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IMPACT AND AMELIORATION OF SEDIMENT AND AGRO-CHEMICAL POLLUTION IN CARIBBEAN COASTAL WATERS

Fate of agro-chemicals in the land water interface, with reference to St Lucia

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EXECUTIVE SUMMARY

- There have been few studies conducted on the impact of agro-chemicals in the St. Lucian environment. In particular, fertiliser studies are lacking.
- Existing studies have focused on the levels of pesticides in potable water, watercourses, the marine environment and aquatic organisms.
- There have been no studies on the bioaccumulation of pesticides and also less information on the fate and transportation of pesticides.
- The limited studies on the human health effects of pesticides have focused on occupational exposure to pesticides.
- Pesticide pollution is largely associated with the banana industry. Improper handling and storage, as well as, intense use of pesticides have contributed to pesticide pollution of the environment.

List of Acronyms

CCA	Caribbean Conservation Association
CEHI	Caribbean Environmental Health Institute
DDE	1,1'-(2,2,dichloro-ethenylidene)-bis(4-chlorobenzene)
DDT	1,1'- (2,2,2 trichloroethylidene)-bis (4-chlorobenzene)
DFID	Department for International Development
EC	European Community
KAPB	Knowledge, Attitude, Practices and Behaviour
LC_{50}	Lethal Concentration$_{50}$ (concentration of a material which will kill 50% of the test subjects when administered as a single exposure
LD_{50}	Lethal Dose$_{50}$ (amount of material which will kill 50% of test subjects in one dose)
MAFF	Ministry of Agriculture, Forestry and Fisheries
MRAG	Marine Resources Assessment Group Ltd
US	United States
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
WIBDECO	Windward Islands Banana Development Corporation

1 INTRODUCTION

Agro-chemicals are added to farming systems to improve production (Vienneau 1997). They include pesticides and fertilisers which “stimulate or regulate the growth of, or control pests of, agricultural, horticultural or plantation crops, and of domesticated livestock” (Hammerton and Reid 1985 cited in Vienneau 1997)

Pesticides can be further defined as “substances or mixture of substances intended for preventing, destroying, repelling or mitigating any pest” (Woudneh 1999), where a pest is “any plant or animal life including an organic function of a plant or any ecto/endo parasite of an animal that is objectionable because of its undesirable effect on plant life or on any movable property, or which is objectionable from a point of view of public health or hygiene” (St. Lucian Pesticides and Toxic Chemical Control Act 2001) . Pesticides can be classified by their chemical composition or by their target organisms. They include herbicides, fungicides, nematicides, rodenticides and insecticides. These may be organochlorines, carbamates, organophosphates or botanicals. DDT, dieldrin and endosulfan, are examples of organochlorines. Carbamates include aldicarb and carbofuran, while, malathion and parathion are both organophosphates. Botanicals such as pyrethrum are extracted from particular plant species (Vienneau 1997).

While pesticides are applied to control specific species, they may also affect non target organisms, altering their behaviour, physiological and reproductive systems (Vienneau 1997). The impact on the non-target organisms depends on the pesticide’s chemical properties such as its toxicity, solubility, mobility and persistence. The pesticide’s environmental impact is also dependent on the method, quantity and time of application, as well as, the nature of the surrounding environment. Weather conditions at the time of application are also a factor. The feeding habits and age of the non-target organisms are also relevant (Walker 1992).

Fertilisers are substances which are “applied to provide a source of nutrients for plant growth” (Allaby 1988). Fertilisers are linked to eutrophication and algal blooms in water bodies receiving agricultural runoff (Addiscott 1996). Algal blooms, in turn, lead to deoxygenation of the water bodies and reduced light penetration (Addiscott 1996). Fisheries resources and coral reefs may be affected.

Worldwide, there is increasing concern about the impact of agro-chemicals on the environment. Most of the studies conducted on the fate, transportation, bio-accumulation, breakdown, environmental and human health effects of agro-chemicals, have taken place in developed, temperate countries. There is less information on agro-chemicals in tropical regimes such as the Caribbean region. The current University of York/MRAG project (DFID Land Water Interface Project R7668) on the “Impact, Amelioration of Sediment and Agrochemical Pollution on Caribbean Coastal Waters” is one step towards addressing this information deficit. This literature review is one component of this larger project. In this document, studies conducted on the environmental impacts of agro-chemicals in St. Lucia are reviewed. Specifically, the literature review focuses on the impact of the agro-chemicals on the land-water interface and marine environment, looking at the fate of the chemicals, bio-accumulation, breakdown and transportation rates.

2 ST. LUCIA

2.1 Geography

St. Lucia's geographic co-ordinates are 13° 53' N, 60° 68' W. The island has a total land area of 620km^2, with approximately 158km of coastline (United States Central Intelligence Agency 2001). The island is largely mountainous. The highest peak is Mount Gimie, which rises to 950m above sea level (United States Central Intelligence Agency 2001, CCA 1991). Major river systems in St. Lucia include Roseau and Troumassee (Figure 2.1). Bays include Choc, Cul-de-Sac and Marigot (Figure 2.2).

