IJEBAS
International Journal of Economic, Business, Accounting, Agriculture Management and Sharia Administration

DDT IN THE ENVIRONMENT: SOURCES, POLLUTION PREVENTION STRATEGIES AND HUMAN HEALTH IMPLICATIONS: A COMPREHENSIVE REVIEW

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Abstract

This review addresses the environmental impact of dichlorodiphenyltrichloroethane (DDT), with an emphasis on its origin, monitoring techniques, pollution tactics, and human health consequences. DDT, a persistent organic pollutant, has been extensively used in agriculture and public health, resulting in its broad dispersion in numerous environments. This study examined the basic causes of DDT pollution, including historical use, agricultural runoff, and incorrect disposal procedures. Furthermore, this study investigated solutions for reducing DDT contamination, including regulatory measures, alternative pest control tactics, and safe disposal procedures. The effects of DDT exposure on human health, including its association with cancer, reproductive abnormalities, and neurological damage, have also been investigated. Overall, this study emphasizes the significance of continued efforts to monitor and reduce DDT pollution in order to protect human health and the environment.

Keywords: ***DDT, Environment, Human Health, Contamination Sources, Pollution Prevention.***

1. INTRODUCTION

Dichlorodiphenyltrichloroethane (DDT) is a synthetic pesticide initially made in 1874 by Austrian scientist Othmar Zeidler, but its insecticidal effects were not identified until 1939 by Swiss chemist Paul Hermann Müller [1]. DDT has rapidly become one of the most commonly used pesticides worldwide because of its ability to eliminate a wide range of insect pests, including mosquitoes, flies, agricultural pests, and disease vectors such as malaria, typhus, and yellow fever [2]. It was commercially available in 1945. The introduction of such powerful and inexpensive pesticides has ushered in an agricultural revolution [3]. During World War II, DDT was critical in protecting military soldiers from insect-borne illnesses and became widely used for both military and civilian purposes. Following the war, DDT manufacturing and use increased dramatically for agricultural pest control and public health mosquito control initiatives, particularly in tropical and subtropical countries where insect-borne illnesses are common [2]. While most other major pesticide families that are still in use today were introduced during the postwar period, DDT remained the most widely used insecticide worldwide until the mid-1960s. It has been credited with several notable public health achievements, including malaria eradication in the United States and Europe [4].

The success of DDT can be attributed to its persistence in the environment, which reduces the need for repeated application. However, owing to its chemical stability and lipophilicity, DDT is being gradually removed by most living organisms [5]. This propensity is shared by the primary DDT metabolite 1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene (DDE). A vast variety of organisms, particularly marine filter feeders, can operate as bioconcentrators, producing amounts of DDT in their flesh that exceed ambient environmental concentrations. These characteristics lead to the buildup of DDT throughout the food chain, particularly in predatory species, at the apex of the ecological pyramid [6]. Humans are not immune to this tendency, as biological monitoring in the 1960s revealed rising DDT levels in the majority of human societies, mostly because of food residue exposure [7]. By the mid-1950s, animal studies demonstrated that DDT exposure may have negative consequences, particularly for reproductive success, and it became clear that this may extend to larger ecosystems.

In 1945, the British Medical Journal published a review of animal experiments that determined that there was no reason to predict hazards in humans [8]. In 1956, 51 volunteers from penal facilities received substantial doses of DDT daily for up to 18 months [9]. Extensive information on absorption and storage was obtained, and no volunteers reported any symptoms or signs of sickness based on the tests employed. According to [10], 59 highly exposed workers in the US chemical industry discovered significant levels of DDT in fat; while patients were not compared to a control group, 8.6% of the study group were diagnosed with diabetes. Other early investigations indicated a relationship between organochlorine levels and cancer at autopsy, but they were questioned because the illness process may have changed DDT storage and mobilization [11]. During the mid-twentieth century, DDT was widely used in agriculture, public health, and home settings, causing massive environmental pollution and raising concerns regarding its influence on human health and the environment. Rachel Carson's landmark book enhanced public awareness of the environmental and health concerns linked with DDT and other pesticides, prompting increasing investigation and regulatory action [12].

