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Review on Organochlorine Pollution in Malaysia

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ABSTRACT: Organochlorine is a type of persistent organic pollutants which can last long in environment due to the resistance towards the microbial degradation. Previously, the organochlorine pesticides are widely used to reduce the pests in the farm so, the crop yield could be increased, and the losses can be decreased. The organochlorine pesticides previously are used without having a proper study on the effect of organochlorine to the environment. Although the use of organochlorine pesticides has been banned, the residues of organochlorine from previous usage, still exist in the environment, causing negative impacts to the environment and human health. The distribution of the organochlorine pollution in Malaysia is required to be studied more to ensure that the organochlorine concentration will not be increasing according to time. Due to the ban of organochlorine pesticides, other pests control methods such as organophosphate pesticides, and integrated pest management are being used by the farmers. However, there are challenges raised such as financial problem of the farmers to afford the new chemicals or methods and the negative effect from the use of new chemicals, and these challenges should be solved to improve the pest control in Malaysia. Impacts of organochlorines on human health and environment are discussed in this review to show the hazard of organochlorines.

KEYWORDS: Organochlorine pollution; health impact; environmental impact; fertilizer; soil contaminations

1. Introduction

Due to rapid human population growth, the food demand has been gradually increasing. The food production should be increased to fulfill the demand and population growth. There are several ways on improving the crop yields such as applying pesticides or providing fertilizers. Fertilizers are sued to provide nutrients for plant growth while pesticides have been invented to reduce the pests damage towards the crops. According to Martyniuk et. al. [1], the pesticides can effectively save the 30% of the crops against the pests. Hence, the pesticides application will be an effective solution to increase the crop yield apart from fertilizers. One of the effective and economic pesticides will be organochlorine pesticides. However, the use of organochlorine pesticides has resulted in organochlorine pollution towards the environment and even risked the human health. In this review article, there will be discussion on the occurrence of

organochlorine pollution, current distribution of organochlorines pollution, current status of pest control, challenges, human health impacts, and also the environmental consideration.

To ensure the most current understanding of organochlorine pollution and its environmental impacts, this review has been updated to include recent findings. Recent studies have highlighted advanced methodologies for detecting and quantifying organochlorine residues in environmental samples, offering greater sensitivity and specificity [2]. Moreover, innovative remediation technologies, such as nanoremediation and enzyme-based degradation, have shown promise in degrading persistent organochlorine compounds more efficiently and eco-friendly than traditional methods [3]. Additionally, the latest epidemiological research has provided deeper insights into the long-term health effects of low-level organochlorine exposure, revealing correlations with chronic diseases beyond previously understood risks [4]. Environmental studies have also documented the ongoing impact of organochlorines on biodiversity, particularly in sensitive ecosystems, where even low concentrations can disrupt the reproductive and feeding behaviors of wildlife [2]. These recent contributions underscore the dynamic nature of research on organochlorine pollution and its implications. They highlight the need for continuous monitoring of environmental and health impacts and the development of innovative solutions to mitigate these enduring challenges. Future research should aim to bridge gaps in our understanding of organochlorine dynamics in the environment, explore the long-term ecological and health consequences, and evaluate the effectiveness and sustainability of emerging remediation technologies.

2. Occurrence of Organochlorine

Organochlorine, a type of chlorinated hydrocarbon exists in the organochlorine pesticides. The organochlorine pesticides are effective in reducing the brown Miridae species which will reduce the productivity of cocoa tree [5], increasing the profit of cocoa farmer by reducing the pests damage towards cocoa trees. There are different types of organochlorine pesticides as listed in Table 1. However, the organochlorine pesticides are widely used before the actual investigation of the side effect towards the environment [1]. With the increment in the use of organochlorine pesticide, the environment has been polluted as the organochlorine is a type of persistent organic pollutants. Persistent organic pollutants are pollutants which will persist in environment for a long period of time, degrading the environment and causing the environment is no longer suitable for some sensitive species to live and even harm the human health. For example, dichlorodiphenyltrichloroethane (DDT) can persist in the soil or environment for 10-15 years after the DDT is released into the environment [6].