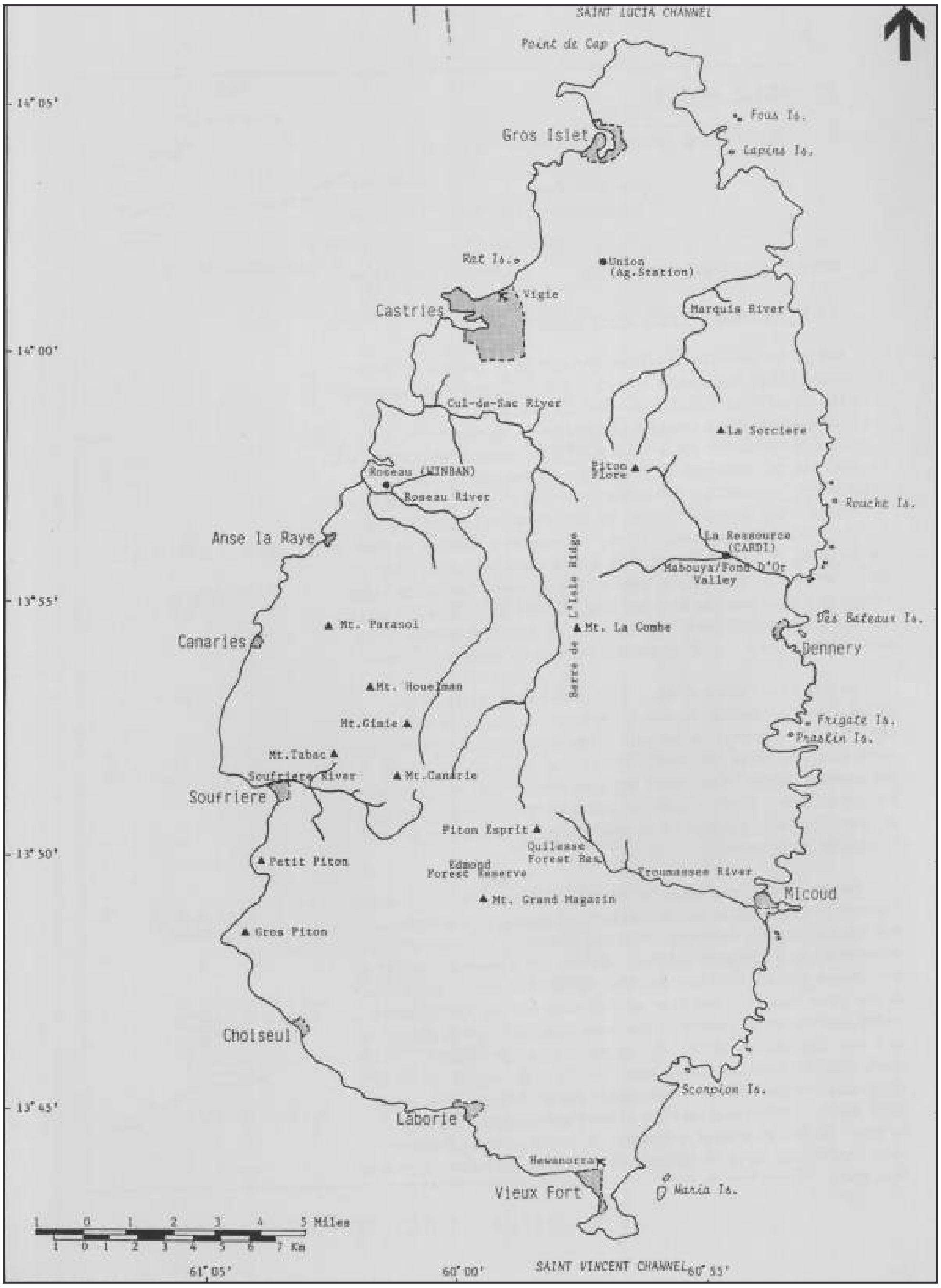

Figure 2.1 Major river systems in St Lucia (Source: CCA 1991)

Figure 2.2 Bays of St Lucia

The island is volcanic in origin, soils are derived from volcanic andesites, basalts and dacites (CCA 1991). The andesite-derived soils extend over approximately half of St. Lucia. They are acidic, found on slopes up to 40° and exhibit low to medium fertility. They are also susceptible to erosion (CCA 1991). Fertile, alluvial soils are found in valleys such as Roseau, Cul-de-Sac, Troumassee, Fond D'Or and Marquis. CCA (1991) has suggested that these valleys are the only areas suitable for intensive agricultural cultivation.

2.2 Agricultural Sector

St. Lucia's main agricultural products are bananas, coconuts and vegetables. Bananas account for 41% of all exports (United States Central Intelligence Agency 2001). Little *et al.* (2001) estimate that approximately 36.4km^2 of land in St. Lucia are under banana cultivation. This crop is cultivated mainly in valleys such as Roseau, Cul-de-Sac and Troumassee. However, bananas are also cultivated in "marginal areas", such as, on steep slopes. Bananas may be inappropriate for these areas as their rooting system are not effective against soil erosion (CCA 1991).

In St. Lucia, bananas are cultivated under a mono-cultural production system. This system depletes natural nutrients, subsequently, there is need for fertiliser application. Mono-cultural systems are also prone to pest infestation and may require heavier pesticide use. Thus, the CCA (1991) has suggested that the mono-cultural banana cultivation system in St. Lucia has high environmental costs.

2.3 Pesticide importation and use

The relative quantities of each category of pesticides (herbicides, fungicides etc.) imported into St. Lucia in 1999/2000 are given in Table 1. Nematicides were the most heavily imported solid pesticides during this period, while insecticides were the most heavily imported liquid pesticides. Almost 100% of the herbicides imported were liquids (Table 1).

Table 2.1 Quantities and categories of pesticides imported into St. Lucia (June 1999 - May 2000)[1].

Pesticide	Total solid pesticide (kg)	Total liquid pesticide (l)
Insecticide	43574	273580
Fungicide	23890	3396
Herbicide	13	156897
Nematicide	1217799	12
Rodenticide	4310	151
Molluscide	-	-
Tickicide	1	106

Woudneh (1999) produced a list of the most commonly used pesticides in the agricultural sector in St. Lucia (See Table 2.2). This list was based on field visits to farms and subsequent observation of the rate and frequency of use of each pesticide. Woudneh (1999) listed Funglaflor and Mertect (active ingredients: imazalil and thiabendazole respectively) as the most commonly used fungicides. These were used for post-harvest dipping of bananas. Little *et al*. (2001) noted that fungicides, such as, Benlate OD (benomyl), Anvil (hexaconazole), Calixin (tridemorph) and Tilt (propiconazole) were used for the control of yellow sigatoka (leafspot disease) in the banana industry.