In response to mounting concerns, several nations have begun to limit or prohibit the use of DDT for agricultural and public health control of mosquitoes. In 1972, the Environmental Protection Agency (EPA) prohibited most DDT applications in the United States [13]. Despite being banned in many countries, DDT is used in select locations for malaria control, particularly in areas where mosquito resistance to alternative pesticides is a concern [14]. However, attempts are underway to develop more environment-friendly malaria management measures. DDT is still prevalent in environments in which exposure is inevitable. While exposure in the developed world has drastically decreased, it remains significant in certain poor nations where DDT is still used for both agricultural and hygiene purposes [15]. This study examined the origin of this pesticide and its effects on the environment and human health. The current monitoring and pollution prevention plans for DDT should be evaluated to a certain extent.

1. Sources of DDT in the Environment

DDT can enter the environment in a variety of ways. First, pesticide firms may produce DDT. In 1996, DDT concentrations in breast milk and the environment were tested in Kafr El-Zayat (one of the largest pesticide manufacturers in Egypt). The results revealed a high amount of DDT in animal food, vegetables, fruits, soil, and water (including groundwater, Nile River, and tap water) [16]. Second, the extensive use of insecticides in agriculture and industry has resulted in DDT pollution of the environment [17]. In the Ebro River basin of Spain, where pesticides have been widely used in agriculture, soil tests have revealed a high incidence of 4,4-DDT and 4,4-DDE [18]. In 2006, the WHO and US Agency for International Development approved indoor DDT spraying to control malaria [19]. The WHO recommends DDT as one of the 12 pesticides used for indoor residual spraying (IRS). DDT is regarded as an effective malaria control method for IRS [20]. Nonetheless, spraying DDT to prevent malaria causes the agent to accumulate in animals via food chains and in the tissues of exposed creatures, as well as in people of sprayed homes [21].

2. Effects of DDT on the Human Health and Environment

DDT exposure has been linked to several detrimental health impacts, as follows:

3.1 Cancer Risks

The International Agency for Research on Cancer (IARC) has classified DDT as a probable human carcinogen. Prolonged DDT exposure has been associated with an increased incidence of some cancers such as breast, liver, and pancreatic cancers.

3.2 Hormonally Sensitive Cancers

DDT is associated with an increased risk of breast cancer. Exposure to DDT and its breakdown product, dichlorodiphenyldichloroethylene (DDE), has been associated with hormonal changes and disturbances in endocrine function, both of which are established risk factors for breast cancer [22]. DDT is classified as an endocrine disruptor, which means that it can disrupt hormonal balance in the body and contribute to the development of hormone-related malignancies, such as breast cancer. A longitudinal study conducted in California discovered that women with higher levels of DDT and DDE in their blood serum had an increased chance of developing breast cancer later in life [22]. Furthermore, a meta-analysis of epidemiological studies found that exposure to DDT/DDE was associated with a moderately elevated risk of breast cancer, particularly in postmenopausal women [23]. DDT and DDE can be built into adipose tissue and remain in the body for years, potentially causing long-term effects on breast tissue [24]. Animal studies have also demonstrated DDT's carcinogenic potential of DDT in mammary gland tissue [25].

3.3 Liver Cancer

In comparison to other forms of cancer, there has been less research on the relationship between DDT exposure and liver cancer. However, several studies have shown that DDT exposure may increase the incidence of liver cancer. Animal studies have indicated the carcinogenic potential of DDT in the liver tissue. Long-term DDT exposure in animal models has been found to cause liver cancer, notably hepatocellular carcinoma (HCC), via oxidative stress, inflammation, and alteration of liver function [26]. Although there have been few epidemiological studies on the link between DDT exposure and liver cancer in humans, some have found favorable relationships. For example, a case-control study conducted in California discovered a suggestive positive connection between DDT exposure and liver cancer risk, particularly among people with significant occupational DDT exposure [27]. DDT is an endocrine disruptor, and its metabolites have been found to exhibit estrogenic characteristics. Endocrine dysfunction and hormonal imbalances have been linked to the development of liver cancer [28]. While the data linking DDT exposure to liver cancer risk remain ambiguous, and more studies are needed to establish a definitive causal association, the possible carcinogenic effects of DDT on liver tissue require additional examination.

3.4 Pancreatic Cancer

Research on the link between DDT exposure and pancreatic cancer is similar limited when compared to that on other forms of cancer. However, some studies have revealed a relationship between DDT exposure and the risk of pancreatic cancer. A study conducted in Shanghai, China, discovered a link between DDT exposure and pancreatic cancer mortality among female textile workers who had been exposed to high amounts of DDT at work [29]. Another study, discovered a possible positive connection between DDT exposure and pancreatic cancer mortality among pesticide applicators [30]. DDT is a persistent organic contaminant that may accumulate in adipose tissue and persist in the body for years. It has been identified as a possible endocrine disruptor and its metabolites have been found to exhibit estrogenic characteristics [24]. Disruption of endocrine function and hormonal changes have been linked to pancreatic cancer [31]. While the data linking DDT exposure to pancreatic cancer risk remains ambiguous, and more studies are needed to establish a definitive causal association, DDT's possible carcinogenic effects of DDT on pancreatic tissue require additional examination.