Due to the destructive effect of organochlorine pesticides towards the environment, the use of organochlorine pesticides has been banned in several countries [7]. However, the previous application of organochlorine pesticides has caused the presence of organochlorine pesticides nowadays due to the high persistency and resistance of organochlorine pesticides against the microbial degradation [1]. As a result, the environment is still polluted by the organochlorine, putting the human and environmental health at risk.

The increasing global population has intensified the need for enhanced food production techniques to ensure food security. Among various strategies to boost crop yields, the use of pesticides has been a common practice to control pests and diseases that affect crops. Organochlorine pesticides, a class of synthetic chemicals characterized by their high chlorine content, have played a significant role in agricultural practices [12]. Organochlorine pesticides,

including well-known compounds such as DDT (dichlorodiphenyltrichloroethane), aldrin, and dieldrin, were initially introduced due to their effectiveness in killing a wide range of agricultural pests and their persistence in the environment, which reduced the need for frequent applications. These properties made them highly popular for agricultural and vector control purposes during the mid-20th century. However, their environmental persistence, coupled with their tendency to bioaccumulate in the fatty tissues of living organisms and their potential for long-range atmospheric transport, raised concerns about their impact on human health and the environment [13].

Table 1. Types of organochlorine pesticides.

Type of organochlorine pesticides	References
Dichlorodiphenyltrichloroethane (DDT)	[1]
Dichlorodiphenyldichloroethylene (DDE)	[8]
Lindane	[8], [1]
Aldrin	[8]
Dieldrin	[8], [1]
Hexachlocyclohexane (HCH)	[6]
Hexachlorobenzene (HCB)	[9]
Dichlorodiphenyldichloroethane (DDD)	
Methoxychlor	[1]
Toxaphene	
Endosulfan	
Chlordanes (CHLs)	[10]
Polychlorinated biphenyls (PCBs)	[11]

3. Distribution of Organochlorine

The organochlorine pollution in Malaysia is a result of agricultural activities as the organochlorine pesticides are used before these pesticides are banned. The organochlorine concentration will be increased due to the development of agricultural activities and industrial activities. The distribution of organochlorine does not fix only to the environment such as water body and soil but also in the body of organisms when the organisms ingest the organochlorine contaminated materials. It is important to study the distribution of organochlorine so that the affected area by the organochlorine can be estimated. However, the research of organochlorine in aquatic environment of Malaysia is mostly focused in West Malaysia while Sabah and Sarawak have less researches about the aquatic pollution [14].

A research done by Vaezzadeh et al. [10] shows the organochlorine concentration in both barnacles and mussels in West Malaysia. The research is carried out in the stations shown in Figure 1. The results of the research show that the barnacles examined in the stations carry Chlordanes (CHLs) ranged from 6.3-230 ng/g of lipid weight, Dichlorodiphenyltrichloroethane (DDTs) ranged from 8.4-170 ng/g of lipid weight, Hexachlocyclohexane (HCHs) ranged from 1.3-18 ng/g of lipid weight, and Hexachlorobenzene (HCBs) ranged from 0.86-7.7 ng/g of lipid weight [10]. While for the mussels examined with lipid percentage of 1.1-2.7%, there are 7.7-140 ng/g of lipid weight, 12-130 ng/g of lipid weight, 1-3.5 ng/g of lipid weight, and 0.41-1.7 ng/ g of lipid weight for CHLs, DDTs, HCHs, and HCBs respectively [10]. Monirith et al. [11] states that Malaysia's mussels are mostly affected by CHLs and polychlorinated biphenyls (PCB) if compared to other organochlorines. These results clearly show that the organochlorine still exists in the ecosystem and even in the body of the organisms.

