



Short Communication

Polycyclic Aromatics Hydrocarbons and Organochlorine Pesticides in the Environment: Sources, Routes, Effects, and Fate

Adelodun AA^{1*}, Afolayemi AE² and Aiyesanmi AF³

¹Department of Marine Science and Technology, The Federal University of Technology, PMB 704, Akure, Nigeria

²Department of Chemical Sciences, Olusegun Agagu University of Science and Technology, PMB 353, Okitipupa, Ondo State, Nigeria

³Department of Chemistry, The Federal University of Technology, PMB 704, Akure, Nigeria

Abstract

Persistence Organic Pollutants (POPs) contamination of sediment, soil, and groundwater is one of the major threats to environmental and human health due to their toxic effects. Thus, this short review is aimed at evaluating the sources, exposure routes, effects, and the fate of polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs) in the environment. As useful as these chemicals may be, their adverse effects on human health and the total environment are of grievous concerns. This short communication provides succinct albeit detailed information on the current environmental status and health risks posed by the residues of PAHs and OCPs, especially in our soils and waters. To this effect, the future environmental effect and eventual fate of pesticides could be progressively monitored and mitigated.

Keywords: Carcinogenicity; Genotoxicity; Organochlorine pesticides; Persistent organic pollutants; Polycyclic aromatic hydrocarbons; Teratogenicity; Toxicity

*Corresponding author: Adelodun AA, Department of Marine Science and Technology, The Federal University of Technology, PMB 704, Akure, Nigeria, Tel: +234 9055487919; E-mail: aaadelodun@futa.edu.ng

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Introduction

Since the advent of industrialization, human exposure to pesticides has become a primary and huge occupational and environmental hazard [1]. Several health issues are associated with the continuous use of pesticides to ensure adequate agricultural yield [2]. As a result, agriculturalists are most susceptible to pesticide-related maladies. Whereas, some non-occupational hazards could result from exposure to polluted ecosystems. Based on available statistics, over a million of acute and chronic illnesses, even death have been attributed to pesticide poisoning globally [3]. The after-effect of abuse or overuse of pesticides on environmental health cannot be overemphasized. The wide range of living organisms prone to one pesticide or the other include microbes, invertebrates, plants, Pisces, and vertebrates [4,5].

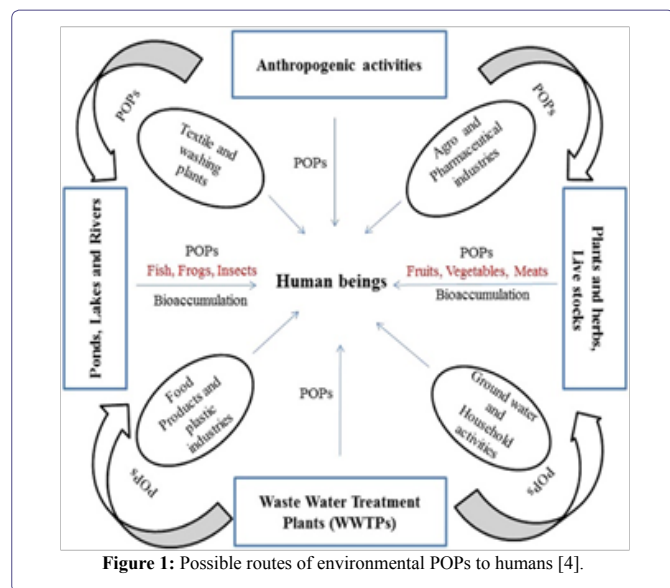
Some pesticides are environmentally refractory, i.e., they tend to be stable in the ecosystem, giving them a long life span. These pesticides are popularly referred to as Persistent Organic Pollutants (POPs). Although these pesticides are effective for their intended use, they are, however, environmentally recalcitrant and toxic [6]. In this mini-review, we examined the nature, route of exposure, and the fate of polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs), the two most prominent groups of POPs. But first, an overview of POPs.

