An Overview Of Endosulfan And The Aftermath Of Its Biohazardous Administration In Southern India

Alan James[1], Denny Emmanuel[2]

[1,2] Department of Regulatory Affairs and Toxicology, University College Dublin, Belfield, Dublin 4, Ireland- D04V1W8

E-mail- [1]alan.james@ucdconnect.ie

Abstract: Endosulfan- one of the popular organochlorine insecticides was launched into the agricultural sector in the 1950s as a part of Green Revolution. Endosulfan was relatively inexpensive but offered high efficacy and stability that led to its extensive use as an agricultural pesticide in the global market for more than 30 years despite being labelled as a restricted Organochlorines (OC)-class agent. However, several cases of endosulfan poisonings started emerging periodically from many parts of the world. The most infamous chapter of endosulfan disaster is arguably the one that happened in Kerala- India over a span of 25 years. The aim of this article is to provide an in-depth overview of the tragic event and its outcomes, that contributed to a global ban recommendation of the dangerous pesticide.

Keywords: Endosulfan, Organochlorines (OC), Persistent Organic Pollutant (POP), Plantation Corporation Kerala (PCK), ban.

1. ENDOSULFAN OVERVIEW

Endosulfan (IUPAC Name: 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide, CAS Registry Number 6994-04-3) is a polychlorinated compound (as shown in Figure 1) with a solid crystalline or flake appearance and cream to brown colour. It has a distinct odour resembling that of Turpentine and has non-flammable nature. It has a melting point of 106 ºC and water solubility of 0.325 mg/L.
Diels-Alder reaction of hexachlorocyclopentadiene with cis-butene-1,4-diol forms endosulfan, which liberates HCl upon reaction with thionyl chloride and produces a mixture of approximately 70% of α-endosulfan and 30% of β-endosulfan. The technical grade endosulfan is thus a diastereomeric mixture of α and β isomers (not less than 94%) illustrated in Figure 2, along with impurities and degradations products.[1]

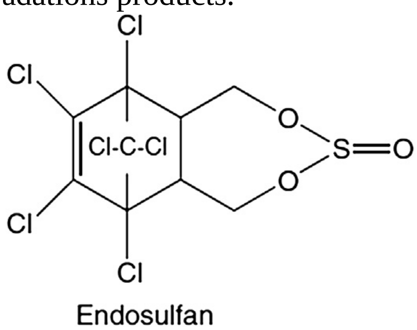

Figure 1. Chemical structure of endosulfan

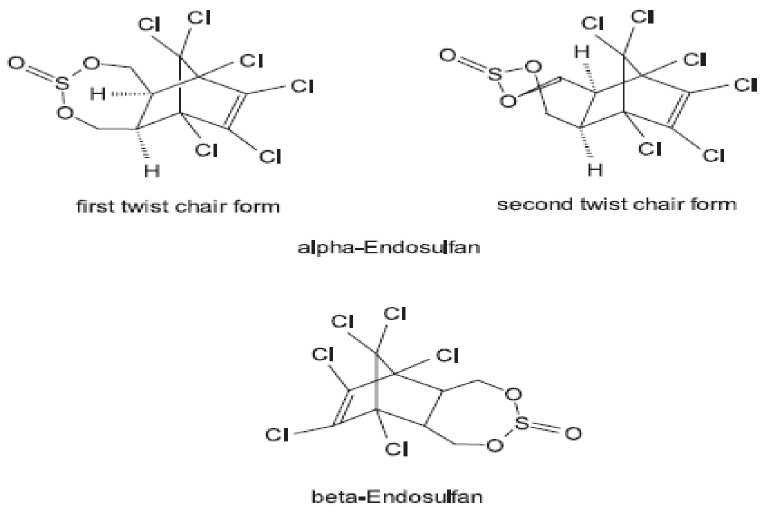

Figure 2. Chemical structure of two asymmetric isomers of α-endosulfan and the symmetrical β-endosulfan