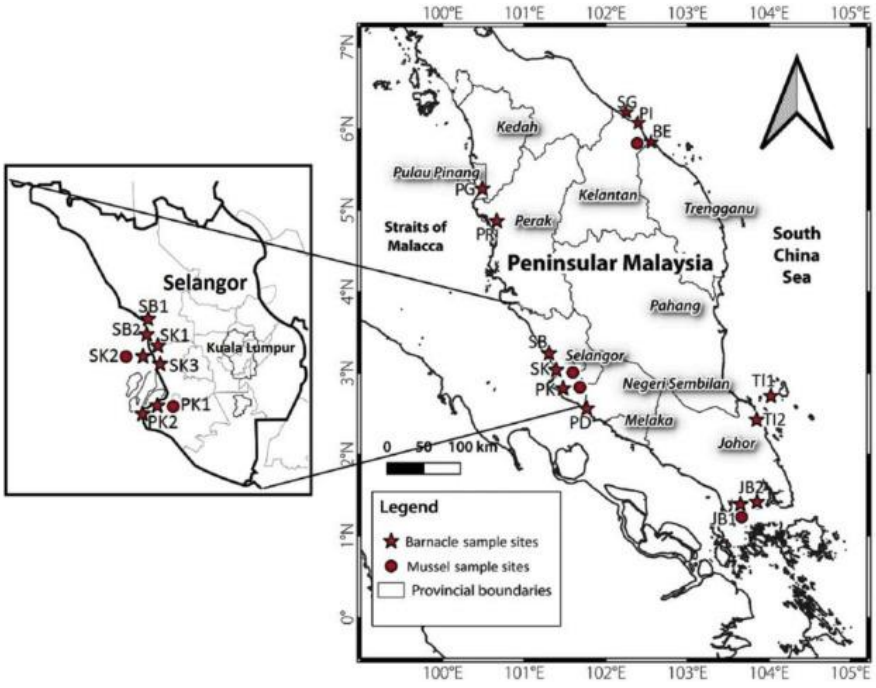

Figure 1. The stations for carrying out research on organochlorine concentration in barnacles and mussels [10].

There are still detectable concentration of the organochlorine pesticides especially α HCH, β HCH, γ HCH, δ HCH, endosulfan sulphate, and 4-4'-DDT in the soil of two low-land paddy fields in Machang, Malaysia. However, the analysis for the chronic daily intake for these organochlorine pesticides by both adults and children at the selected area will not risk the life as the intake does not exceed the hazard quotient. Although the current concentration of selected organochlorine pesticides does not harm human life, the use of organochlorine pesticides should be stopped in the paddy fields. Apart from Machang, Kundasan Highlands, Cameron Highlands, and Muda Scheme, which are the agricultural fields show different types and levels of organochlorine contamination [15]. The agricultural lands will be contaminated by more types of organochlorine than that in paddy fields. This might because the different plants in agricultural lands require different types of organochlorine to reduce the different types of pests [15].

According to Leong et. al. [16], there are some organochlorine pesticides such as lindane or dichlorodiphenyldichloroethylene (DDE) detected in Selangor River in 2002 and 2003. The detected concentration will be varying according to seasons and sampling sites. Some organochlorines can be detected during raining season while some can only be detected during dry season. Although the sampling sites are along the same river, different organochlorines concentration will be collected at different sites. Organochlorine pesticides, due to their persistence and bioaccumulative nature, pose significant environmental risks. These chemicals can biomagnify up the food chain, leading to reproductive failures in top predators like certain birds of prey, and disrupt aquatic ecosystems by harming fish populations and diversity. They also persist in soils, impacting soil health and terrestrial organisms, and pose direct health risks to humans through contaminated food and water, including cancer and neurological disorders. Addressing the widespread impact of these pollutants requires focused efforts on monitoring, remediation, and ecosystem restoration strategies [17].