Herbicides commonly used in St. Lucia include Gramoxone (active ingredient: paraquat), as well as, Roundup (glyphosphate), Talent (asulum) and Touchdown (glyphosate). These herbicides have been applied to weeds in agricultural areas (Woudneh 1999). Miral and mocap were the most commonly used nematicides (active ingredients: isazofos and

[1] Source: St. Lucia Pesticide Control Board.

ethoprop respectively). The insecticide Pirimicid was commonly used for soil insects in banana cultivated areas (active ingredient: pirimiphos-ethyl).

Table 2.2 List of the most commonly used pesticides in the agricultural sector in St. Lucia[2].

Pesticide	Active Ingredient	Class
Funglaflor	Imazalil	Fungicide
Furadan	Carbofuran	Nematicide
Gramoxone	Paraquat	Herbicide
Mertect	Thiabendazole	Fungicide
Miral	Isazafos	Nematicide
Mocap	Ethoprop	Nematicide
Primicid	Pirimiphos-ethyl	Insecticide
Roundup	Glyphosate	Herbicide
Talent	Asulum	Herbicide
Touchdown	Glyphosate trimesium	Herbicide
Vydate	Oxamyl	Insecticide/Nematicide

2.4 Fertiliser importation

The type and quantities of fertilisers imported into St. Lucia for the period 1995-1999 are given in Table 2.3. Fertilisers imported included ammonium nitrate, ammonium sulphate and urea.

Table 2.3 Fertiliser imports into St. Lucia (1995 - 1999)[3].

Year	Ammonium nitrate (tonnes)	Ammonium sulphate (tonnes)	Urea (tonnes)	Others (tonnes)
1995	17	334	31	6730
1996	7	-	9	8027
1997	38	2	18	5760
1998	-	-	1650	2913
1999	2	-	1404	4486

[2] Adapted from Woudneh (1999).
[3] Adapted from the St Lucia Ministry of Agriculture, Forestry and Fisheries Agricultural Statistical Report (1999).

3 ENVIRONMENTAL IMPACTS OF PESTICIDES IN ST. LUCIA

3.1 General

In St. Lucia, the potential for pesticide pollution is high, given the frequent and intense use of pesticides coupled with inappropriate handling, disposal and storage methods (Woudneh 1999; Little *et al.* 2001). Little *et al.* (2001) noted that Calixin and other fungicides used for leaf spot control in bananas, were not dangerous to humans and the environment, provided they were used correctly. However, given the existing improper handling, equipment leaks and chemical spillages, environmental and occupational health hazards were likely. Woudneh (1999) noted that used pesticide containers were often discarded in piles in agricultural areas. Also, pesticide containers were rinsed in watercourses or remnant solution was poured into drains. Fungicides, in particular, after being used in banana post-harvest treatment, were disposed of in drains (Woudneh 1999).

Spraying techniques also influence the environmental impacts of pesticides. Both aerial and ground spraying have been utilised in St. Lucia (Woudneh 1999, Little et al. 2001). Knapsack sprayers (ground spraying) have been used to apply Gramoxone and Roundup (herbicides), while scoop spraying has been used for the application of granular nematicides like Miral and Mocap. Woudneh (1999) suggested that water transport is the major method of transport for pesticides applied by knapsack and scoop spraying.

Aerial and ground spraying have both been used for the application of Calixin and Tilt, for the control of sigatoka. Woudneh (1999) suggested that drift deposition was a major transport mechanism for these fungicides. Aerial spraying has resulted in pesticide drift onto non-banana lands, entry into watercourses and deposition in communities. Pesticide spray drift has been observed on homes and vehicles in Roseau and Cul de Sac area. Little *et al.* (2001) indicated that ground spraying was often carried out by untrained personnel who did not handle the pesticides properly, resulting in environmental contamination and occupational health hazards.

Little *et al.* (2001) have suggested that aerial spraying is the most efficient method for sigatoka control in St. Lucia’s banana industry. However, the authors have noted the importance of clear zoning of the banana lands so that non banana areas are not affected. Also, Little *et al.* (2001) have recommended public awareness programmes on the proper handling and storage of pesticides.

3.2 Freshwater systems

Studies have been conducted on the levels of pesticides in watercourses and potable water supplies in St. Lucia. The Caribbean Environmental Health Institute (CEHI) (1998) reported on the level of paraquat in potable drinking water sampled from taps at CEHI. The results of this study are shown in Table 3.1.

Generally, levels fell under 1.0µg/l, however, in 1995 the level of paraquat was as high as 5.3µg/l. The reason for this high value was not determined. A specific United States (US) standard for paraquat was not located, however, the Canadian standard for paraquat in drinking water (10µg/l) was not surpassed (CEHI 2000). The European Community (EC) has set a general guideline level of 0.1µg/l for individual pesticides in drinking water. Paraquat levels were higher than this guideline value in four out of the five samples.

Table 3.1 Levels of paraquat in drinking water collected at CEHI headquarters (1994-1995)

Date	Free paraquat (µg/l)
11/1994	0.5
12/1994	0.4
01/1995	0.6
08/1995	5.3
10/1995	0.0

The United States Environmental Protection Agency (USEPA) has established a health advisory for paraquat of 0.1mg/l per day for a 10kg child and a 0.1mg/l health advisory for 10day exposure for a 10kg child. Health advisories are not US Federal standards but technical guidance levels. The Reference Dose (an estimate of the daily oral exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime) set by the USEPA, is 0.0045mg/kg (USEPA 2000). The Lethal Dose for paraquat in humans is 30mg/kg (Tomlin 1994). Chronic effects of paraquat in humans include liver and gastrointestinal damage (Briggs 1992).

