

# A Critical Review of the Transport and Health Effects of Persistent Organic Pollutants

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## Abstract

Persistent organic pollutants (POPs) are toxic chemicals which affect the health of human beings and the environment adversely. These pollutants could be transported by wind and water. They could affect people and animals in other countries far from where they were generated initially. POPs persist in the environment for a long time before they are degraded. They bioaccumulate in organisms through the food chain. These chemicals include the organochlorine pesticides and other halogenated organic compounds such as polychlorinated biphenyls (PCBs) and dioxins. The aim of this review is to examine the transport of these pollutants from their point of application and look into their effects on human health. Recent studies reported the gradual introduction of these banned chemicals under different trade names into the environment. Therefore, this review will re-enlighten the public on the dangers in the transportation as well as the harmful effects of these pollutants as they also biomagnify in human. Proper measures on the handling, usage and regulation of these contaminants especially the synthetic organochlorine pesticides should be rekindled worldwide.

**Keywords:** persistent organic pollutants, bio-accumulate, bio-magnify, toxic, environment; health.

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## INTRODUCTION

Toxic compounds are made of organic and inorganic substances [1]. These compounds include organochlorine pesticides, polychlorinated Biphenyls (PCBs), and poly aromatic Hydrocarbons (PAH) and fire retardants [2, 3]. Inorganic toxic chemicals such as lead, mercury, zinc, cadmium, acids and salts are also included in toxic compounds classification. These chemicals have severe effect on the ecosystem and water bodies [4]. They could be threat to human and aquatic systems and resist environmental breakdown [5]. They are not easily degradable and they persist in the environment for a long time [6-11].

Agrochemicals such as organochlorine pesticides contaminate drinking water. Their effect is a great concern as they affect the water systems and aquatic lives [12-14]. Pollution of water by agricultural chemicals adversely affects the fish and wildlife [15]. Generally, bacteria and viruses found in water cause diseases in human public drinking water supplies. However, pollution by synthetic organic pollutants is of global concern due to their toxicity and persistence [16].

Runoff from minning operations could also be a source of water pollution as the exposed rocks during the mininig operation create acidic runoff. This acidic runoff could seep into neaby water bodies and changes aquatic environment pH [17].

Organic chemicals such as asphalt used for road constructions could also pollute water systems. When water, is in contact with these surfaces, they could runoff and be absorbed into the surrounding environment. Their presence in water could be harmful to aquatic eco system. Chemicals used for the care of lawns could also enter into the environment through runoff or other sources. Moreover, chemicals that are used for the maintenance of boats could also leak into the water thereby contaminating it [17].

The most toxic of these pollutants to man are the persistent organic pollutants(POPs) which cause different health issues such as cancer, birth defects, developmental defects, diabetes, seizures ,convulsions and possibly death. Therefore, this review aimed at creating awareness to the public on the dangers of these pollutants in the environment. Recent published work on these contaminants revealed that they are still present in the environment. Farming, contributed to this

menace as farmers continue to use these banned chemicals especially in developing countries to control pests affecting their crops in order to increase their yield. The organochlorine agrochemicals are highly potent for the control and killing of pests thus their demand for agricultural activities have increased in developing nations. Although, these chemicals have been banned globally, farmers in developing nations are still buying them under different trade names. Thus, the general objective of this review is to examine the transport route of exposure to these pollutants and their human health effects.