4. Current Status of Pest Control in Malaysia

Due to the persistency of organochlorine in the environment, Malaysian government has banned the use of organochlorine pesticides. Although the organochlorine pesticides have been banned, the residues from the previous usage still exist in the natural environment. the residues take time to be totally degraded so it is important to restrict the new sources of organochlorine. As a result, replacements of organochlorine products have been introduced to reduce the pests. The organochlorine pesticides are initially been used to control the Aedes population before the use of organochlorine insecticides are banned. After the organochlorine has been banned, malathion or permethrin has been used to reduce the Aedes mosquitoes' population in Malaysia. The malathion or permethrin will be released through fogging to disturb the life cycle of the Ae. Albopictus [18]. Both malathion and permethrin could change the development period at each state of Aedes albopictus' life cycle, which will lead to the increase in mortality. Besides, temephos, an effective larvicide, is used to kill the larva of Ae. aegypti. By killing the larva of the mosquitoes, the population of mosquitoes can be reduced as less larva can grow to adult mosquitoes. As a result, the risk of people suffering Dengue Aedes can be reduced.

Apart from chemicals used to control the population of Ae. aegypti, there is another technology called self-limiting technology by releasing population of genetic modified mosquitoes into the environment to control the original population in the environment. The breeding between genetically modified species with original species will result in the increment of mortality rate to the offspring [19]. In 2009, Ae. aegypti OX513A population is released into the environment and successfully reduce the population growth of original Ae. aegypti population up to 90 % [19]. Organophosphate pesticides are introduced and replaced the use of organochlorine pesticides in controlling the pests' population. The organophosphate pesticides have shorter persistency period in the environment than the organochlorine pesticides [20], causing less damage towards the environment. As a result, the organophosphate pesticides are being the trend of pesticides choice in agriculture. The examples of organophosphate pesticides are listed in Table 2.

Table 2. Types of organophosphate pesticides.

Types of organophosphate pesticides	References
Chlorpyrifos	
Diazinon	
Dimethoate	
Malathion	[21]
Fenitrothion	
Methidathion	
Pirimiphosmethyl	
Tolchlofosmethyl	

Due to environmental concern, vegetable productions in Cameron Highlands have implemented other ways such as integrated pest management (IPM) and biological control [22]. Although some of the farmers do not join IPM program, the farmers still apply IPM by rotating the types of crops planted as shown in Figure 2. The crop rotation reduces the number of same pests in the farm as not all pests will feed on the same crops, and thus reduces the volume of pesticides applied in the farm [22]. By applying IPM, the farmers can reduce the pesticides used in the farm, causing less pollution towards the environment.

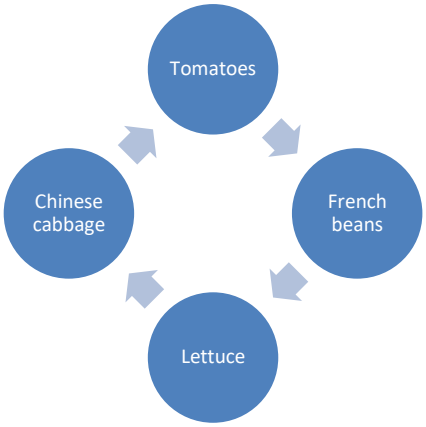

Figure 2. Examples of crops rotation [22].

5. Challenges

Although the organophosphate pesticide is used to replace the persistent organochlorine pesticide, the organophosphate pesticides will raise some problems before the organophosphate pesticides are totally degraded in the environment. The organophosphate pesticides are toxic to gene especially for children. This is because the organophosphate pesticides may cause cholinesterase, promoting the growth of cancer cells when the damaged cells are not repaired [23]. This will increase the mortality risk of children, so it is encouraged to avoid children from being exposed to the places which have just been applied the organophosphate. Although the organophosphate pesticides such as Tricel 21.2 EC, and other insecticides such as Diflubenzuron 25%, are effective in prolonging the life cycle of insects by increasing the eggs hatchling time and growth period, the expenses for purchasing these environmental friendly pesticides are not affordable by all farmers [24]. Consequently, the farmers will look for alternatives which are cheaper and efficient but not necessarily safe to both environment and human health.