In addition to paraquat testing of potable water, CEHI (1998) also studied the levels of paraquat in surface water in St. Lucia. Results are presented in Table 3.2. Specific standards for paraquat in aquatic environments were not located. However, values obtained exceeded the EC guideline level of 0.1µg/l for individual pesticides in drinking water. This has human health implications in that sample points such as the Roseau Dam are drinking water sources Apart from the dams however, the intake points of those rivers from which water is extracted, are high in the upper reaches of the catchment areas. (The Water and Sewerage Company pers. comm.). Lloyd and Thorpe (1997) have indicated that pesticide use is minimal in the upper catchment areas, thus, human health effects from pesticides may also be minimal

Table 3.2 Levels of paraquat in selected rivers and dams in St Lucia (1994-1995)

Date	Site	Free paraquat (µg/l)
11/94	Bois d'Orange River	0.7
11/94	Bois d'Orange River	0.5
11/94	Choc River	0.8
11/94	Choc River	1.0
11/94	Cul-de-Sac River	0.6
11/94	Roseau Dam	0.6
11/94	Roseau River	0.5
12/94	Choc River	0.0
12/94	Cul-de-Sac River	0.0
12/94	Roseau River	0.0
05/95	Soufriere River	0.0
05/95	Soufriere Dam	0.0
09/95	Cannelles River	0.0
10/95	Cannelles River	0.0
11/95	Choc River	0.8

Paraquat has environmental impacts on non target species, in addition to its human health effects. Briggs (1992) for example, noted that paraquat exhibits low to medium toxicity to fish but high toxicity to birds. The LC_{50} for rainbow trout (96hr) is 32mg/l (Tomlin 1994).

CEHI (1998) also conducted a wider pesticide screen of surface and potable water in St. Lucia. The results of this screening exercise are given in Table 3.3. DDT and associated metabolites, picked up in the screen, were not used for agricultural purposes but were part of a vector control programme (CEHI 1998). None of the potable water levels exceeded the EC drinking water guideline limit of 0.1µg/l for individual pesticides. Surface water levels of all pesticides were generally below 0.05µg/l. The exceptions were ethoprop in the Roseau River (0.09µg/l) and the p'p-DDT in the Soufriere River (0.08µg/l).

Table 3.3 Results of pesticide screening of surface and potable water in St Lucia (1998)

Pesticide	Potable water Victoria (µg/l)	CEHI potable water (µg/l)	Soufriere River (µg/l)	Cul-de-Sac River (µg/l)	Fond Dor River (µg/l)	Roseau River (µg/l)
Aldrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Azinphos- ethyl	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadusafos	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carbofuran	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Coumaphos	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cyfluthrin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cyphenothrin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Diazinon	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Dieldrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Diuron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Endosulfan sulfate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ethoprop	<0.05	0.06	<0.05	<0.05	<0.05	0.09
Imazalil	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Isazofos	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lindane	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
o,p'- DDE	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
o,p' DDT	<0.02	<0.02	0.05	<0.02	<0.02	<0.02
Oxamyl	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
p,p' DDT	<0.02	<0.02	0.08	<0.02	<0.02	<0.02
p,p'DDD	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
p,p'DDE + o,p'DDD	<0.02	<0.02	0.03	<0.02	<0.02	<0.02
Pirimiphos-ethyl	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Profenophos	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Propiconazole	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Propoxur	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tetramethrin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
α Endosulfan	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
β Endosulfan	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Woudneh (1998) further quantified the levels of ethoprop and pirimiphos-ethyl in the Roseau River (See Table 3.4). Standards for ethoprop and pirimiphos-ethyl in drinking or surface waters were not located, however, Woudneh (1998) noted that the levels of ethoprop in all water samples exceeded the 0.1µg/l guideline established by the EC for individual pesticides in drinking water. Ethoprop is a cholinesterase inhibitor. It affects the nervous system and can cause nausea, and dizziness in humans. Respiratory paralysis and death can result at very high exposures. Ethoprop is also a suspected mutagen (Briggs 1992). Ethoprop is extremely toxic to mammals and birds (Briggs 1992). The acute oral LD_{50} for rats is 62mg/kg and mallard ducks is 61mg/kg. The acute oral LC_{50} for fish (96hrs) is 13.8mg/l (rainbow trout) (Tomlin 1994).

Out of 21 water samples tested for pirimiphos-ethyl, 16 exceeded the EC guideline value of 0.1µg/l for individual pesticides in drinking water. The acute oral LD_{50} for rats is 140-200mg/kg. The acute oral LD_{50} for mallard ducks is 2.5mg/kg and the acute oral LC_{50} for fish (96hrs, brown trout) is 0.02mg/l (Tomlin 1994)

Table 3.4 Concentration of ethoprop and pirimiphos-ethyl in the Roseau River, St Lucia[4].

Site no.	27/07/98		06/08/98		19/08/98		07/09/98	
	Ethoprop (µg/l)	pirimiphos-ethyl (µg/l)	Ethoprop (µg/l)	pirimiphos-ethyl (µg/l)	Ethoprop (µg/l)	pirimiphos-ethyl (µg/l)	Ethoprop (µg/l)	pirimiphos-ethyl (µg/l)
1	1.65	0.52	2.23	0.15	0.88	<MDL	1.16	<MDL
2	2.23	0.27	2.58	0.10	1.36	0.11	2.67	<MDL
3	-	-	2.01	0.32	1.92	0.19	1.60	<MDL
4	-	-	-	-	3.40	0.15	1.63	<MDL
5	1.78	0.29	1.78	0.82	0.94	0.52	1.95	<0.19
6	-		4.08	0.29	4.28	0.19	1.92	0.08

Woudneh (1998) linked the levels of ethoprop and pirimiphos- ethyl in the water samples to intense farming activity in the Roseau Valley. The author noted that there were 143 farmers in the valley, growing bananas and small vegetables, on approximately 3.1km^2 of land.