### Persistent Organic Pollutants

Persistent organic pollutants (POPs) are organic pollutants that are very toxic, stable and persist for long period with adverse effect on human and the environment. They could also accumulate in aquatic lives [2, 4, 6-7]. POPs are of great concern and a treaty was signed in Stockholm, Sweden on May 2001 on the eradication of these initial 12 POPs known as “dirty dozen” [18]. Twelve initially banned POPs are aldrin, chlordane, dichlorodiphenyl trichloroethane (DDT), dieldrin, endrine, heptachlor, hexachlorobenzene, mirextoxaphane, polychlorinatedbiphenyls (PCBs), dibenzodioxin (Dioxins), polychlorinated dibenzofurans (furans). Chlordecone, hexacyclochlorohexane, hexabromodiphenylether, lindane, pentachlorobenzene, tetrabromodiphenylether, perchlorooctasulphuricacid, endosulfans, and hexabromocyclododecane were the additionally banned POPs known as the nasty nine [19, 20]. Chemicals intentionally produced are used currently for the control of agricultural disease. Additionally, industrial processes are made of POPs as active ingredients [19]. POPs such as dioxin, can also be produced unintentionally in the environment. These could result from industrial processes and combustion. Municipal

and medical wastes incineration as well as burning of trash could also lead to the production of these pollutants [5]. Majority of these POPs, were used as pesticides in the past. They were also used as solvents, pharmaceuticals and industrial chemicals. Some POPs such as volcanoes and biosynthetic pathway occurs naturally [9].

### Transport of persistent organic pollutants

POPs are halogenated organic compounds with high fat solubility. Therefore, they bio accumulate in lipid tissues and exert negative effects on the environment. Through the process of long range transport [10-15]. This transportation route allows them to travel far from their source and re-concentrate into potentially dangerous pollutants [21, 22]. The long range transport of POPs involve their entering into the gas phase (Figure1) [23]. They can also volatilize from soils, vegetation or water bodies into the atmosphere [22-23]. They resist degradation and also travel long distances before being deposited [24]. These pollutants deposition results in their accumulation in areas far from where they were used initially .emitted or produced [21-22, 25]. They could also be found in environments where they have never been used before [26]. They move up the food chain and bioaccumulate in diet [9-15]. Their level increase as they are processed and metabolized in certain tissues of organisms [27-28]. A positive relationship exists between low level exposure of these contaminants and various diseases of man [29]. Human health risk assessment may be produced by government agencies which will take into account the pollutants bioavailability and dose response [27-28]. Several studies have been carried out globally on POPs especially OCPs and PCBs level [30-31]. Pollution studies outcome of environmental and biological matrices reveal that these contaminants are still present in the environment [23].

