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Contamination Of Zimbabwean Seed Cotton With Endosulfan Pesticide Residues

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Abstract: Cotton production in Zimbabwe involves intensive use of synthetic chemicals such as endosulfan for the control of bollworms. The presence of endosulfan residues in seed cotton poses a threat to the health of humans who come in contact with fibres or cotton dust containing this chemical if it exceeds the recommended residue limits. This study set forth to determine the levels of endosulfan in seed cotton produced in four major cotton production areas in Zimbabwe. Soxhlet extraction was used for isolation of endosulfan from seed cotton samples and further sample clean-up was done using solid phase extraction (SPE). The analytical procedure was done using a gas chromatograph equipped with an electron capture detector (GC/ECD). The results showed that maximum concentrations of endosulfan in Gokwe North, Gokwe South, Sanyati and Chinhoyi were 3.11ppm, 0.85ppm, 1.2ppm and 0.1ppm respectively. The recommended limit for endosulfan in cotton fibres is 0.5ppm. Pesticide concentrations which exceeded the maximum recommended limits of 0.5ppm were linked to the pesticide application practices namely application rate, frequency of spraying, pre-harvest interval and the method of application.

Keywords: analysis, endosulfan, extraction, pesticide, residue, seed cotton

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I. INTRODUCTION

In Zimbabwe, cotton was referred to as 'white gold' in the past decade as it was one of the most economically viable crops in the country [1]. Cotton production has faced a lot of challenges in the country that include among others; drought, declining cotton prices, lack of funding for cotton farmers and side-marketing. Despite the challenges facing cotton production, cotton is still an important cash crop for many rural households in Zimbabwe and also of great importance to the country's economy [2]. There are 250,000 to 300,000 rural households in Zimbabwe whose livelihoods depend primarily on the growing and vending of cotton hence this crop plays an important role in poverty alleviation [3]. Despite the fact that cotton is a very important cash crop in the country, it is well known as the world's "dirtiest" crop as it uses approximately 16% of the world's insecticides, more than any other major crop [4]. During local cotton production, intensive application of pesticides is used to control the wide variety of pests which attack cotton, such as bollworms. Zimbabwe is among the 33 countries which responded to a survey by Environmental Justice Foundation (EJF) where it listed that its local cotton farmers used at least one hazardous pesticide (endosulfan) among the ten most commonly used ones [5]. Endosulfan is mainly used to control a variety of cotton pests such as heliothis and spiny bollworms, jassids, leaf eaters and lygus. The use of highly poisonous pesticides such as endosulfan has been banned in many countries in the world, mostly Commonwealth countries. However, most developing countries, including Zimbabwe, still use this hazardous pesticide during cotton production [6, 7]. At the Stockholm convention in 2011, a world ban of endosulfan was proposed and the ultimatum given was that this pesticide should be phased out by the year 2017 [8], however this chemical is still in use during local cotton production. The chemical structure of endosulfan is shown in Figure 1.

