965. Chronic (long-term) oral exposure to hexachlorobenzene in humans results in a liver disease with associated skin lesions. Epidemiologic studies of persons orally exposed to hexachlorobenzene have not shown an increased cancer incidence (Naghdi et al., 2023). However, based on animal studies that have reported cancer of the liver, thyroid, and kidney from oral exposure to hexachlorobenzene, Environmental Protection Agency has classified hexachlorobenzene as a probable human carcinogen (Chen et al., 2023).

4. PHOTOCHEMICAL SMOG

Photochemical smog is a mixture of pollutants that are formed when nitrogen oxides and volatile organic compounds react to sunlight, creating a brown haze above cities. It tends to occur more often in summer, because that is when we have the most sunlight.

4. 1. Primary Pollutants

The two major primary pollutants, nitrogen oxides and volatile organic compounds, combine to change in sunlight in a series of chemical reactions, outlined below, to create what are known as secondary pollutants.

4. 2. Secondary Pollutants

The secondary pollutant that causes the most concern is the ozone that forms at ground level. While ozone is produced naturally in the upper atmosphere, it is a dangerous substance when found at ground level. Many other hazardous substances are also formed, such as peroxyacetyl nitrate.

4. 3. Sources of Photochemical Smog

While nitrogen oxides and volatile organic compounds are produced biogenically (in nature), there are also major anthropogenic (man-made) emissions of both. Natural emissions tend to be spread over large areas, reducing their effects, but man-made emissions tend to be concentrated close to their source, such as a city.

4. 3. 1. *Biogenic Sources*

In nature, bushfires, lightning and the microbial processes that occur in soil generate nitrogen oxides. Volatile organic compounds are produced from the evaporation of naturally-occurring compounds, such as terpenes, which are the hydrocarbons in oils that make them burn. Eucalypts have also been found to release significant amounts of these compounds.

4. 3. 2. *Anthropogenic Sources*

Nitrogen oxides are produced mainly from the combustion of fossil fuels, particularly in power stations and motor vehicles. Volatile organic compounds are formed from the incomplete combustion of fossil fuels, from the evaporation of solvents and fuels, and from burning plant matter—such as backyard burning and wood-burning stoves. In Adelaide in 2000, an estimated 66% of nitrogen oxides (NO and NO_2) came from motor vehicles, and a further 20% from fuel combustion. Motor vehicles contributed 44% of volatile organic compounds emissions, and area sources including petrol and solvent evaporation contributed 33% (Aslam et al., 2023).

4. 4. Formation of Smog

Below is a simplified explanation of the chemistry of smog formation. Nitrogen dioxide (NO_2) can be broken down by sunlight to form nitric oxide (NO) and an oxygen radical (O):

$$NO_2 + Sunligt \rightarrow NO + O$$

Oxygen radicals react with atmospheric oxygen (O_2) to form ozone (O_3):

$$O + O_2 \rightarrow O_3$$

Ozone is consumed by nitric oxide to produce nitrogen dioxide and oxygen:

$$O_3 + NO \rightarrow NO_2 + O_2$$

Harmful products, such as peroxyacetyl nitrate, are produced by reactions of nitrogen dioxide with various hydrocarbons (R), which are compounds made from carbon, hydrogen and other substances:

$$NO_2 + R \rightarrow Products\ such\ as\ \text{peroxyacetyl nitrate}$$

The main source of these hydrocarbons is the volatile organic compounds. Similarly, oxygenated organic and inorganic compounds (RO_x) react with nitric oxide to produce more nitrogen oxides:

$$NO + RO_x \rightarrow NO_2 + Otherproducts$$

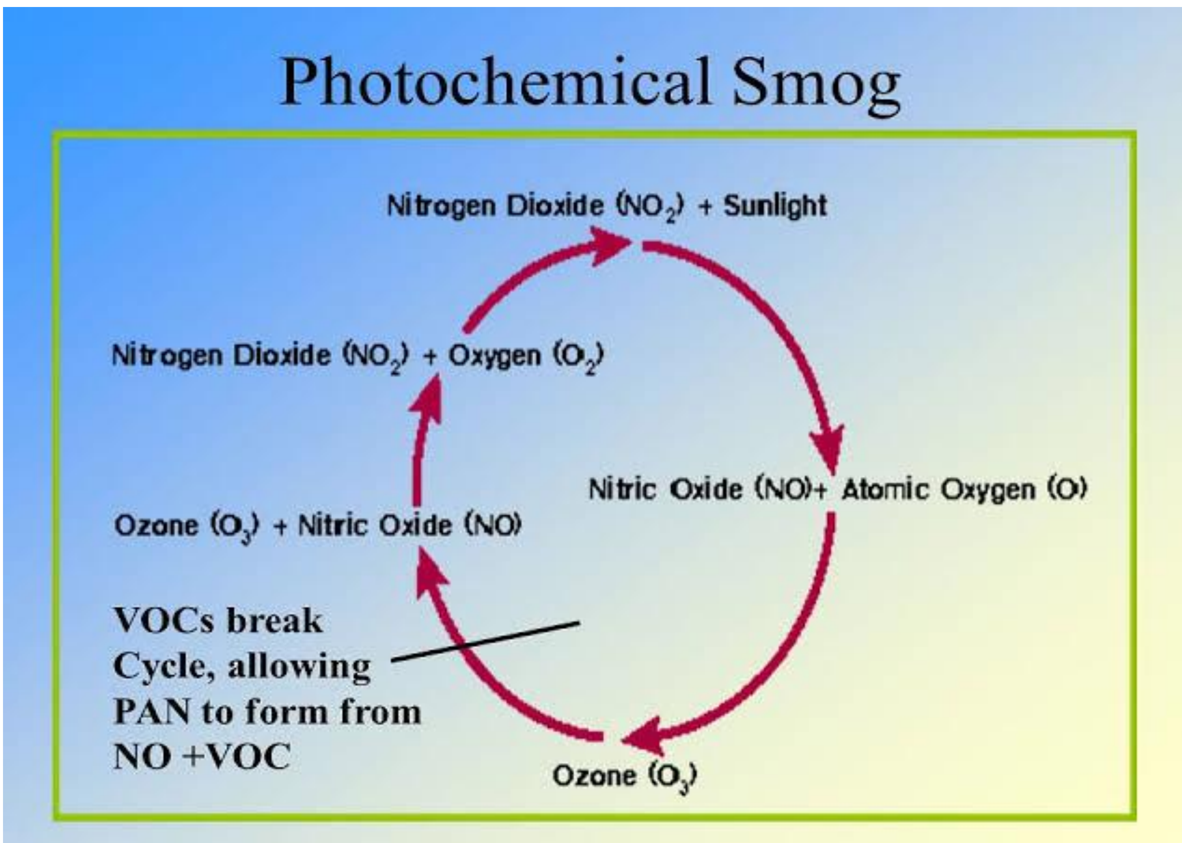

Figure 4. Photochemical smog cycle (Ruan et al., 2023)

The significance of the presence of the volatile organic compounds in these last two reactions is paramount. Ozone is normally consumed by nitric oxide. However, when volatile organic compounds are present, nitric oxide and nitrogen dioxide are consumed allowing the build-up of ground level ozone. However, location and weather can have an effect on photochemical smog.

4. 4. 1. Topography

The topography of the area surrounding a city can vastly influence the formation of photochemical smog. Because of the restriction of air movement, a city in a valley can experience problems that a city on an open plain may not. A city such as Adelaide can experience restrictions of air movement because of its position between the coast and the Adelaide Hills.

4. 4. 2. *Meteorology*

Normally the layer of air closest to the earth's surface is warmer than the air higher in the atmosphere because the heat of the sun is re-radiated (warmed by the earth's surface). The higher level cool air sinks and is then warmed and displaced upwards in a convection cycle (Figure 5).