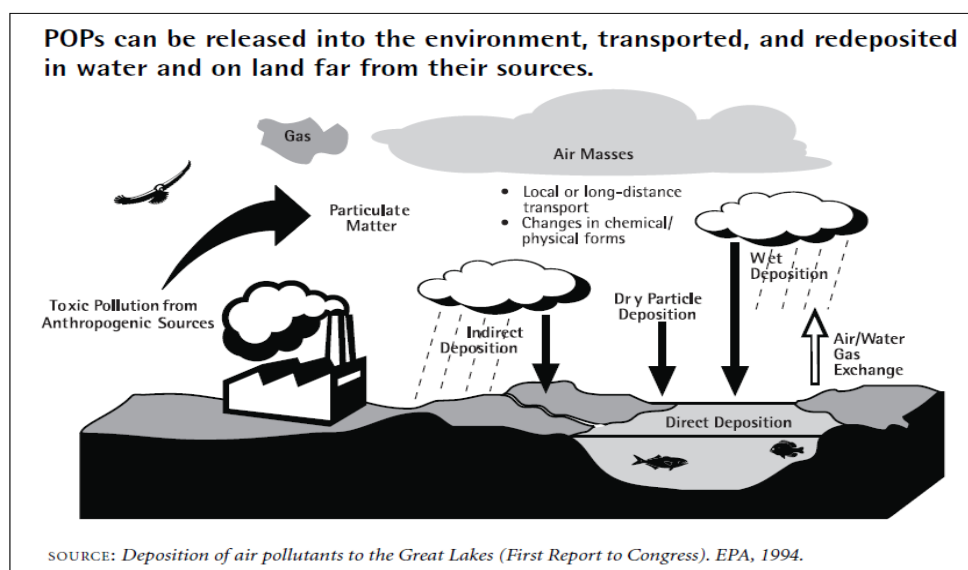


Fig-1: Transportation of POPs in the environment

### Types of persistent persistent organic pollutants (pops) dirty dozens

Table 1 contains the twelve POPs banned at the Stockholm convention known as dirty dozens. This dirty dozens include: aldrin, chlordane, dichlorodiphenyltrichloroethane (DDT), dieldrin, endrine, heptachlor, mirex and toxaphane hexachlorobenzene, polychlorinated biphenyls (PCBs) and, polychlorinated dibenzo dioxins (Dioxins), polychlorinated dibenzofurans (furans) (Figure) [4]. Surprisingly, Some of these banned POPs

are organo chlorine pesticides while the others are heavy chemicals and unintentional by products [5-6]. The organochlorine pesticides among the twelve dirty dozen are aldrin, chlordane, dichlorodiphenyltrichloroethane (DDT), dieldrin, endrine, heptachlor, mirex and toxaphane hexachlorobenzene, polychlorinated biphenyls (PCBs) and, polychlorinated dibenzo dioxins (Dioxins), polychlorinated dibenzofurans (furans) and unintentional by-products.