An Overview of POPs

The nature and classes of Environmental POPs

Characteristically, POPs are organics which, albeit toxic, are resistant to degradation. They bioaccumulate within living tissues and could be dispersed by air and water, as well as by migratory species across international boundaries [6]. Being volatile organic compounds, POPs evaporate quickly in warm regions of the world, thereby are transported through the atmosphere and condense in the mountainous areas where the temperatures are usually at the sub-zero [7]. Therefore, it has been observed that the Polar Regions are characteristic of high levels of POPs [8]. Figure 1 provides a generalized route of environmental POPs.

By classification, POPs include polychlorinated biphenyls (PCBs), perfluorinated compounds (PFCs), brominated compounds, dioxins, furans, organochlorinated pesticides (OCPs), and polycyclic aromatic hydrocarbons (PAHs) and furans. Most of these classes are anthropogenic in origin. However, the sources of dioxins and furans could be natural (i.e., volcanic or vegetation fire origins) [9,10]. Generally, POPs are anthropogenic products, pre-designed for control of agricultural pest invasions, as well as for industrial use. As for the latter, it could be premeditated (e.g., polychlorinated biphenyls, hexachlorobenzene, brominated compounds, perfluorinated compounds) or unintended by-products of chemical processes or incineration (dioxins and furans) [11]. Because of their long-term, trans-boundary phenomena, the adverse effects of POP pollution on humans and the ecosystem, in general, are accumulative [12].



Sources of Environmental POPs

Several natural and anthropogenic activities release POPs into the environment. Aside from agricultural and zootechnic sources, waste dumps and landfills emissions contribute to air-borne POPs. Similarly, unclean burning of domestic plastic waste also plays some part [13]. Elsewhere, fluid wastes generated from the clean-up of pesticide facilities are often POPs-laden [13]. Also, wastes from electrical power [10] and e-waste recycling facilities [14,12] have been identified as viable sources of POPs [14]. Prominent among other sources, are chemical and petrochemical industries, roads and railroads construction and maintenance, and wastewater treatment plants [15].

Polycyclic Aromatic Hydrocarbons (PAHs)

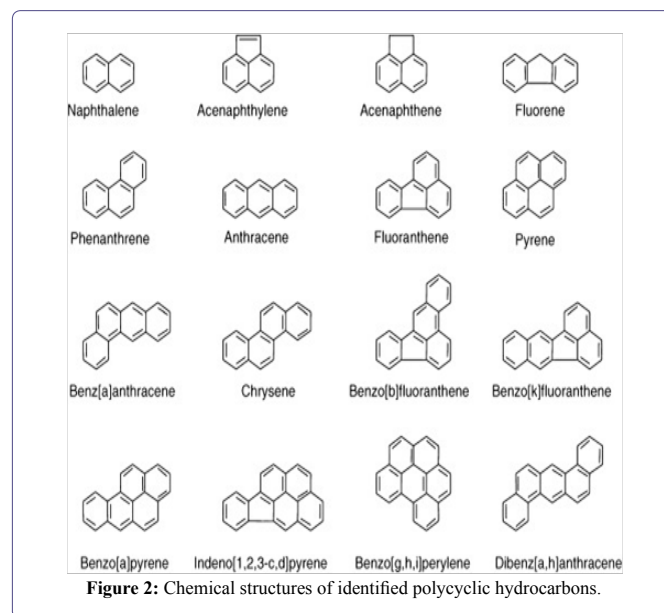
Nature of PAHs

By their nomenclature, PAHs are a class of organics made up of two or more fused unsubstituted aromatic rings. They are plain aromatics, without any heteroatom [16]. The United States Environmental Protection Agency (USEPA) has identified sixteen PAHs in the environment (Figure 2). This group of POPs is generally resistant to all forms of degradation. Their refractiveness ensures their long life in the environment [17].

Similar to the general sources of POPs, PAHs are both human-made and naturally formed [16]. They are products of incomplete combustion of petroleum products [18]. PAHs are usually found as complex mixtures, with each component having a different degree of toxicity. Some of these PAHs are carcinogens and mutagens [19].