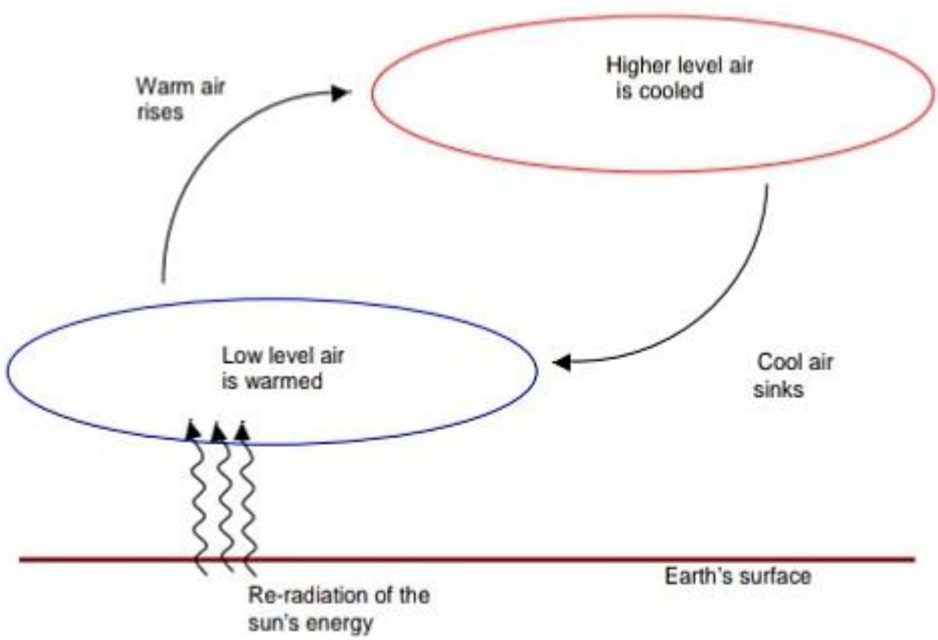

Figure 5. Convention cycle

This condition is called 'unstable' and helps to carry pollutants upwards, where they are dispersed and diluted. This cycle is usually assisted by higher wind speeds. However, when the opposite occurs - a temperature inversion - cities can experience prolonged periods of photochemical smog (Fu et al., 2021). An inversion is formed when a ceiling of warmer air traps the cooler layer of air, which contains the pollutants, near the ground's surface. This hinders the ability of the pollutants to rise to the atmosphere and be dispersed. After an inversion has formed, it keeps any smog that is present close to the ground, maximizing its detrimental effect. There are two major processes that enable an inversion to happen and both are usually accompanied by low wind speeds. The first, advection, is when an upper layer of warmer air is blown in, trapping the layer of cool air below it. This 'stable' condition may last for several days. A variation of this is when a cooler layer of air, such as a sea breeze, is blown in underneath a warmer layer, creating the same effect. The second process, radiation inversion, usually occurs overnight. The ground cools and in turn cools the air layer closest to it, resulting in the lower air layer being cooler than air above it, forming an inversion.

5. REDUCING POLLUTION

The most effective way of reducing the amount of secondary pollutants created in the air is to reduce emissions of both primary pollutants.

The main method of lowering the levels of nitrogen oxides is by a process called 'catalytic reduction', which is used in industry and in motor vehicles (Jabbar et al., 2023). For example, a catalytic converter fitted to a car's exhaust system will convert much of the nitric oxide from the engine exhaust gases to nitrogen and oxygen. In Australia, all motor vehicles built after 1985 must be fitted with catalytic converters. Nitrogen is not in the actual fuels used in motor vehicles or power stations; it is introduced from the air when combustion occurs. Using less air in combustion can reduce emissions of nitrogen oxides. Temperature also has an effect on emissions - the lower the temperature of combustion, the lower the production of nitrogen oxides. Temperatures can be lowered by using processes such as two stage combustion and flue gas recirculation, water injection, or by modifying the design of the burner (Jones, 2021).

There are various ways to reduce volatile organic compounds emissions from motor vehicles. These include the use of liquefied petroleum gas or compressed natural gas rather than petrol, decreasing distances vehicles travel by using other modes of transport, such as buses and bikes, and implementing various engine and emission controls now being developed by manufacturers.

Globally, the rapid development in industrialization and urbanization is the primary cause of the rising pollution problem. Because of population growth and agricultural reliance, the earth's finite natural freshwater resources will be under severe strain until 2030. The conservation of the environment necessitates a well-thought-out strategy for removing or mitigating the contaminants' reversible and irreversible effects (Kaur et al., 2020).

The conventional technologies are energy-intensive, had high maintenance and operation costs, and provided insufficient treatment, along with the production of ecologically toxic sludge/wastes. Phytoremediation technology has piqued the interest of many academics across the world as an environmentally friendly clean-up option with various advantages over traditional approaches.

It can also be used to recover valuable metals and can be used for the production of renewable energy. This chapter will explore the application of integrating phytoremediation of aquatic pollution with energy and element recovery as well as other ecological services. The problems associated with the application of these technologies and future prospects are also comprehensively discussed (Krishnan et al., 2024).

Around the world, people and governments are making efforts to combat pollution. Recycling, for instance, is becoming more common. In recycling, trash is processed so its useful materials can be used again. Glass, aluminum cans, and many types of plastic can be melted and reused. Paper can be broken down and turned into new paper. Recycling reduces the amount of garbage that ends up in landfills, incinerators, and waterways (Tchinsa et al., 2021).

Austria and Switzerland have the highest recycling rates. These nations recycle between 50 and 60 percent of their garbage. The United States recycles about 30 percent of its garbage. Governments can combat pollution by passing laws that limit the amount and types of chemicals factories and agribusinesses are allowed to use. The smoke from coal-burning power plants can be filtered. People and businesses that illegally dump pollutants into the land, water, and air can be fined for millions of dollars. Some government programs, such as the Superfund program in the United States, can force polluters to clean up the sites they polluted.

International agreements can also reduce pollution. The Kyoto Protocol, a United Nations agreement to limit the emission of greenhouse gases, has been signed by 191 countries. The United States, the world's second-largest producer of greenhouse gases, did not sign the agreement (Anandan et al., 2020). Other countries, such as China, the world's largest producer of greenhouse gases, have not met their goals. Still, many gains have been made. In 1969, the Cuyahoga River, in the U.S. state of Ohio, was so clogged with oil and trash that it caught on fire. The fire helped spur the Clean Water Act of 1972. This law limited what pollutants could be released into water and set standards for how clean water should be. Today, the Cuyahoga River is much cleaner. Fish have returned to regions of the river where they once could not survive (Jabbar et al., 2023).

But even as some rivers are becoming cleaner, others are becoming more polluted. As countries around the world become wealthier, some forms of pollution increase. Countries with growing economies usually need more power plants, which produce more pollutants.

6. CONCLUSION

Organic pollutants have been viewed as global threat. Reducing pollution requires environmental, political, and economic leadership. Developed nations must work to reduce and recycle their materials, while developing nations must work to strengthen their economies without destroying the environment. Developed and developing countries must work together toward the common goal of protecting the environment for future use.

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