3.5 Reproductive Disorders and Abnormalities

1. Male Reproductive Effects: DDT exposure is associated with poor male reproductive health, including lower sperm quality, motility, and hormone levels. Several studies have found links between DDT exposure and male infertility, as well as an increased incidence of reproductive abnormalities such as cryptorchidism and hypospadias in male children [32, 33].

2. Female reproductive effects: Exposure to DDT has been linked to female reproductive problems and abnormalities. Animal studies have revealed that DDT exposure can affect ovarian function, resulting in altered estrous cycle, lower fertility, and poor embryo implantation. In humans, DDT exposure has been linked to monthly irregularities, early menopause, and an increased risk of gynecological diseases, such as endometriosis and polycystic ovary syndrome (PCOS) [34,35].

3.6 Developmental Effects

Exposure to DDT during crucial fetal development or early childhood may increase the risk of late-life reproductive abnormalities and developmental problems. Animal studies have shown that prenatal DDT exposure can cause abnormalities in reproductive organ development and function as well as changes in sexual behavior and reproductive performance in adulthood [36,37].

3.7 Neurological Effects

DDT has been linked to a number of neurological consequences, including developmental neurotoxicity [38-40], cognitive impairment [41-43], and increased risk of neurological illnesses [44].

3.8 Bone Mineral Density

Limited evidence has revealed that DDT exposure may affect bone mineral density, potentially leading to bone health concerns. This concern is supported by animal research and epidemiological studies [45, 46].

3.9 Endocrine Disruption

Exposure to DDT impairs endocrine function and affects hormone regulation and signaling. According to previous studies, DDT is an endocrine disruptive chemical [24, 34], which may contribute to a variety of health problems through hormonal disruptions. Its capacity to imitate or disrupt natural hormones may have negative effects on reproductive, developmental, and metabolic processes, raising concerns about its environmental and public health implications that require additional exploration.

3.10 Respiratory Effects

DDT may irritate the respiratory tract and cause symptoms such as coughing, wheezing, and chest discomfort. People with pre-existing respiratory disorders may be particularly vulnerable to DDT [47]. While the data linking DDT to particular respiratory outcomes are weak, investigations have found respiratory effects linked with exposure to comparable pesticides [48].

3. Current Techniques for Monitoring and Assessing DDT Levels in The Environment

Gas chromatography-mass spectrometry (GC-MS) and high-performance liquid chromatography (HPLC) are now used to monitor and analyze DDT levels in the environment in combination with various detection methods [49,50]. These approaches enable the exact measurement of DDT residues in the air, water, soil, and biological samples. Furthermore, immunoassay-based approaches, such as enzyme-linked immunosorbent assay (ELISA), provide quick screening results [51]. Advanced technologies such as passive air samplers and biomonitoring using biological markers offer complementary techniques for measuring long-term exposure patterns [52]. Continuous monitoring networks and multinational alliances have improved the worldwide surveillance efforts for DDT pollution.

4. Strategy to Avoid DDT-Related Environmental Pollution

Strategies to reduce DDT-related environmental contamination include regulatory measures, alternative pest management methods, remediation techniques, and public awareness campaigns. Regulations prohibiting or regulating the use of DDT have been established worldwide [53]. Integrated pest management (IPM) techniques encourage the adoption of non-chemical alternatives and minimize pesticide consumption [54]. Phytoremediation and bioremediation are environmentally acceptable strategies for removing DDT from polluted locations [55]. Furthermore, public education campaigns raise knowledge about the dangers of DDT and promote environmentally friendly methods for reducing exposure [56]. Collaboration among governments, companies, and communities is critical for successful DDT contamination prevention and control.