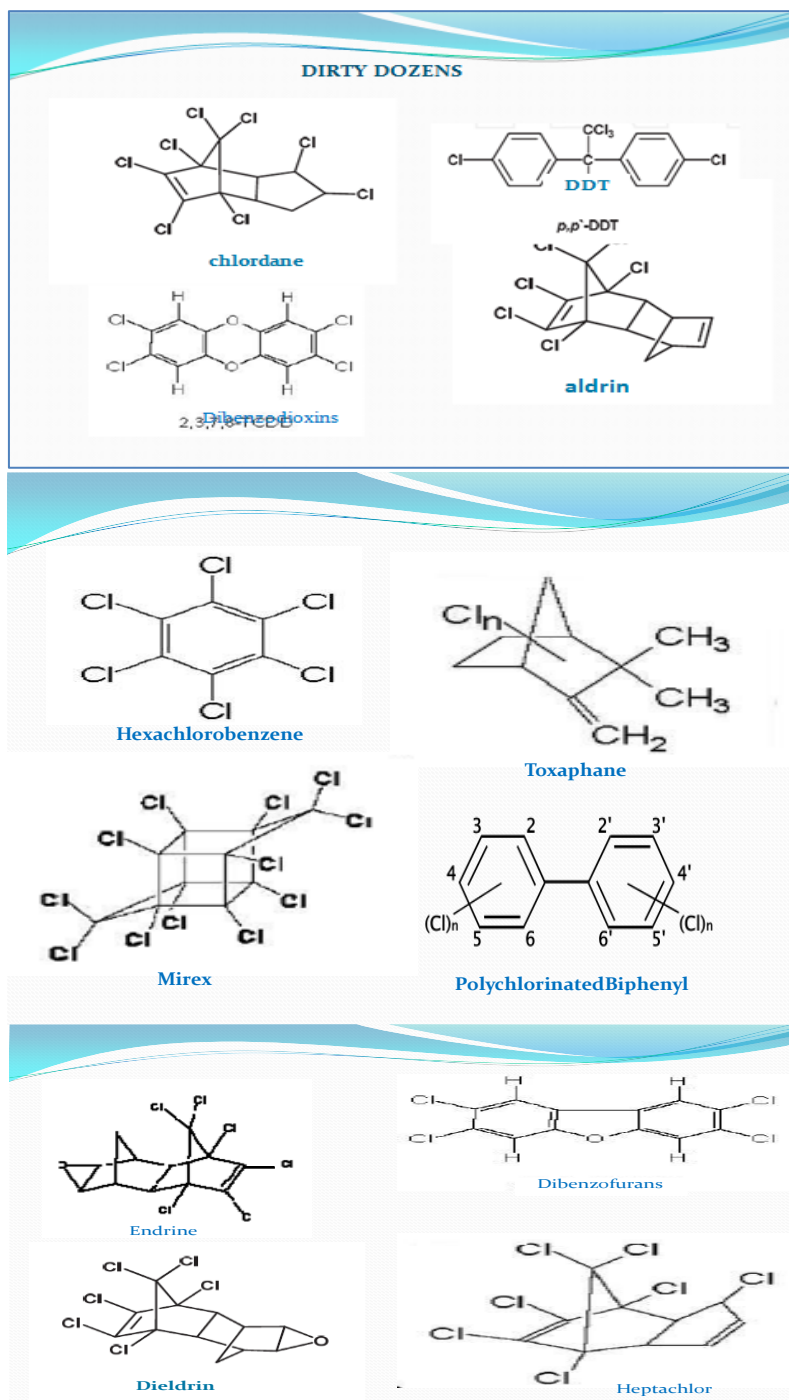


Fig-2: Structures of Dirty dozens

### Organochlorine Pesticides

Organochlorine pesticides (OCP) are organic chemicals made by man to control insect pests. They were phased out due to their toxic and persistent nature [32]. Health effects such as cancer in humans and ecosystem are also of concern from exposure to these halogenated chemicals [2, 9, 10, 14]. They were produced originally to protect crops, livestock, buildings and households from insects which cause damage to them. However, due to their high insecticidal potency, in pest's control, they were tremendously used over the years in agriculture. They were banned at the Stockholm convention [3-6, 16-20]. OCPs have been used in many commercial products under a wide range of trade names [20].

Organochlorine pesticide contamination of the environment has been a major concern and threat to human and ecosystem [16, 18]. When pesticides reach the soil after application. Its residues affect the soil quality by disturbing soil organisms and decomposers [9-12]. This action decreases microbial biomass of the soil and affecting the ecosystem [13-14]. Pesticide residues in soils cause toxicity to plants, and their products thereby contaminating the food chain [22]

These pollutants get into the aquatic environment through effluent release, domestic sewage and industrial waste water discharges, agricultural fields runoff, leaching, equipment washing, disposals of empty containers dumping of wastes into water system and atmospheric deposition [23]. Ecological impacts in water contamination is by pesticide is based on bioaccumulation and biomagnifications. In bioaccumulation, pesticide residues enter into the water and moves into an organism from a surrounding medium where they are metabolized and excreted [14-15].

Bioaccumulation involves the transformation of food energy within the food chain as smaller organisms are eaten by larger organisms [32-33]. The concentrations of pesticides and other chemicals are increasingly magnified in the tissue and other organs. High concentrations of these pollutants could be observed in top predators including man [33].

### Poly Chlorinate Biphenyl (PCBs)

PCBs are synthetic organic with 209 distinct congeners [23]. They are stable and commonly used in capacitors and other electrical equipment. They have low insulating and boiling capacity [16, 18-19] are classified as possible carcinogen by International Agency for research on cancer [33]. They were

specifically produced as specific mixture of congeners known as arochlors [33]. They appear in natural environment due to unintentional and irresponsible human activities [in game]. They could also be released into the environment when wastes containing PCBs are incinerated or stored in landfill (WHO 2000, CDC 2000). Their possible impact on human health and environment made these chemicals to be banned or restricted in many countries [34]. They do not degrade easily and they are resistant to degradation by acids, bases, oxidation, hydrolysis and changes in temperature [23]. PCBs could generate extremely toxic dibenzodioxins and dibenzofurans during incineration [23]. They penetrate the skin, latex rubber [31]. Studies have shown that environmental matrices have been contaminated with PCBs [23]. Studies have also shown that biological species bioaccumulate PCBs from eating fish and other contaminated aquatic animals [23] [30].