The environmental fate of PAHs is primarily driven by their ease of dispersion and solubility in the atmosphere and hydrosphere, respectively [20]. Some PAHs are easily dispersed, encouraging transboundary movement on a global scale, while exhibiting environmental persistence [21]. Generally, PAHs are poorly hydrophilic, i.e., they are highly lipophilic. However, when found in water, they may undergo photodecomposition upon contact with the

UV region of insolation [22]. During photochemical reactions in the troposphere, PAHs may react with other air pollutants (such as O_3 , NO_x , and SO_x), yielding more deleterious secondary pollutants (such as nitro-PAHs, dinitro-PAHs, and sulphonic acids, respectively). There is a general knowledge that the denser the PAH (based on the number of benzene rings), the more toxic it is. Therefore, PAHs of four and more condensed aromatic rings more environmentally unfriendly than those of three or two rings [23].



Further, PAHs are mainly of anthropogenic origin and have no significant natural sources [16]. Although there are thousands of PAHs in the environment, in practice, only 16 PAHs are regarded as priority pollutants.

Sources of PAHs

Because they are lipophilic, PAHs are usually found in soil, sediment, and lipophilic tissues, rather than in the atmosphere or water bodies. For instance, natural oil deposits (such as crude oil and coal) contain wide varieties and large quantities of PAHs [24].

Besides, some household and human activities possess or generate PAHs. Common among them are cigarette smoke, smoldering fireplaces, gas-burner, and charred food materials. Other potential sources of PAHs in the environment include disposal from public sewage treatment, irrigation with coke oven effluent, leachate from bituminous coal storage sites use of soil compost and fertilizers [17]. Primary among them are the outdoor sources of PAHs are gas stations, machine shops, rail, chemical manufacturing plants, incinerators, chemical waste storage facilities, oil refineries, landfills, automobile engines, etc. [25].

Some natural sources of PAHs include volcanic eruptions and forest fires. Most PAHs found in the environment are products of incomplete combustion or pyrolysis [26].

Environmental Fate of PAHs

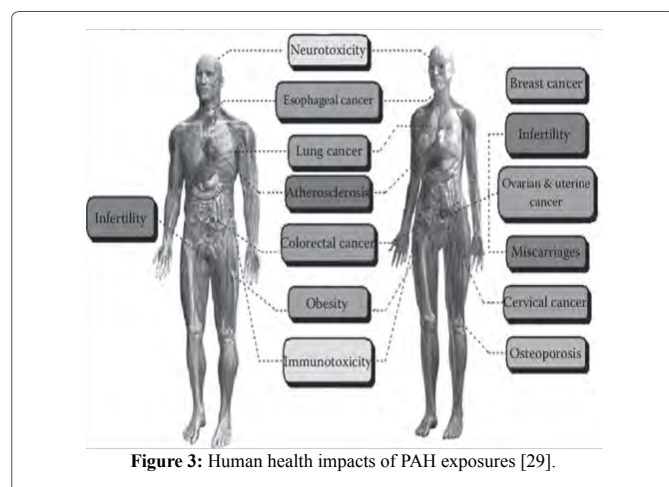
When dispersed into the atmosphere from the thermal oxidation

of fuels, PAHs may adsorb onto fine or coarse dust particles. From there, they may be carried under the air current and get deposited into another environmental sphere. Or, they may undergo photo-oxidation, which breaks down the PAH within a week [20]. Due to their high hydrophobicity, PAHs have an inherent preference of adsorbing onto soils or sediments at the bottom of water bodies. When the condition is suitable, they may solubilize in an oily fluid in the contaminated water. Therefore, the toxicity of PAHs is primarily driven by metabolism and photo-oxidation, which, in turn, determines the occurrence, number, and magnitude of secondary pollutants generated [22].

Noteworthy, some mixed microbial populations have been identified to be capable of remediating PAH pollution of sediments and soils. Some processes have been effectively viable over a short period of a few weeks to months. PAHs in soils are unlikely to exert toxic effects on terrestrial invertebrates, except when the soil is contaminated [27].

Health Effects of PAH Exposure

The negative health impacts of PAH exposure are usually evinced in the reproductive, developmental, and immune aspects of humans [28]. Generally, the toxicokinetic studies of PAH on mammals have identified olfactory, oral, and dermal routes of poisoning [20]. Based on gender, Figure 3 summarizes the various health effects humans are susceptible to upon exposure to PAHs.