Endosulfan was invented in 1954 by Farbwerke Hoechst (Germany) and has been used worldwide under several market names, mainly Thiodan. There are various types of Endosulfan formulations such as emulsifiable concentrate, wettable powder, smoke tablets and ultra-low volume liquid products. The pesticide is usually applied on crops using air-blast or ground boom sprayers in temperate areas.[2] Among its diverse applications, endosulfan is well regarded for the control of tsetse fly on agricultural products including tea, coffee, cotton, fruits, vegetables, grains and tobacco in tropical countries and as an effective wood treatment agent.[3,4] According to a report in 2005, around 12,800 tonnes of endosulfan was estimated as the global production volume per annum.[5] India was regarded as the largest producer with 5400 tonnes/year and assumed to have utilized approximately 113,000 tonnes over a period of 1958-2000.[6] United States, being the first-ever user of endosulfan, was considered to have used nearly 26000 tonnes till the year 2000.[5] Annual use of endosulfan in China was estimated as 2800 tonnes during the years 1998-2004.[7] The aggregate global use of endosulfan is summed up to be at least 308,000 tonnes over the first 50 years since its launch.[5]

The aggressive and persistent use of endosulfan has resulted in enormous cases of intentional and unintentional poisonings due to ingestion, inhalation or percutaneous exposure. All these events have revealed the immense toxic potential possessed by the agrochemical, owing to the significant morbidity and mortality rates observed in the poisoning incidents.[8-14]

The principal toxic effect of endosulfan is Neurotoxicity (CNS hyperstimulation) characterized by seizures.[11,15] Its potent neurotoxicity is attributed to Chloride-channel antagonism as well as inhibition of Calcium and Magnesium ATPase enzymes involved in the transmission of nerve impulses. Endosulfan also exhibits estrogenic agonism and anti-androgen nature.[16,17] Patients usually exhibit hepatic, renal and cardiac toxicities up on endosulfan intoxication and severe poisonings are characterized by complications such as kidney failure, nausea, vomiting, rhabdomyolysis, hypotension, confusion, tremors and coma.[11,15] Death due to respiratory failure and biochemical instability as a consequence of uncontrolled seizure activity is usually observed within 4 to 8 hours post exposure.[15]

Early and aggressive symptomatic treatment is crucial since there is no specific antidote for endosulfan intoxication.[11] Symptomatic treatment often includes gastric lavage and limiting the aspiration of pesticide into lungs, followed by intragastric administration of 30% v/v magnesium or sodium sulphate containing activated charcoal. Benzodiazepines are preferred for treating convulsions while topical exposure of endosulfan requires cleansing with soap water.[1]

Animal studies have revealed that Endosulfan is capable of exerting toxic effects such as piloerection, hyperactivity, respiratory distress, convulsions, hepatotoxicity, renal failure and death.[18] Endosulfan is categorized as a Persistent Organic Pollutant because of its reluctance to degrade or eliminate from the environment.[15] Endosulfan is capable of accumulating in the cells of phytoplankton, zooplankton, vegetables, marine animals and thus persist in the environment for several months to years.[19]

Ecotoxicological studies have also revealed the capability of endosulfan to undergo long-range transport to remote locations like the Arctic.[2] Degradation process of endosulfan isomers in temperate/tropical soil and water bodies can be biotic or abiotic, depending on the favourable environmental conditions.[15] Endosulfan upon oxidation forms endosulfan sulphate, which is more toxic than the former. Hydrolysis of endosulfan results in the formation of endosulfan diol, which may further get converted into the less toxic metabolites like endosulfan ether, endosulfan hydroxyl ether, endosulfan dialdehyde, and endosulfan lactone.[19]