### Dichlorodiphenyl Trichloro Ethane (DDT)

DDT was initially used in the second half of world war II to control malaria and typhus among civilians and the troops and after the world war it was used as an agricultural insecticide [4-6] [19]. DDT is one of the "12 dirty dozen" banned globally at the Stockholm convention in 2001 [16, 18-19]. Despite its ban, it is still being used for disease control in some developing countries [4-5]. The major metabolites of DDT are DDD and DDE [35]. DDT bioaccumulates in fatty tissue because of their lipophilicity [36]. DDT and its metabolites magnify through the food chain. The apex predators such as birds concentrate more of the chemicals than the other animals in the same environment [37]. DDT and its metabolites are resistant to metabolism in humans [13, 24]. The half-life of this compound is 6 to 10 years [26, 36].

### Polychlorinated Dibenzon Dioxins

Dioxins are unintentional industrial by products processes that are toxic and persistent in the environment [18, 19]. The half-life of Polychlorinated Dibenzon Dioxins is 7-11 years [2, 18-19]. The most important source of human exposure of dioxin is through fatty food of animal origin [2] and breast milk [3].

### Polychlorinated Dibenzon Furans

Polychlorinated dibenzofurans are POPs compounds with one or several hydrogen in the dibenzo furans structure replaced by chlorine atoms. Dibenzofurans are much more toxic than their parent compound and their properties and structure are similar to dibenzodioxins [3-6]. They are also classified among the "dirty dozen" [16].

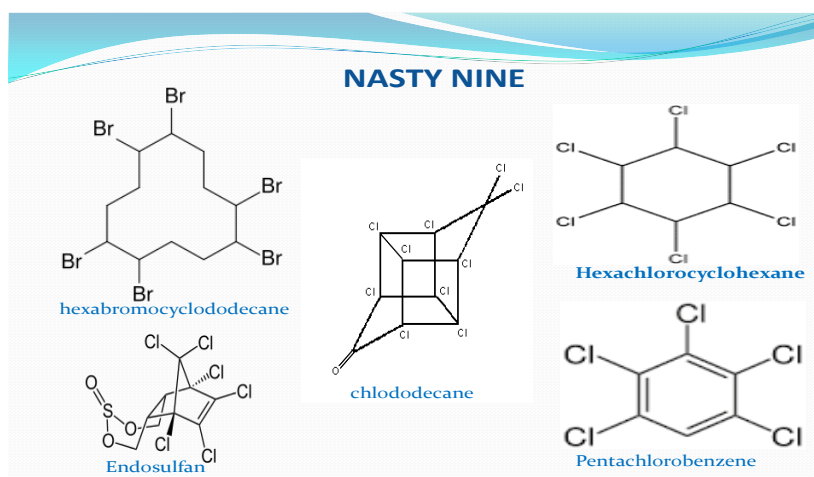
**Table-1: Route of Exposure and Some Human Health Effects of Dirty Dozens**