As regards plants, PAHs are commonly adsorbed via translocation. The rate of such uptake is driven by the level of the PAH in the soil or underlay water, the maturity of the plants, the hydrophilicity of the PAH, and other physicochemical properties of the water/soil system.

Acute effects

The health impact of PAHs is mostly based on the toxicity of the PAH, length of exposure, dosage, and the route of exposure. Other minor factors include the health status-quo and age of the affected organism, in this case, man. Up till today, the propensity of most PAHs to induce acute health defects is unclear. Exposure via inhalation and ingestion has been traced to soil tilling, an occupational hazard of agricultural practitioners who have been exposed to excessive levels of PAHs. Symptoms often experienced include eye irritation, nausea, vomiting, and diarrhea [30].

Chronic effects

On the other hand, the health defects attributed to chronic exposure to PAHs include deteriorating immune system, cataract, damage to internal organs, such as the kidney, lungs, and liver, resulting in jaundice. Sometimes, some difficulty with breathing (i.e., asthma-like symptoms), redness and skin inflammation, etc. may ensue. Specifically, naphthalene, the lightest PAH, has been indicted for causing hemolysis, the breakdown of red blood cells [31].

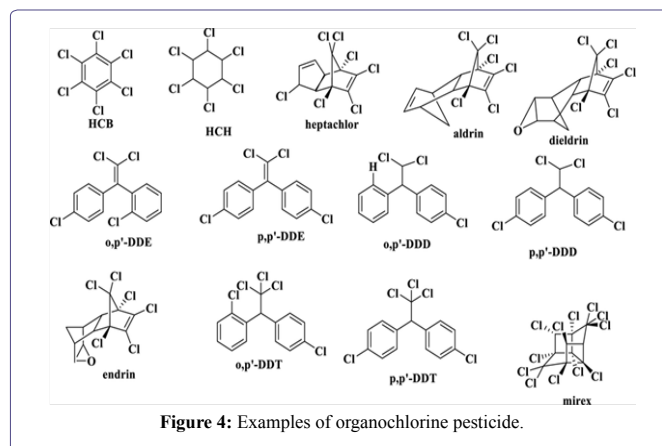
Organochlorine Pesticides (OCPs)

Nature of OCPs

As the name implies, OCPs are chlorinated organic compounds popularly and effectively used for the control of agricultural pests. They are a class of POPs characterized by high environmental refractiveness [2]. Due to that fact, and that they are non-polar compounds, bearing only carbon, hydrogen, and chlorine, OCPs are ubiquitously found in the environment [32]. Representative compounds in this group include DDT, methoxychlor, dieldrin, chlordane, toxaphene, mirex, kepone, lindane, and benzene hexachloride.

When classified broadly, OCPs could be grouped into five viz: dichloro-diphenyl-trichloro ethane (DDT and analogues, ... kelevan, murex, and the toxaphenes [33]. Because chlorine has a relative atomic weight, of most OCPs are much denser than water, thereby they could easily sink and settle underwater, attaching themselves onto solid surfaces of soils and sediments.

In terms of peculiar applications, OCPs have been earlier successfully used in the control of malaria and typhus, before their use was banned due to their toxic residual effect [2]. Data have shown that approximately 40% of all pesticides are OCPs [34]. The chemical structure of some OCPs is depicted in Figure 4. DDT is the most popularly used OCP. Similar to PAHs, OCPs are chemically and biologically refractory. Also, they are highly lipophilic, making them exhibit high biomagnification and bioaccumulation potencies [35].



Sources of OCPs

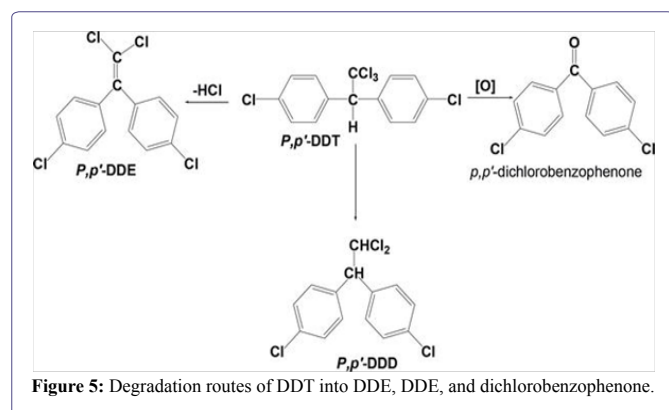
Similar to most pesticides, OCPs are primarily applied to agricultural farmlands to control pests. Usually, OCPs enter into