In addition to the pesticide specific studies documented, Lloyd and Thorpe (1997) developed a water quality biotic scoring system for St. Lucia, which incorporated *inter alia*, pesticide elements. Lloyd and Thorpe (1997) monitored stream and river quality using aquatic benthic macroinvertebrate composition, as well as, chemical and physical parameters. The authors noted that the most important factors affecting biotic composition were physical parameters like turbidity and soil erosion. Pesticides were less important. The effects of pesticides were insignificant in upper catchment areas (<183m), significant in the middle reaches between (61-183m) and damaging in the lower catchment areas (<61m). Lloyd and Thorpe (1997) suggested that the limited impact of pesticides in the upper catchments were linked to low agrochemical use, characteristic of poor farmers and marginal farming practices in the upland catchment areas. Specific pesticide levels were not available in the Lloyd and Thorpe report.

Woudneh (1999) also collected 48 water samples from river systems across St. Lucia (See Table 3.5). Samples were analysed for ethoprop and pirimiphos-ethyl. Out of the 48 samples tested, 10 samples showed pesticide concentrations higher than the EC guideline for individual pesticides in drinking water of 0.1µg/l. These 10 samples were taken from the Roseau, Cul-de-Sac, Vieux Fort and Anse-la-Raye rivers. The Roseau River water samples exhibited the highest levels of the pirimiphos-ethyl while the Vieux Fort River showed the highest levels of ethoprop.

[4] Adapted from Woudneh (1998)

Table 3.5 Concentration of ethoprop and pirimiphos-ethyl in selected river systems in St Lucia (1998 – 1999)[5].

River	Sample Station	First data set		Second data set	
		Ethoprop (µg/l)	Pirimiphos-ethyl (µg/l)	Ethoprop (µg/l)	Pirimiphos-ethyl (µg/l)
Marquis	42	<MDL	<MDL	<MDL	<0.10
	43	<MDL	<MDL	<MDL	<MDL
	44	<MDL	<MDL	<MDL	<MDL
	45	<MDL	<MDL	<MDL	<MDL
Fond D'Or	51	<MDL	<MDL	<MDL	<MDL
	54	<MDL	<MDL	<MDL	<MDL
Dennery	61	<MDL	<MDL	<MDL	<MDL
	63	<MDL	<MDL	<MDL	<MDL
Fond Troumassee	101	<MDL	<MDL	<MDL	<MDL
	103	<MDL	<MDL	<MDL	<MDL
Vieux Fort	131	<MDL	<MDL	0.60	<MDL
	132	<MDL	<MDL	2.00	1.00
	133	<MDL	<MDL	2.00	1.50
L'Ivrogyne	192	<MDL	<MDL	<MDL	<MDL
Soufriere	202	<MDL	<MDL	<MDL	<MDL
	203	<MDL	<MDL	<MDL	<MDL
Canaries	211	<MDL	<MDL	<MDL	<MDL
Anse La Raye	222	<MDL	0.14	<MDL	<MDL
Roseau	241	<MDL	3.10	0.50	4.00
	242	<MDL	<MDL	<MDL	<MDL
Cul- de- sac	251	<MDL	<MDL	<MDL	<MDL
	253	<MDL	<MDL	<MDL	0.32
Choc	271	<MDL	<MDL	<MDL	<MDL

Of the commonly used pesticides listed in Table 2.2, Woudneh (1999) suggested that the nematicides were major potential water pollutants given their high mobility, water solubility and relatively low soil sorption coefficient values. Thus, active ingredients such as isazofos and ethoprop, through agricultural runoff and leaching, were more likely to be found in watercourses (Woudneh 1999). Paraquat and glyphosate (active ingredients in herbicides) were deemed less likely to enter watercourses because of their high soil affinity. However, given the steep slopes on which bananas were cultivated, and the high erosive potential of the soil (CCA 1991), these less soluble chemicals were likely to enter watercourses through soil transport mechanisms (Woudneh 1999).

3.3 Marine Environment

Apart from fresh water systems, there has been some pesticide monitoring of the marine environment around St. Lucia. Shim (1985) and Ramsammy *et al.* (1985) both cited in Vienneau (1997) examined the concentration of lindane, pp'DDT, endrin, heptachlor and

[5] Adapted from Woudneh (1999). Key MDL= 0.05µg/l.

aldrin in the Castries Harbour, Vigie Choc and Cas en Bas. The highest concentration of pp'DDT was found in the Castries Harbour (61.2µg/l) while Vigie Choc had the highest concentration of heptachlor (8.2µg/l) and lindane 10.8µg/l. Endrin and aldrin were detected in the Castries harbour at concentrations of 13.2µg/l and 6.9µg/l respectively (See Table 3.6). Pesticide levels for all pesticides exceeded USEPA standards for coastal water quality (USEPA 1999) including human health criteria for the consumption of the organism. Table 3.6 highlights the USEPA coastal water criteria. These standards have also been adopted as a recommended interim water quality criteria for protection of aquatic life by a Regional Workshop on Coastal Water Quality Criteria and Effluent Guidelines for the Wider Caribbean (International Oceanographic Commission and United Nations Environment Programme 1991). Table 3.7 also shows the United States Food and Drug Administration (USFDA) action levels for pesticides (USFDA 2001). These action levels are the levels the USFDA will take legal action to remove products from the market.