2. BACKGROUND TO THE INCIDENT IN KERALA

The Endosulfan tragedy in Kerala is regarded as one of the worst pesticide disasters in history and is highly attributed to pesticide-dominated agriculture and green revolution technologies. The incident occurred in Kasaragod District where the deadly pesticide was aerially sprayed on cashew plantations for a period of 25 years (1975-2000). The aerial spraying method is assumed to be recommended for cost reduction as it was estimated that one day of aerial spraying is equivalent to saving 500 days of individual work. Aerial spraying was performed thrice a year for over two decades in approximately 4696 acres of cashew plantations in the district to eradicate the tea mosquito attacks on cashew blooms.[20,21,22] These plantations were located in hilly areas with several water bodies inside and outside that ran off into the valleys with human inhabitations. Although the presence of schools, houses and wells near to the areas of cashew plantations rendered it unsafe for aerial spraying, the Plantation Corporation of Kerala (PCK) relentlessly continued the use of endosulfan in vulnerable areas for decades and jeopardized the health and wellbeing of living organisms, especially humans.[22]

Routes Of Exposure

Residents in the affected areas were assumed to have either Dietary Exposure (by ingesting food sprayed with endosulfan or by drinking water contaminated with endosulfan), Occupational Exposure (via topical or inhalation routes during mixing, loading and/or applying endosulfan or by immediately re-entering the endosulfan-treated areas) or Accidental Exposure (via topical or inhalation routes due to proximity to endosulfan use).[23]

Impact On Human Health

The Endosulfan tragedy in Kerala resulted in the death of at least 4000 people and also induced chronic health ailments in more than 10,000 residents of the affected area.[20] Exposure to endosulfan through food, water, air or soil resulted in a high incidence of neurological complications as well as congenital and reproductive abnormalities among the affected people. Endocrine disruption reported in various studies revealed the potential health implications in future generations. People in the affected area also suffered from severe CNS disorders, blood and liver cancer, topical diseases, asthma, psychiatric disorders and suicidal tendencies, infertility and undescended testes among males, miscarriages and hormonal irregularities among females.[22]

Health Implications for Children

The worst affected group in the disaster were children and infants who had suffered from permanent disability and disfigurement. Most of them were having severely bruised thin legs and knees, large head with an extremely feeble body. The majority of the victims exhibited congenital anomalies, physical deformities, mental retardation, cerebral palsy, epilepsy and hydrocephalus as an aftermath of endosulfan exposure.[22] Study reports have also revealed that endosulfan exposure caused a significant delay in sexual maturity among boys.[1]

Occupational Toxicity

According to survey reports, the majority of the workers in the cashew plantations were not provided with proper safety precautions (chemical-resistant footwear, gloves, headgear and respirator) during preparation, mixing and application of pesticides. These workers were identified with skin diseases, enlargement of lymph nodes, chronic asthma and even death by cancer. The situation was agitated by the lack of regular medical check-ups and the unavailability of medical attention when prompted.[24]

Environmental Impact

Observational studies in the endosulfan-affected environmental areas in Kerala revealed that animals, birds and insects that were predominantly seen before the endosulfan revolution started gradually disappearing as a consequence of the insecticide spraying. These organisms include hog rats, squirrels, crows, butterflies, fishes, frogs and snakes. Besides, these areas also witnessed the absence of honeybees that were abundantly found in the past, thus negatively impacted the source of income of local farmers. Endosulfan spraying had cost the affected areas their faunal diversity over the years. Water and soil samples in and around the plantation area revealed the presence of endosulfan residues even after 10 years since aerial spraying was ceased, indicating the capability of endosulfan to persist for a considerable period in the environment and exert its toxic effects.[22]

Controversy

The extend of Endosulfan disaster in Kerala is strongly associated with absolute negligence of the National rules outlined in the Insecticides Act-1968, Insecticides Rules-1971, Water (Prevention and Control of Pollution) Act-1974 and the Environment (Protection) Act-1986. The Plantation Corporation of Kerala conducted aerial spraying on cashew plantations without abiding by the rules in place, which demands the use of approved pesticides according to the standard guidelines and aerial operations require to be notified to the public at least 24 hours prior to commencement for the sake of adopting precautionary measures. Also, all water bodies in and around the locality need to be covered to prevent exposure and contamination. The Insecticides Act and Rules also denies permission for the aerial spray of pesticide over an area abundant with water sources and human inhabitation. However, PCK was reluctant to consider any of these guidelines and continued to spray endosulfan aerially thrice a year for 25 years over an area consisting of 13 water streams and nearly 4 lakh residents.[22]