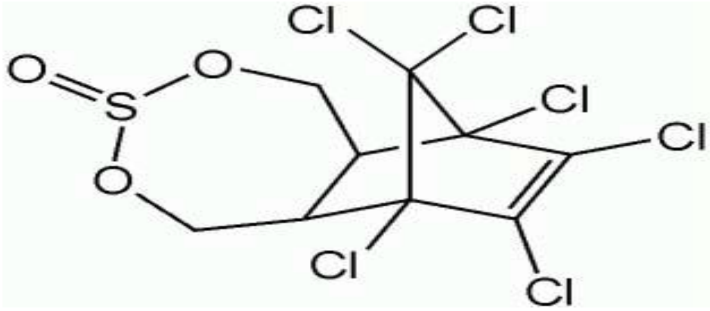

FIGURE 1.0 Chemical structure of endosulfan

Endosulfan is a persistent organic pollutant with severe effects on humans and the environment due to both acute and chronic exposure [9]. It is known to be an endocrine disrupting chemical and can cause adverse developmental and reproductive defects as it is readily absorbed by humans via the stomach, lungs and through the skin [10, 11]. Some farmers are not fully aware of the health risks resulting from exposure to endosulfan hence they wear little or no protective clothing during pesticide spraying, cotton picking and handling. In a study by Zvimba *et al* (2004), endosulfan was singled out as the major insecticide responsible for the majority of incidents of acute poisoning due to agrochemicals in Zimbabwe. Research indicates that persistent and hazardous pesticides that are applied during cotton production such as endosulfan are present in cotton fibres and clothing [12]; [13]. In 2004, a team of scientists analysed garments manufactured from cotton originating from Uzbekistan and United States of America (USA) and their research uncovered detectable traces of parathion and endosulfan as well as numerous persistent organic pollutants such as aldrin, endrin and dichlorodiphenyltrichloroethane (DDT) [5]. It was therefore of great importance to investigate the levels of contamination from endosulfan in locally produced cotton.

II. EXPERIMENTAL

Materials

Seed cotton was obtained from four major cotton production areas in Zimbabwe, namely Gokwe North, Gokwe South, Sanyati and Chinhoyi. Ten samples were collected from each of the four sampling areas. All the reagents used were of analytical reagent grade and used without further purification. Alpha endosulfan, beta endosulfan and endosulfan sulphate were pure standards of ≥98% purity, purchased from Sigma Aldrich Chemical Company, in Germany. All solvents and other chemicals used were of analytical grade. Anhydrous and granular sodium sulphate was used as a dehydration agent in all extraction procedures.

Sample preparation

The seed cotton samples were first air-dried and de-linted to obtain the cotton fibres for analysis. Samples were cleaned up from foreign contaminants and blended using a homogeniser to ensure uniformity during the extraction process.

Extraction

Cotton lint sample of 5g ± 0.01g was transferred into a sintered glass thimble. The soxhlet thimble was placed into the extraction apparatus which contained 150ml of n-hexane solvent and the extraction procedure was done for 6hours. Sodium sulphate was used for the removal of water.

Concentration

After the extraction was complete the samples were filtered then the solution was evaporated to dryness and reconstituted in 2ml of n-hexane.

Clean-up

Solid phase extraction was used for the clean-up step. A clean-up column was prepared with 10g of activated fluorisil in acetonitrile. Approximately 0.5g of sodium sulphate was used to top up the column. The samples were loaded into the column, eluted with 50ml n-hexane and collected in a 250ml flat bottomed flask. The cleaned up samples were then evaporated to dryness and further reconstituted in 1ml n-hexane and injected on GC/ECD.

Analysis

Perkin Elmer Clarus 500, with an auto sampler was used for the analysis of alpha endosulfan, beta endosulfan and endosulfan sulphate. Duplicate analysis was done for each of the analysis and the average quantities were determined. Injection mode was set to split less with a sample injection volume of 1µL. Inlet temperature was set at 260^{0}C while µECD detector temperature was set at 300^{0}C. Ultra High Purity Nitrogen was used as the carrier gas at a constant pressure of 10psi and flow rate of 1ml/min. Chromatography column used was Equity 1701 and the temperature gradient was as follows:

Initial: 60^{0}C (1min)
Ramp 1: 30^{0}C/min to 180^{0}C
Ramp 2: 5^{0}C/min to 250^{0}C (5min)
Ramp 3: 3^{0}C/min to 280^{0}C (10min)

III. RESULTS AND DISCUSSION

Endosulfan is an endocrine disrupting chemical and can cause adverse developmental and reproductive defects as it is readily absorbed by humans via the stomach, lungs and through the skin [10, 11]. Figures 2-5 show the concentrations of endosulfan in the four cotton production areas under study. According to the European Union Eco label for Textiles, the maximum residue limit (MRL) of endosulfan in seed cotton should be 0.5ppm.