Table 3.6 Concentration of pesticides in coastal waters around St Lucia[6].

Site	Pesticide				
	Heptachlor (µg/l)	Lindane (µg/l)	Pp'DDT (µg/l)	Endrin (µg/l)	Aldrin (µg/l)
Castries Harbour	6.5	7.0	61.2	13.2	6.9
Vigie Choc	8.2	10.8	29.2	-	-
Cas en Bas	-	3.5	31.2	-	-

Table 3.7 US coastal water quality criteria and USFDA action levels for Seafood[7].

Pesticide	Saltwater criteria		Human health criterion: pesticide limit in water for consumption of aquatic organism (µg/l)	USFDA Action level for seafood (edible portion) (µg/g)
	CMC (µg/l)	CCC (µg/l)		
Lindane	0.16		0.063	
Dieldrin	0.71	0.0019	0.00014	0.5
Endrin	0.037	0.0023	0.81	
Heptachlor	0.053	0.0036	0.00021	0.3
DDT	0.13	0.001	0.00059	5.0
Chlordane	0.09	0.004	0.0022	0.3
Aldrin	1.3	-	0.00014	0.3

USEPA coastal water quality standards have been divided into Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) (USEPA 1999). The

[6] Adapted from Shim (1985) and Ramsammy *et al.* (1985) both cited in Vienneau (1997). Key: – no data

[7] Adapted from USEPA (1999) and USFDA (2001). Key: CMC = criterion maximum concentration, CCC= criterion continuous concentration.

CMC is the maximum concentration of a toxicant to which organisms can be exposed for a short period without causing an acute effect. The CCC is the concentration of a toxicant to which organisms can be exposed indefinitely without causing deleterious effects.

Singh and Ward (1992 cited in Vienneau 1997) quantified pesticide levels from 17 coastal sites around St. Lucia, during the period 1986-1989. They found lindane, dieldrin along with DDT and its derivatives, at concentrations of 5-40ng/l, 4ng/l and 4-20ng/l respectively. Lindane levels did not exceed USEPA, CMC criterion in salt water. Dieldrin levels exceeded the CCC but not the CMC criterion. DDT levels were over the CCC concentration prescribed but not the CMC levels.

Ramsammy *et al*. (1985 cited in Vienneau 1997) quantified pesticide levels in marine organisms in the Castries Harbour. Tissue samples of *Brachidontes exustus* (mussel), *Mugil curema* (mullet), and *Crassostrea rhizophorae* (oyster) were analysed for chlordane, pp'DDD, pp'DDE, dieldrin and aldrin. The highest concentrations of chlordane and pp'DDE were found in the oyster samples. Pesticide levels for all the organisms are given in Table 3.8. The levels of these pesticides did not exceed USFDA action levels seen in Table 3.7.

Table 3.8 Concentration of pesticides in *Mugil curema*, *Brachidontes exustus* and *Crassostrea rhizophorae* from the Castries harbour[8].

Species	Compound	Concentration (ng/g)
Mugil curema	Chlordane	0.06
	pp'DDD	0.01
	pp'DDE	0.01
	Dieldrin	0.01
	Aldrin	<0.01
Brachidontes exustus	pp'DDE	0.01
Crassostrea rhizophorae	Chlordane	0.16
	Dieldrin	0.02
	pp'DDE	0.16

Singh and Ward (1992 cited in Vienneau 1997) also analysed pesticide levels in marine organisms. In addition to the three species studied by Ramsammy *et al*. 1985, Singh and Ward (1992) studied *Isognonon altus* (flat tree oyster). Chlordane was found in the highest concentrations in the lipid samples of *M. curema*, *I. altus* and *C. rhizophorae*. See Table 3.9. Pesticide levels found in the organisms did not exceed USFDA action levels (Table 3.7).

Human health effects through the consumption of the four aforementioned seafood species may not be noteworthy. These species are not consumed in any great quantity in St. Lucia (Fisheries Division, St. Lucia pers. comm.)

Gaskin *et al.* (1974 cited in Vienneau 1997) examined pesticide residues in whales and dolphins found in coastal waters off St. Lucia. Muscle, liver and kidney samples were taken from *Globicephala macrorhynchal* (pilot whale) and *Stenella longirostris* (long snouted dolphin). The authors reported DDT concentrations ranging from 0.01µg/g to 7.38µg/g in blubber. Dieldrin was detected in blubber, at levels ranging from 0.001µg/g to 0.05µg/g. However, the authors suggested that the pesticide residue levels found in these organisms

[8] Adapted from Ramsammy *et al.* (1985 cited in Vienneau 1997).

were not necessarily reflective of pesticide concentrations in the waters surrounding St. Lucia, given the migratory habits of the species studied.

Table 3.9 Concentrations of selected pesticides in *Mugil curema, Brachidontes exustus, Crassostrea rhizophorae* and *Isognonon altus* from selected coastal sites around St. Lucia[9].