Due to less farmers receive the formal education from Department of Agriculture, the farmers apply the crop rotation without having the proper knowledge on plants selecting. For example, there are farmers who select the plants, which all belong to the feed of same pests, P. xylostella [22]. As a result, the pest population will increase although the plant species is changed from time to time. In order to protect the crops against pests, the farmers will use more pesticides or stronger pesticides to reduce the pests, causing more environmental pollution. There will be more residues on the vegetables when more pesticides are used, increasing the risk on human health.The challenges of organochlorine pollution span health risks, economic burdens, educational gaps, and environmental damage, presenting a multifaceted problem. Addressing these requires comprehensive strategies, including enhanced health monitoring for early detection of pollution-related diseases, investment in cost-effective and sustainable remediation technologies, community education programs to raise awareness and promote safer alternatives, and stronger environmental policies to prevent new contamination while rehabilitating affected ecosystems. Together, these approaches can mitigate the adverse effects of organochlorines, safeguarding public health and environmental integrity [25].

6. Organochlorine on Human Health Impact

Organochlorine residues in the environment will be ingested by human through contaminated food intake and even water consumption [25]. The organochlorine will negatively impact the human health, causing an individual to suffer diseases when the accumulation of organochlorine in the body exceeds certain amount. The organochlorine is endocrinal disruptor for human. The organochlorine in the body will disrupt the hormones secretion in the human, which is very dangerous. The hormones in human body is very important to maintain the human health. Without proper hormones secretion, an individual could suffer endocrinal diseases or some abnormality to the physiology. According to Toft and Thulstrup [25], there are some females, who are exposed to DDEs and PCB, have higher chance of getting irregular menstrual cycle. This is because hormones are responsible in controlling the menstrual cycle. When the hormones secretion in the body are disrupted, the menstrual cycle will be affected. Apart from menstrual cycle, there are studies state that the increased amount of DDE and DDT concentrations in women will reduce the amount of pregnandiol-3-glucorinide in the women's body [25]. The pregnandiol-3-glucorinide, which is metabolized from progesterone, is a type of hormones required for reproduction for human. The organochlorines especially HCB and DDT might increase the amount of estradiol in males when the HCB and DDT concentration in the male's body is increased, but the mechanism which results in this hormone alteration is still unknown. Araki et al. [26] states that the increment of p,p'-DDE and o,p'-DDT concentration will result in the reduction of the prolactin hormones in cord blood for male foetus, increasing the risk of male offspring suffering the respiratory distress syndrome.

The organochlorine in the human body will result in the growth of cancer cells in human body. The late recovery of damaged cells due to the organochlorine in the body will promote the growth of cancer cells. The increasing risk in the growth of cancer cells will increase the mortality rate of human, causing human population reduction. If the concentration of organochlorine achieves high level in the body of individual, there will be an imbalance between antioxidants and free radicals in the body, causing damage to the cells and might lead to colorectal cancer to the individual [27]. Arrebola et al. [28] states that beta-HCH has high risk contributing to breast cancer. The xenoestrogens in the complex organochlorine mixtures will increase the generation of MCF-7 cells, and the antiandrogenic properties of p,p'-DDE has increased the generation of CAMA-1 cells when the sex steroids are existing [29]. Both MCF-7 and CAMA-1 are cell line for breast cancer, so the increment in the amount of MCF-7 and CMAM-1 will increase the risk of getting breast cancer [29]. The increase in risk of breast cancer will result in the increase in mortality rate of female, causing the reduction in women population. This will further lead to reduction of birth rate. [12] states that the presence of organochlorine pesticides in the body will disturb the mitosis process of cells, promoting the growth of cancer cells such as. There is report stating that Indian population with epithelial ovarian cancer will have high organochlorine concentration in the body [12]. This shows that the organochlorine might be the cause of epithelial ovarian cancer.