POPs	Classification of POPs	Exposure Route	Acute and chronic human health effects	References
Aldrin	organochlorine pesticides	Ingestion inhalation, Skin	Cancer	[34-35]
Chlordane	Organochlorine Pesticides	Ingestion Inhalation Skin	testicular cancer changes in their liver function, respiratory infections ,immune system activation, anxiety, depression ,blurry vision	[16][18] [34][35]
Dieldrin	Organochlorine Pesticides	Ingestion Inhalation Skin	endocrine disruption.testicular descent , Parkinson breast cancer, immune and reproductive system damage	[35, 38]
Endrin	Organochlorine Pesticides	inhalation, ingestion and skin	Culvulsion, the central nervous system disorder;	[34, 35, 38]
<b>Heptachlor</b>	organochlorine pesticides	Ingestion (drinking water and food and breast milk) decrease	Type 11 diabetes	[34, 38]
<b>Hexachlorobenzene</b>	Organochlorine pesticides (fungicides)	Ingestion Inhalation Skin	liver diseases, skin lesion with discolouration, ulceration, hotosensitivity, bone and thyroid effects	[34, 35, 38]
<b>Mirex</b>	Organochlorine pesticides	Ingestion Inhalation Skin	liver problems, endocrine disruption and cancer	[34, 35]
<b>Toxaphane</b>	Organochlorine pesticides	Ingestion Inhalation Skin	tyroid, liver and kidney	[34, 35]
<b>Polychlorinated Biphenyl</b>	Industrial chemicals	mainly by ingestion (food)	Skin damage (chlorance) liver damage, immune compromise and motor control problems	[27, 34, 35]
<b>Dichlorodiphenyl Trichloro Ethane (DDT)</b>	Organochlorine pesticides	Ingestion Inhalation Skin	endocrine disrupting carcinogenic disruption in human semen quality menstruating gestational length and duration of lactation thyroid function in pregnancy and childhood	[27,34,35, 38]
<b>Polychlorinated Dibenzon Dioxins</b>	Unintentional by-products	Ingestion nhalation skin	Reproductive, developmental and immune system interference and cancer risks, skin disease (chlorance) liverdamage, metaboismalterations, serum lipid level alterations, alteration of thyroid function, diabetes and immocological effects sperm count and motilitydamage	[35, 38-39]
<b>Polychlorinated Dibenzon Furans</b>	Unintentional by-products	Ingestion inhalation skin	carcinogenic,mutagenenic and tetragenic	[2,34,35]

**Nasty Nine**

The additionally banned POPs are referred to as nasty nineas shown in Figure 3 include: chlordecone, Hexabromodiphenylether, lindane, pentachlorobenzene,

pentabromodiphenylether, alpha hexachlorocyclohexane, betahexachlorocyclohexane, perchlorooctasulphuric acid (PFOS), endosulfans, and hexabromocyclododecane[20]



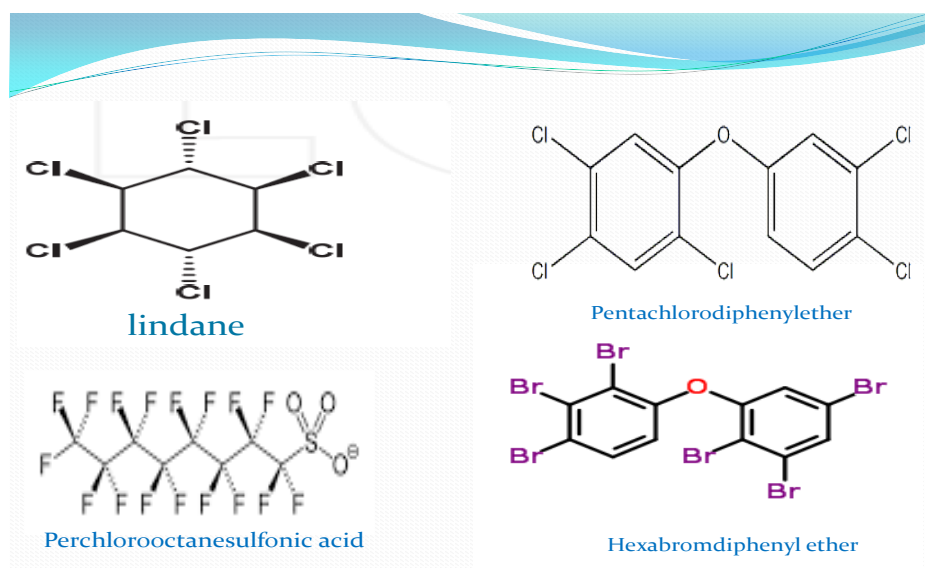


Fig-3: Structures of the Nasty Nine

### Types of Nasty Nine

#### Chlodecone

Chlordecone also known as kepone is a known POP and banned globally by the Stockholm convention. Chlordecone was included in 2009 banned chemicals known as nasty nine. They also persist in the environment and are harmful to the environment and human [18].