Moreover, PCK illegally continued the aerial spraying till 2001 after the Central Insecticide Board (CIB) imposed a ban in 1993. Despite early evidence of endosulfan toxicity in and around the plantation areas, PCK company denied the findings and continued promoting the use of endosulfan for several more years until there was a strict intervention from the government.[21]

Action Taken

Although several protests and movements were conducted in Kerala state against the use of endosulfan in the lights of its emerging toxic effects since the 1980s, the first legal initiative was witnessed in 1998 that led to a district-level ban of endosulfan in Kasaragod in 2001. The same year witnessed the government of Kerala suspending endosulfan use in response to strong public demands, which was the first instance of state-level action on pesticide regulation in the country, and hence the Pesticide Manufacturers and Formulators Association of India (PMFAI) immediately challenged the suspension.

However, Kerala High Court ordered a temporary ban on endosulfan use in the year 2005 against the interests of PMFAI. Later, the evidence of endosulfan residue in water samples observed during the temporary ban period in Kerala triggered the Supreme Court to impose a Nation-wide ban on the use, sale, manufacture and export of Endosulfan in May 2011. The victims of the dreadful incident have been entitled to a compensation of approximately 5 lakh INR each from the state government as directed by the Supreme Court order in 2017.[21]

Global Scenario

The aggressive and uncontrolled use of pesticides across the world has been common since the era of the green revolution and modern agricultural industry. Endosulfan use has been a controversial topic for decades due to its immense toxic effects on living beings and the environment. Although this insecticide has been proven to be an extremely effective pest control measure in the agriculture sector, many countries started imposing endosulfan gradually due to its persistent consequences.

Endosulfan is declared 'highly hazardous' by the United States Environmental Protection Agency (USEPA) and the European Union (EU), while the Industrial Toxicological Research Centre (ITRC) in India and the United Nations Environment Programme-Global Environment Facility (UNEP-GEF) categorized endosulfan as 'extremely hazardous'. According to reports in 2010, several countries like Australia, New Zealand, Singapore, Bangladesh, Brazil, Indonesia, Korea and Thailand had already banned endosulfan use because of its persistence in the environment in addition to the health implications in farmers and wildlife.[20] The Stockholm Committee for Persistent Organic Pollutants serves to identify and globally regulate organic compounds that are persistent, bioaccumulative, capable of long-distance transport and inducing adverse effects.[25] The Committee in 2009 inducted endosulfan into the list of POPs and later recommended for a global ban in 2011, which coincidentally happened in the same year when endosulfan was banned in India in the lights of Kerala tragedy.[20]

3. CONCLUSION

The infamous event of endosulfan in Kerala is the best example of the serious consequences associated with the long-term use of extremely potent chemicals. Endosulfan and similar chemicals tend to get promoted aggressively due to their high efficacy and low cost, however, these benefits are certainly outweighed by the associated risks in most instances. In addition to its wide range of acute toxic effects as well as reproductive and developmental damage on long-term exposure in humans and animals, endosulfan also possess a significant threat to the ecosystems due to its slow degradation rate, high environmental stability and long half-life.

Although endosulfan has been banned globally since 2011, illegal use of the same is still assumed to prevail in certain countries such as India and China. It is recommended to adopt advanced techniques and methodologies for assessing the effects of aggressive use of harmful pesticides on the ecosystems and is strongly advisable to promote eco-friendly alternative measures such as the use of bio-pesticides. The existing legislation and regulations on pesticide manufacture and use need to be intensified and updated promptly when required, to limit the hazardous outcomes. Also, it is important to enhance the awareness among farmers as well as the general public regarding the toxic outcomes of harmful pesticides so that their use can be minimized.

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