FIGURE 2.0 Concentration of endosulfan in Gokwe North seed cotton
FIGURE 3.0 Concentration of endosulfan in Gokwe South seed cotton
FIGURE 4.0 Concentration of endosulfan in Sanyati seed cotton
FIGURE 5.0 Concentration of endosulfan in Chinhoyi seed cotton

95% of the cotton samples showed presence of endosulfan residues and 35% of these were above the recommended limit of 0.5ppm. The maximum concentrations of endosulfan in seed cotton for Gokwe North (Figure 2), Gokwe South (Figure 3), Sanyati (Figure 4) and Chinhoyi (Figure 5) were 3.11ppm, 0.85ppm, 1.2ppm and 0.1ppm respectively while the minimum concentrations were 0.12ppm, 0.03ppm, 0.03ppm and 0.04ppm respectively. All samples from the four sampling areas contained residues of endosulfan indicating the intensive use of this insecticide for the pest control particularly bollworms. 60% of samples for Gokwe North and 40% each for Gokwe South, Sanyati and Chinhoyi exceeded the maximum residue limit of 0.5ppm.

There was a higher mean concentration of endosulfan residues in seed cotton from Gokwe North, Gokwe South and Sanyati when compared to Chinhoyi. This can be attributed to the intensive pesticide use due to higher incidence of bollworms in these cotton production areas hence farmers tend to make intensive use of endosulfan so as to improve their yields. The other contributing factor may be that in Chinhoyi farmers follow Cotton Research Institute (CRI) recommendations during pesticide application whilst farmers in Gokwe North, Gokwe South and Sanyati do not follow recommended pesticide application practices. Concentrations of endosulfan lower than 0.5ppm may still be toxic and have damaging effects of human health and the environment.

Endosulfan has proven to be very effective in suppressing bollworm populations; however farmers do not follow recommendations when applying endosulfan to their cotton plants due to the perception that overdosing of chemicals may suppress pest incidences hence improving yields. Farmers may be exposed to endosulfan through inhalation of cotton dust and dermal contact during the picking and handling of seed cotton. Cotton bolls left in the fields usually become a source of stock feed for the farmers' livestock hence the bio-accumulation of endosulfan residues may occur in the fatty tissues of livestock. As endosulfan moves up the food web it bio-accumulates and this is a major cause for concern as meat and milk products from the farmers' livestock may contain traces of this toxic chemical [11]. Endosulfan has been linked to congenital physical disorders, mental disabilities and deaths in farm workers and communities across the globe. Symptoms of poisoning include headaches, dizziness, nausea, vomiting, mental confusion, convulsions, hyperactivity, seizures, coma and respiratory depression, in severe cases resulting in death [10].

There is some indication that endosulfan can have adverse effects on the immune system at low levels of exposure. There is mounting evidence that organochlorine compounds including endosulfan can act as hormones and may also be part of the cause for the disease in the quality of semen, an increase in testicular and prostate cancer, an increase in defects in male sex organs, and increase in incidence of breast cancer [11]. The continuous spraying of persistent insecticides like endosulfan leads to the accumulation of harmful pesticide residues in the seed cotton. The detection of endosulfan in seed cotton during harvesting may be attributed to the persistent nature of this organochlorine insecticide which has a half-life of 30-70days for the beta and alpha isomers in the environment [9, 11]. The half-life of total endosulfan (alpha- and beta- endosulfan and endosulfan sulphate) in the environment is 5-8months and the breakdown product, endosulfan sulphate is more persistent than the parent compound. The Environmental Protection Agency (EPA) classifies endosulfan as a highly toxic chemical under the category Toxicity Class I and it is a Restricted Use Pesticide, meaning that it should only be used by professional applicators hence the usage of the chemical by local cotton farmers is of great concern [14].

IV. CONCLUSION

The findings of this study are similar to those of El-Nagar *et al* (2012) who detected residues of a number of organochlorine insecticides residues in seed cotton samples during the harvesting season. The presence of endosulfan residues in cotton fibres is a serious concern as these residues may be present in further textile processing and products. Dermal contact with seed cotton and inhalation of the resultant cotton dust which contains endosulfan residues leads to aforementioned adverse health problems and damage to the environment.

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