#### Alpha Hexachlorocyclohexane

Alpha hexachlorocyclohexane is an organochlorine which is a by-product of an insecticide called lindane. It bioaccumulates and biomagnifies in environmental and biota matrices [16].

#### Hexabromodiphenylether

They are halogenated compounds usually used as flame retardant [40]. They have been used in a wide variety of products. They are also used for building materials, electronics manufacturing and furnishings. They are also used in the making of motor vehicles, airplanes; plastics and polyurethane. They are similar to PCBs and other poly halogenated compounds which consist of two halogenated aromatic compounds [41]. Hexa bromodiphenylether consist of 209 congeners [42]. The commercially available PBDE products are not simple compounds and no single congeners but rather a mixture of congeners. The lower brominated PDEs with 1-5 bromine atoms per molecule are regarded more dangerous because they bioaccumulate [25].

#### Lindane

Lindane was originally being used as agricultural insecticide and as a pharmaceutical compound for treating for lice and scabies [8]. The production and agricultural use of lindane was banned under the Stockholm convention on persistent organic pollutants [2-6]. Lindane is persistent and transported long distances. It can bioaccumulate in food

chain [18]. It is broken down in soil, sediments and water into less harmful substances by algae, fungi and bacteria [43]. The alpha and beta isomers of lindane are more toxic than lindane but do not have insecticidal properties [43]. Lindane is classified by WHO as a moderately hazardous [44]. It is restricted and regulated under the Rotterdam Convention [20].

#### Pentachlorobenzene (PeCB)

Pentachlorobenzene is a chlorinated aromatic hydrocarbon [20]. It is an intermediate in the manufacture of pesticides especially fungicides. It is also used as fire retardants. It was added to chemical compounds covered by the Stockholm convention [45]. It is toxic in aquatic organisms [20]. It persists in the environment [3-6]. They are also used as flame retardants [45].

#### Perfluorooctanesulfonic Acid (PFOS)

PFOS is a fluorosurfactant that lowers the surface tension of water. It is a dominant commercial mixture and harmful to human and the environment [4-8]. They are toxic, persistent and they bioaccumulate in mammalian species [46-47].

#### Endosulfan

Endosulfan is a agrochemical with acute toxicity and bioaccumulation potential and role as an endocrine disruptor and threats to human health and the environment, it was banned globally under the Stockholm Convention [20].

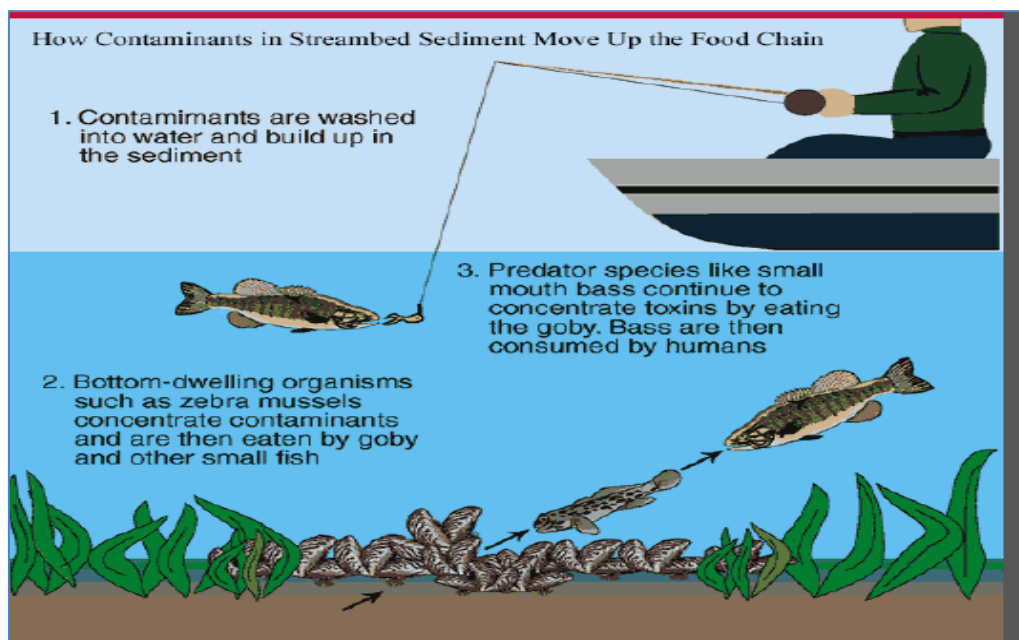
It is used to control pests but it has negative effect on the populations of some beneficial insects [48]. It is considered to be moderately toxic to honey bees [20]. Its chemical properties are similar to aldrin, chlordane and heptachlor [48]. It is one of the most toxic pesticides [20]. It is responsible for many fatal pesticide poisoning and at low dosage; it can cause death [44].