The organochlorine can cause immunotoxicity which will disturb the normal functionality of human immune system if an individual accidentally ingests the organochlorine contaminated food. Distortion of immune system will cause an individual to be more easily infected by the virus or bacteria, increasing the risk of death. For example, the heptachlor, which is one of the organochlorines, will increase the survival chance of K562 tumor cells by reducing the ability of immune system to trap and kill the tumor cells [30]. This will increase

the risk of the individual to get a tumor as the growth of tumor cells are hard to be controlled by the immune system. Some reports state that the DDE will alter the secretion of immunoglobulin, especially Immunoglobulin A and Immunoglobulin G, which might lead to disruption of immunity for the affected individual as the immunoglobulin is important to in removing the pathogens which enter the body [30]. Rivero et al. [31] states that PCB and 2,3,7,8-tetrachlorodibenzo-p-dioxin, which are also the organochlorines, have the potential on affecting the immune system. The pentachlorophenol will reduce the functionality of Natural Killer cells in the human body [30], showing that some organochlorines are cytotoxic which might lead to cells malfunction. When the immune cells cannot function well, the immunity of an individual will be reduced, and the individual will have higher chance to suffer diseases than normal people.

The organochlorines are dangerous towards pregnant women as the organochlorines might affect the fetus during pregnancy if the pregnant women are affected by the organochlorines. The pregnant mothers who are infected by organochlorines will increase the risk of spontaneous abortions [32]. There is a study states that about 6.85 % of women who are accidentally exposed to organochlorines suffer spontaneous abortions in India although only 336 cases are included [25]. The minimum amount of organochlorines detected is 226 ng/g or lipid in the affected women who have suffer spontaneous abortions [25]. Besides, the affected mothers have higher risk of giving birth with low weight or even preterm birth, causing increment on newborn mortality. According to Toft et al. [25], when the pregnant mothers have more than 60 ng/g of lipid of organochlorines in the body, the baby born will have less 150g of weight, and be born one week earlier than that by mothers who are exposed less than 15 ng/g of lipid of organochlorines. Besides, the organochlorines will affect the development of fetus before born, causing the physical changes to the baby born. When the pregnant mothers are exposed to high concentration of organochlorines, there will be higher risk of fetus development disruption, causing malformation of physical features such as hyperpigmentation and neonatal teeth [25]. If the malformation affects the reproductive system of the newborn, the reproductive system of the newborn will be negatively affected. The children are the future manpower for a country. If the children are born unhealthy or with some disability, the country may lack of manpower in the future, slowing down the country development.

7. Environmental Consideration of Organochlorine

The organochlorines in the environment will not only affect the human but also the entire ecosystem including natural habitats, and animals. The organochlorines will degrade the natural habitat, causing the living organisms in the habitat to be affected by the organochlorines. The affected organisms' population will be decreased if the organisms are very sensitive to the organochlorines or have lower survivability. The organochlorines are dangerous in the environment as the organochlorines will undergo the bioaccumulation and biomagnification across the food chain as shown in Figure 3. The predators at higher trophic level will have higher concentration of organochlorines in the body through consumption of prey at lower trophic levels. Potapowicz et al. [33] states that seabirds which feed on fish have higher organochlorine pesticides concentrations in body than the fish. This shows that the organochlorine pesticides which are originally in the body of fish will be accumulated in the body of consumers which feed on the fish including predators and human. Ravindran et. al. [34] states that the earthworms, which are one of the food sources, will be contaminated by the

organochlorines residues in the soil, and when the birds consume the contaminated worms, the organochlorines will accumulate in the body of the birds. However, the birds will face severer problems than mankind when the organochlorine concentration in the body is high. The birds metabolize the organochlorine pesticides accumulated in the body at a lower efficiency, causing reduction of resistance towards the organochlorine pesticides [33]. As a result of low ability of detoxification for birds, the organochlorine pesticides accumulated in the bird's body will increase gradually, causing health effect towards the birds.