Species	Pesticide	Pesticide concentration in lipid (ng/g)	Pesticide concentration in muscle (ng/g)
Mugil curema	Aldrin	0.21	ND
	Chlordane	13.34	0.25
	Dieldrin	1.04	0.02
	Lindane	ND	ND
	pp'DDD	1.41	0.03
	pp'DDE	1.33	0.02
Brachidontes exustus	Aldrin	-	-
	Chlordane	-	-
	Dieldrin	-	-
	Lindane	-	-
	pp'DDD	-	-
	pp'DDE	0.55	0.05
Crassostrea rhizophorae	Aldrin	-	-
	Chlordane	13.35	1.39
	Dieldrin	-	-
	Lindane	-	-
	pp'DDD	-	-
	pp'DDE	0.88	0.09
Isognonon altus	Aldrin	-	-
	Chlordane	67.05	8.90
	Dieldrin	1.25	0.13
	Lindane	5.98	0.79
	pp'DDD	-	-
	pp'DDE	1.16	0.21

3.4 Transport and fate of pesticides

Pesticide migration and persistence in St. Lucia has been studied by CEHI (1998). Pirimiphos-ethyl and ethoprop were applied to two banana plants in the Roseau valley, according to WIBDECO guidelines. Surface soil samples and water samples were collected 7 days prior to pesticide application, one day after application and 7 days after application. Samples were collected at 7 sites, in August of 1995 as described in Figure 3.1. The results showed the presence of pirimiphos-ethyl and ethoprop in soil samples after application to the banana plant. Pirimiphos-ethyl was able to migrate vertically into the soil and horizontally within the soil towards watercourses (See Table 3.10 and Table 3.11).

[9] Adapted from Singh and Ward (1992, cited in Vienneau 1997). Key: ND= not detectable.

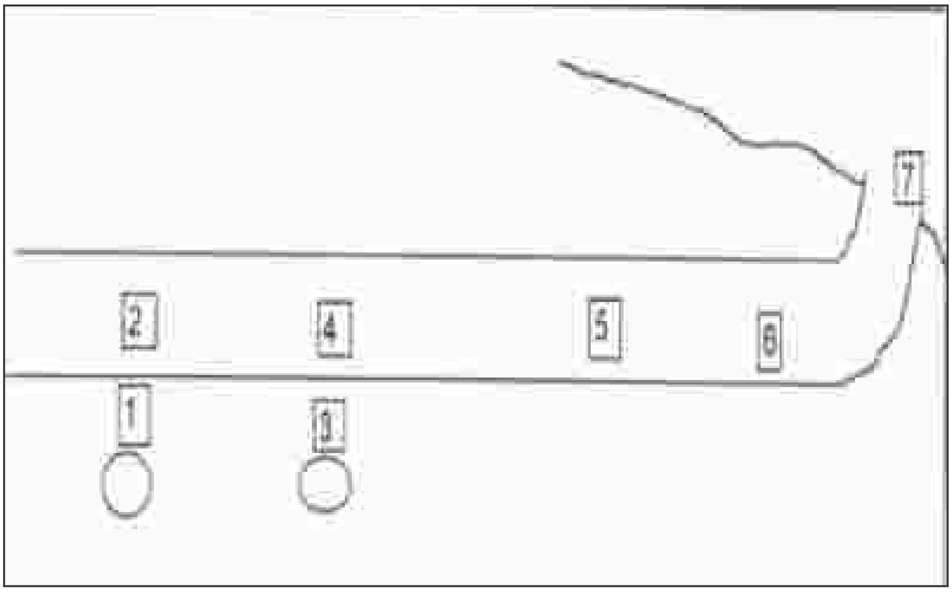

Figure 3.1 Sample stations used by CEHI (1998) (Image not drawn to scale)

Key O = banana plant □ = sample stations

Station

1 0.3m from pesticide application, base of Tree 1
2 Ditch opposite Tree 1
3 0.3m from pesticide application, base of Tree 2
4 Ditch opposite Tree 2 (2m from Tree1)
5 Ditch 4m from Tree 1
6 Ditch 8m from Tree 1
7 Stream, mouth of ditch

Table 3.10 Concentration of ethoprop in soil samples at various distances from a sprayed banana plant (Roseau, St. Lucia, August 1995)[10].

Sample point	Ethoprop level 7 days before pesticide application (µg/kg)	Ethoprop level 1 days after pesticide application (µg/kg)	Ethoprop level 7 days after pesticide application (µg/kg)
1	0.00	0.00	83.40
2	2.54	0.00	0.00
3	0.00	0.00	0.00
4	11.87	0.00	0.00
5	50.46	126.11	0.00
6	0.00	0.00	0.00
7	0.00	0.05	0.00

3.5 Human health effects of pesticide use in St. Lucia

St. Lucia specific information on the human health effects of pesticide contaminated food and water is lacking. Human health studies of pesticides in St. Lucia have instead been focused on occupational exposure.

[10] Adapted from CEHI (1998).

Magloire (1990) conducted a Knowledge, Attitude, Practices and Behaviour (KAPB) survey of 130 occupational pesticide users, including, vector control officers, banana farmers and banana farm workers. This study was carried out in tandem with direct biological measurement of cholinesterase levels of the workers who participated in the KAPB survey. The measurement of blood cholinesterase levels provided an indication of organophosphate and carbamate exposure, as generally speaking, blood cholinesterase levels are lowered by the presence of the aforementioned pesticides. Biological monitoring results were compared against two control groups, namely, unexposed farm workers and food handlers.

Table 3.11 Concentration of pirimiphos-ethyl in soil samples at various distances from a sprayed banana plant (Roseau St. Lucia August 1995)[11].

Sample point	Pirimiphos-ethyl concentration, 7 days before pesticide application (µg/kg)	Pirimiphos-ethyl, concentration, 1 day after pesticide application (µg/kg)	Pirimiphos-ethyl concentration, 7 days after pesticide application (µg/kg)
1	10.95	281.47	1540.96
2	4.53	79.31	373.67
3	0.00	986.81	5357.64
4	0.00	902.22	240.35
5	0.00	53.89	845.19
6	0.00	505.87	1661.09
7	0.00	0.00	0.00

The KAPB study revealed that workers overestimated their knowledge of pesticide exposure, in that skin and eye exposure were not well recognised routes of exposure. Nasal and oral routes of exposure were identified by 89% and 88% of the workers respectively, but skin and eye exposure were only identified by 57% and 64% respectively. Twenty eight percent of the workers, at some time, had felt ill as a result of pesticide use. Symptoms experienced by the workers surveyed, included, runny eyes, difficulty in breathing, sneezing, itching skin, dizziness and headaches.