### Hexabromododecane (HBCD)

Hexabromocyclododecane (HBCD), is a brominated flame retardants [49]. It is used as thermal insulators in building, automobile, and furniture [18]. It is also used in making packaging materials, videocassette, housing recorder, as well as electrical

equipment [20]. It is toxic and found in environmental samples [20]. It could be found in biological systems and aquatic organisms [49]. It is also persistent, bioaccumulative and undergoes long range transportation [3, 9].

### Bioaccumulation of pops



**Fig-4: POPs contaminants bioaccumulation**

Source: Pests, Pesticides, Pesticide Risks & USAID's Response. Visit [www.encapafrika.org](http://www.encapafrika.org)

**Table-2: Route of exposure and human health effects of the nasty nine**

Persistent organic pollutants	Classification of Persistent organic pollutants	Route of exposure	Acute and chronic human health effects	References
Chlodecone	Organochlorine Pesticides	Ingestion inhalation, skin	Severe convulsions resulting from degradation of synaptic junctions	[49]
Alpha Hexachloro Cyclohexane	Organochlorine Pesticides (by-product of lindane)	Ingestion inhalation, skin	Altered thyroid hormone, poor brain development	[50]
Hexabromodiphenyl ether	flame retardants	Ingestion inhalation, skin	reproductive (infertility) and neurological problems mental and physical development disorder	[41] [44] [51]
Lindane	Organochlorine Pesticides	Ingestion inhalation, skin	skin irritation, seizures burning sensations itching ,dryness and rashes nervous carcinogenic system, liver and kidneys	[9] [34] [38]
Beta Hexachlorocyclohexan	Organochlorine Pesticides	Ingestion inhalation, skin	poor brain development human immune system damage	[35] [50]
Pentachlorobenzane	chlorinated aromatic hydrocarbons	Ingestion inhalation, skin		[51]

Perfluorooctanesulfonic Acid (PFOS)	anthropogenic fluoro surfactant	Ingestion inhalation, skin	immune system cancer, stunted growth, Preeclampsia in pregnant women. Thyroid hormone disorder	[27] [34] [46] [52]
<b>Endosulfan</b>	Organochlorine Pesticides	Ingestion inhalation, skin	Development defects as sexual maturity delay in boys and sex hormones interference. endocrine distruptor death in humans	[34] [44] [53]
<b>Hexabromododecane</b>	flame retardants	Ingestion inhalation, skin	liver and brain damage	[54]

## CONCLUSION

Several studies on POPs showed that they are still present in the environment despite their ban. Organochlorine pesticide residues have continued to be detected in environmental and biological matrices till date. This could be attributed to their continuous production, under different trade names. Their transport in the environment as described in this article are also of great concern since they are very persistent. Some of these POPs affect people and environment in areas where they are not applied. They could also pass through international boundaries. Therefore, proper measures should be taken towards exposure to these pollutants in order to avert the possible health effects revealed by this article.

**Author's contributions:** The authors contributed equally to this study. All the authors read and revised the final manuscript.

**Competing interests:** The authors declare that they have no competing interests.

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