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5. DISCUSSION

The influence of DDT on human health is a major issue owing to its extensive usage and persistence in the environment. DDT, a known endocrine disruptive chemical, has been associated with a variety of negative health effects owing to its interference with hormone transmission and control [24]. Studies have frequently found links between DDT exposure and reproductive diseases such as lower fertility, poor pregnancy outcomes, and developmental abnormalities [39, 57]. Furthermore, DDT exposure has been linked to metabolic abnormalities, such as insulin resistance and obesity, both of which are risk factors for chronic illnesses, including diabetes and cardiovascular disease [24]. DDT exposure has also been linked to respiratory consequences, with studies finding respiratory tract irritation and worsening pre-existing illnesses [47, 48]. Furthermore, DDT exposure has been associated with neurodevelopmental abnormalities in children, raising concerns about its effects on cognitive function and behavior [39].To reduce health concerns associated with DDT exposure, comprehensive pollution prevention techniques are required. Regulations such as bans and limitations on DDT usage are critical for reducing environmental pollution [53]. Alternative pest control strategies, such as integrated pest management (IPM), encourage sustainable farming practices while lowering the need for chemical pesticides [54]. Research demonstrates that DDT exposure has serious consequences for human health, including reproductive, metabolic, respiratory, and neurodevelopmental impacts. Efforts to recognize and reduce these dangers through regulatory measures and alternative pest management methods are critical for preserving public health and the environment.

6. CONCLUSION

According to this study, DDT is the most widely used and efficient pesticide for assisting people in resisting undesired species and producing major agricultural advances. The extensive use and manufacturing of DDT after World War II was the principal source of DDT in the environment. However, because several detrimental repercussions of this pesticide have been revealed, DDT usage has been banned globally. Despite rigorous regulations, DDT is still illegally used in many nations, particularly in poor ones. The harmful effects of DDT on the environment and human health have been identified and have been widely reported to warn communities and avert unintended outcomes. Despite being phased out, DDT continues to have an impact on the environment and human health owing to its long-lasting residual effectiveness and accumulation in the food chain. DDT has numerous detrimental effects on wildlife, including thicker eggshells in herring gulls, peregrines, falcons, and hawks; increased levels of endocrine-disrupting chemicals in the tissue of alligators; disease syndrome in grey and ringed seals in the Baltic, which leads to a decline in seal populations; and DDT is a neurodevelopmental toxin, as evidenced by numerous behavioral and neurochemical changes in adult mice exposed to DDT during the prenatal and neonatal periods.

Several efforts have been made worldwide to monitor DDT, including the use of chemical and physicochemical indicators, biomarkers, gas chromatography-electron capture detectors, gas chromatography-mass spectrometry, education and propaganda, legislation and policy instruments, national management plans, and encouraging other effective insect control measures in agriculture. Nonetheless, decreasing the negative consequences of DDT remains a continuing concern for scientists and environmentalists, as well as for people who are at risk of exposure to chlorine compounds. This paper does not provide a full update on all incidences of DDT effects on the environment and people across the world, nor does it provide the best approaches for dealing with DDT residues in soil and water (including groundwater) environments that are currently in use worldwide. Therefore, future studies should focus on measures to limit the consumption and deleterious repercussions of DDT residues, particularly in the impoverished and growing nations of Asia and Africa.

7. RECOMMENDATIONS

Based on these findings, various suggestions can be made to alleviate the health hazards associated with DDT exposure.

- Contract Regulatory Measures: Governments should impose and tighten rules governing the manufacture, use, and disposal of DDT and other persistent organic pollutants. This involves adopting and abiding by international treaties, such as the Stockholm Convention on Persistent Organic Pollutants.
- Promote Alternative Pest Control Methods: Encourage the use of integrated pest management (IPM) techniques that prioritize non-chemical, environmentally friendly pest control methods. This might involve biological control, crop rotation, and habitat alteration to lessen dependency on chemical pesticides.
- Improve Monitoring and Surveillance: Strengthen monitoring procedures for DDT levels in environmental media and human populations. This involves the development of sensitive and cost-effective analytical techniques for identifying DDT residues and biomarkers associated with exposure.
- Educate and Raise knowledge: Launch public education programs to raise knowledge of the health dangers connected with DDT exposure as well as the need for pollution reduction. Targeted outreach should involve communities, healthcare providers, lawmakers and other stakeholders.
- Encourage Research and Innovation: Invest in research to better understand the causes of DDT toxicity and to develop effective techniques for minimizing its health impacts. This involves investigating the long-term health effects of DDT exposure and developing innovative clean-up approaches for polluted settings.
- Promote International Collaboration: Encourage collaboration among governments, organizations, and researchers to exchange information, resources, and best practices for tackling DDT contamination and its health consequences worldwide.

Implementing these suggestions allows politicians, public health professionals, and communities to collaborate to reduce DDT exposure and safeguard human health and the environment from the harmful effects of this persistent organic pollutant.

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