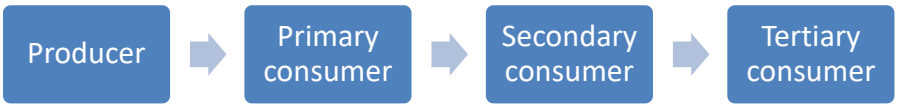

Figure 3. Food chain.

The organochlorines are immunotoxins to animals in which the secretion of immune cells will be disturbed. According to Sawyna et al. [35], the high level of organochlorine pesticides in the Atlantic stingray will promote the secretion of white blood cells. This shows that the organochlorine pesticides will alter the immune system in the stingrays and might lead to a challenge to the immune system for the stingrays. The organochlorine will affect the endocrinal system for the animals by changing the hormones secretion, raising problems to the animals in the life cycle. The organochlorine pesticides can change the sex characteristics of some animals, causing the alteration of sex ratio to the populations [36]. The imbalance sex ratio in the populations might reduce the population size in the future as either male or female population will exceed the other, causing the population with smaller number becomes the limiting factor for mating. The endocrinal disrupting property of organochlorine might cause a change to the genetics of the species due to the change in hormone and enzyme secretion [36]. This will then lead to an increment of extinction risk of the affected population. As a result, there will be more species facing extinction problems and ecosystem will be further disrupted when the affected species are the keystone species in the ecosystem.

The organochlorine in the animals' body could lead to reproductive problems. According to Potapowicz et al. [33], the reproductive system of fish especially gonads will store the highest concentration of HCHs in the body, and the HCHs will migrate from the liver to the ovary of catfishes and carps when these fishes during reproduction. The PCBs and organochlorines in the tissues of Eurasian otter might disrupt the recovery of otter's population by affecting the reproduction. The reproduction disorders will increase the risk of abnormal development of the offspring, such as development of asymmetry wings in seabirds, causing increment in the survival difficulty [33]. Reducing in survivability will increase the risk of being preyed, causing the decrease in the population size. Apart from animals, the habitat could be degraded by the presence of organochlorines in the habitat. According to Blondel et al. [37], the presence of organochlorine pesticides in the soil has reduced the amount of $N\text{-}NH_4^+$, potential nitrogen mineralization, and microbial biomass, causing disruption towards the nitrogen cycle in the soil. This has caused a change to the soil environment, and the change may lead to the change of members in affected soil ecosystem. The change of $N\text{-}NH_4^+$ might affect the ammonifying bacteria through the metabolism or even the survival of the bacteria although the organochlorine pesticides will not affect other nitrogen forms in the soil [37]. The

change in the members of subterranean ecosystem will disrupt the subterranean ecosystem, leading to a change in ecosystem function.

8. Conclusions

The organochlorines are dangerous and destructive chemicals to the environment. The organochlorines can persist in the environment for long period due to the resistance against the microbial degradation. Although the use of organochlorines has been banned in many countries, the residues of organochlorines from the previous use are still affecting the environment negatively. The organochlorines will affect the human health when the organochlorines are accidentally ingested by consuming the contaminated food and water. It is important to study the distribution and concentration of the remaining organochlorines in the environment to ensure there will be no increment in the organochlorine concentration. The banning of organochlorine pesticides has led to the application of other pest control methods such as IPM, biological control, and other replacement chemicals such as organophosphate pesticides, which are more environmental friendly. However, the change in the pest control methods has raised some problems, including increment of financial problem of the farmers, the lack of proper knowledge of farmers regarding the new methods, and the negative impacts brought by the replacement chemicals on the human health. Overall, the organochlorines pollution in Malaysia is reduced after the ban of the use of organochlorines. Future research should focus on innovative and sustainable methods for the detection, removal, and management of organochlorine pollutants to mitigate their long-term effects on ecosystems and human populations. By doing so, we can work towards a cleaner, healthier environment for future generations.

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Competing Interest

All authors have no competing interest to declare.

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