Of the workers surveyed, 65% never wore protective clothing while using pesticides. Farm owners did not wear the protective gear because they could not afford it, while the banana workers felt that managers should supply the protective gear. There was a significant difference in cholinesterase levels between workers who at least wore protective gear occasionally compared to those who did not. As indicated previously, blood cholinesterase levels are lowered by organophosphate and carbamate exposure.

Biological monitoring results demonstrated no statistical difference between the cholinesterase levels of the pesticide exposed groups and two control groups. Magloire (1990) noted that this was not in keeping with similar studies in Nicaragua and Malaysia where pesticide exposed groups had significantly lower cholinesterase levels compared to control groups. Magloire (1990) suggested that these unexpected results may be linked to gender differences in the control groups. Alternatively, even though the control groups were not exposed to pesticides on the job, they might have utilised pesticides at home (Magloire 1990).

[11] Adapted from CEHI (1998).

4 FERTILISERS

The Ministry of Agriculture, Forestry and Fisheries of St. Lucia and WIBDECO have indicated there is a lack of studies on the impact of fertilisers in the St. Lucian environment.

5 DISCUSSION AND RECOMMENDATIONS

The available literature has highlighted the frequent and intense use of pesticides in St. Lucia. Inappropriate handling, storage and disposal of the chemicals and the resultant potential for environmental pollution has been noted.

Pesticide research has been skewed geographically towards certain areas, such as the Roseau Valley. Research has also been concentrated on the banana sector. Nematicides sprayed in banana growing areas, have been identified as potential water pollutants given the water solubility of their active ingredients. Banana cultivation on steep slopes encourages soil erosion and the movement of pesticides, such as paraquat and glyphosate through soil transport mechanisms. Pesticide drift has also been highlighted as an important transport mechanism.

Pesticide active ingredients such as ethoprop and pirimiphos-ethyl have been found in water courses around the island. The highest level of ethoprop was found in Roseau River in 1998. The highest level of pirimiphos-ethyl was found the View Fort River during the period 1998-1999. Paraquat has been detected in the Bois d'Orange River, Choc River, Cul-de-Sac River, Roseau Dam and Roseau River. The highest level of paraquat was found in the Choc River in 1994. DDT and its metabolites have been found in the Soufriere River. Overall, pesticides have been identified as a greater problem in the middle and lower reaches of the catchment areas rather than the upper reaches.

Pesticide levels in drinking water supplies have also been examined. Levels of paraquat in drinking water have exceeded the EC 0.1µg/l guideline limit for individual pesticides in a 1994-1995 study, but not in subsequent 1998 study. Specific water quality standards may need to be established for St Lucia.

Lindane, heptachlor, DDT and metabolites, and aldrin, chlordane have been found in the coastal waters of St. Lucia. Pesticide residues have also been found in marine organisms such as oysters and fish.

There had been one pesticide migration and persistence study in St. Lucia. This was a study of pirimiphos-ethyl and ethoprop in the Roseau valley. There has also been only one human health study of the impact of pesticides. This study was focused on occupational exposure to pesticides. More research is needed on the human health and social impacts of pesticides in St. Lucia, both on the human health effects due to occupational exposure and also due to contaminated food are greatly needed.

Thus, as is evident from this literature review, there is little available information on the environmental impacts of agro-chemicals in St. Lucia. There have been studies conducted on pesticides, but none on fertilisers. Most of the work has been carried out by CEHI during the 1980's and 1990's. This information needs to be updated.

In general, little information exists for tropical countries on the rate of degradation of pesticides in the environment and therefore additional study is needed in this area.

Research has also been skewed geographically towards the Roseau Valley area. While this is justifiable, given the high level of agricultural activity in that area, there is also need to study the impact of pesticides in other agricultural areas.

Research has also been concentrated on the banana sector. This is reflective of the importance of the banana sector to the St. Lucian economy and the heavy use of pesticides for the cultivation of the crop. However, the utilisation and fate of pesticides used on other crops also requires study.

Research has also been focused on pesticide levels in the fresh water and marine environment. There has also been some work on pesticide residues in aquatic organisms. Additional focus is needed on the bioaccumulation of pesticides (up the food chain) and the chronic toxicity of residues to aquatic fauna during different periods of agricultural activity. More research is especially needed on pesticide residues in terrestrial organisms and pesticides in soil and also on the transport, fate and persistence of pesticides in the marine and terrestrial environment.

Literature reviews, such as this one, should be repeated periodically to update information on the fate of agro-chemicals in the environment. MAFF or other selected organisations, like CEHI, should compile all nationally available research, including studies on the impacts of pesticides on drinking water, terrestrial environments and marine and freshwater environments and share information to enhance local programmes as well as identify gaps of where further research is needed.

Capacity and financial resources in organisations such as CEHI and UWI, should be investigated to see what is feasible in terms of further research. Given limited capacity and resources, effectively targeted research activities and long term monitoring programmes need to be established and sustainable financing mechanisms need to be sought to fund research institutions and laboratories (i.e. through chemical companies or other organisations).

Thus, given the limited information on pesticides and fertilisers in St. Lucia, projects such as the current Land Water Interface Project R7668: Impact and amelioration of sediment and agrochemical pollution on Caribbean Coastal Waters (DFID Natural Resources Programme) are crucial. The aforementioned project intends to, *inter alia*, document the levels and impacts of agro-chemicals on coastal waters. Once generated, this information will contribute to a better understanding of the agro-chemical pollution problem. This in turn would allow for better management and policy decisions with an aim towards reducing the human health and environmental impacts of agro-chemicals in St. Lucia.

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