the hydrosphere via run-offs from industrial discharges, municipal wastewaters, and accidental discharge from factories [36]. Specifically, PCBs are used as dielectric and coolant fluids in electrical converters, carbonless copy paper [37]. Also, they are found in heat transfer fluids, plasticizers, plastic, and rubber products [38]. OCP residues linger in the environment over many years, and their persistence encourages long-distance transport after volatilization from the primary source of emission, be it from production or application [39].

Environmental Fate of OCPs

Generally, OCPs resist any form of physical, chemical, or biological degradation [40]. The use of agricultural pesticides for agricultural production has led not only to the increase in yield but also to increase environmental pollution. Due to their high environmental reactivity and persistence, OCPs dispersed in water are transferred along in the food chain, bioaccumulating (bioconcentrating) in aquatic animals up to it gets to man [36].

As for DDT, upon exposure to some microbes, especially *Enterobacter aerogenes* in the soil, it undergoes degradation into DDE or DDD, as depicted in figure 5.



Health Effects of OCP Exposure

Expectedly, OCPs have a high tendency to store up in the fatty tissues of all forms of animals, as well as in the tissues of plants. Especially, they have been reportedly found concentrated in the fillets of fishes [41]. When in the human body, these chemicals can easily find their ways into the urinary and reproductive systems [42]. Apart from their bioaccumulation in fatty tissues, OCPs can be absorbed orally, transdermally, by inhalation, and through the gastrointestinal tract [43].

Toxicokinetic studies have shown that OCPs usually access humans via the dermal and olfactory routes. Those that are commonly exposed to are cyclodienes, hexachlorocyclohexane, and endosulfan. Humans could get exposed to OCPs through the ingestion of fatty food, such as meat, fish, poultry, and dairy products, etc. [44]. Many of the organochlorine molecules are carcinogens and neurotoxic [45]. On many occasions, different types of OCPs have been implicated in cases of hypertension, cardiovascular disorders, among other life-threatening diseases. Also, OCPs are endocrine-disrupting chemicals (EDCs), altering the molecular circuitry and function of the endocrine system [43].

Traces of OCP residues have been found in the blood samples of farm workers and their families where OCPs have been previously applied. Worse is the effects of such poisoning on the central nervous system during acute and highly concentrated exposure. In recent years, traces of dioxins have been found in human ovarian follicular fluid, causing endometriosis. Other autoimmune illnesses associated with such exposure include multiple sclerosis and eczema [46]. Especially in children, dioxins cause learning disability (LD) [47].

Consequently, because of the measures put in place by various countries to ban the use of PAHs and OCPs for pest control, as well as strict embargos on all chemical and thermochemical processes that form these chemicals, there are expectations of a steady reduction in their environmental presence. Similarly, the mitigative measures and enforcement of laws implemented by relevant governing institutions (such as WHO, USEPA) are already yielding positive results as regards the future outlook of PAHs and OCPs in the environment [48]. Although, these efforts are being sabotaged by recalcitrant farmers who have prioritized their immediate commercial gain over the long-term health of their family, neighbors, customers, and the nations. While efforts are incessantly made toward the control of these organic pollutants, scientists are encouraged to research for environmentally benign alternatives to PAHs and OCPs, to ensure that agricultural products are sufficiently available to cater for the ever-growing human population. Thence, to achieve a successful reduction of the environmental, health, and economic impacts of PAH and OCP pollutions, all efforts from all levels of global citizenship must be harmonized.

Conclusion

We have provided a mini-review of the nature, sources, environmental fate and health impacts of Polycyclic Aromatic Hydrocarbons (PAHs) and Organochlorine Pesticides (OCPs). Although several detailed reviews are available, this short review provides an updated information, as well as a condensed easy-to-read appraisal of these serious environmental problem that seems recalcitrant to mitigate. With the information provide, man can easily plan towards avoiding or controlling the pollution of these unwanted organics in our environment.

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