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Environmental Pollution due to Pesticide Application in Cardamom Hills of Idukki, District, Kerala, India

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Abstract: *Intensive agricultural practices often include the use of pesticides to enhance crop yields. However, the improvement in yield is associated with the occurrence and persistence of pesticide residues in soil and water. Kerala, being the largest production centers of cardamom in India and cardamom the highest pesticide consuming crop, the risk of environmental contamination especially in soil and water is high. The objective of the study was to determine the present contamination levels in water and soil samples of Cardamom plantations in Idukki district. Sampling points were selected on purposive sampling technique from the entire plantation area in the district. 100 water samples and 38 soil samples were collected from the cardamom plantations or from adjacent water sources and analysed for pesticide residues. Standard protocol in collection, storage, custody procedures, transportation and analysis were followed to achieve maximum accuracy in results. This paper presents the existing contamination pattern and the interpolated locations of high risk contamination due to persistent pesticide residues. The study shows that the water sources are not contaminated but soil got contaminated with persistent pesticide residues of the toxic chemicals used in Cardamom Plantations, mainly of endosulfan, DDT and organophosphorous pesticides. The soil nature is highly sensitive to adsorption and hence there is a high risk of contamination of soil and surrounding water bodies due to leaching and run off if the present frequency and dose of pesticide application is continued. A balance between the investment and profit in cardamom farming is to be evolved which can control the pesticide application suitable for soil characteristics and growth pattern keeping the banned toxic pesticides out of market. It is the responsibility of the present generation to keep the environment from pollution and contamination which are harmful for the present and future generation.*

1. INTRODUCTION

Pesticides may reach the soil through direct application to the soil surface, incorporation in the top few inches of soil or through the unauthorized dumping of unwanted pesticide products. Pesticides may enter ground water sources and surface run-off during rainfall, thereby contributing to the risk of environmental contamination. All pesticides are subject to degradation or metabolism once released into the environment. The objective of present study is,

- Identify contaminated areas and sources of contamination.
- Investigate residual levels of pesticide in the environment, soil and water.
- Locating probable places of highly contaminated area using GIS applications.

The fate of pesticides in soil and water environments is influenced by the physio-chemical properties of the pesticide, the properties of the soil and water systems (presence of clay size particles, organic matter and pH), climate, biology, and other factors [6]. The rates of degradation and dissipation vary greatly from pesticide to pesticide and situation to situation. The solubility of common pesticides in soil and water is very less and its half life period very short [7]. There are very few references or studies for pesticide residues in elevated areas covering large hilly area where the environment is exposed to frequent application of toxic pesticides. The sampling protocols were developed to meet regulatory mandates of the Pesticide Contamination Prevention Act (PCPA) of 1986 and to provide further understanding of the agronomic, chemical, and geographic factors that contribute the movement of residues to soil and water [12]. How long the pesticide remains in the soil depends on how strongly it is bounded by soil components and how readily it is degraded. Common pesticides used in Cardamom plantations are ‘organophosphorous' and ‘organochlorine’ compounds. Although some organophosphorous compounds are highly toxic to humans, they generally break down rapidly and rarely have been found in the environment. Organochlorine compounds such as Endosulfan, are more toxic and its half life varies from weeks to months depending upon the physical and chemical properties of soil system such as moisture content, organic matter and clay contents [10,11]. Another group are carbamate pesticides including aldicarb, carbofuran, and oxamyl. These compounds tend to be soluble in water and weakly adsorbed to soil. Consequently, if not degraded in the upper soil layers, they have a tendency to migrate to groundwater.

2. MATERIALS AND METHODS

Idukki town is located at 9^0 51′N 76°58′E / 9.85°N 76.97°E Coordinates. The project area is Idukki District and the sampling points are located in Devikulam, Udumbanchola, Peermade and Thodupuzha Taluks. Water samples were collected from 100 locations and soil samples from 38 large and medium plantations across the district based on a random sampling technique from the data base collected from authorized agencies. The sampling points were marked with GIS Coordinates for identification and for further monitoring (Fig.1).

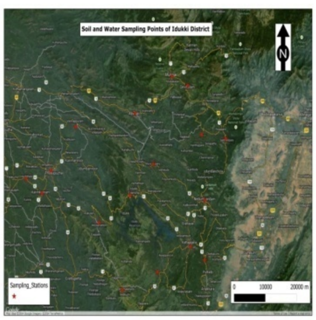

Fig. 1: Soil and water sampling points of Idukki district

A chain of custody procedure was followed to ensure the legitimacy of each sample [4]. Samples were collected from the study areas in March to July 2013 and January 2014, during and after rainy season. Water samples were collected following standard methods and stored in plastic containers at medium temperature and carried out the analysis within 48 -52 hrs. Each soil sample was a composite of 10 subsamples collected from each site using random sampling method within a grid. A grid was established by identifying the approximate center of a field and dividing the field into 5 rows. Soil was collected from each row and from a depth of 0-15 cm using a soil auger [4]. After the collection of soil samples the soil auger, bucket, sieve and mixing tool were rinsed with tap water and dried before next use. The subsamples were dried under shades for 24 hours and thoroughly mixed and sieved through 4.75 mm brass sieve and stored in air tight plastic bags. The samples were labeled with place and date of collection, code number etc and shipped to the Laboratory within 48 hours of collection.

2.1 Protocols followed in testing

Quantitative determination of insecticide residues by GCECD and GC-MS techniques are followed for pesticide analysis. All the 100 samples were tested for physical, chemical (including heavy metals) characteristics and analyzed for common pesticide residues. 13 selected samples from the plantations were tested at Pesticide Residue Research and Analytical Laboratory, Vellayani, Kerala, the NABL Accredited Laboratory for analyzing the presence of any pesticide residue which is being commonly used for Cardamom and to confirm the results so as to avoid any manual errors. The Water samples tested in the Pesticide Residue Research and Analytical Laboratory, Vellayani, Kerala follows the guidelines issued by : Association of Official Analytical Chemists (AOAC) 18^{th} Edition 2007: 991.07 and 990.06. The chemical characteristics of the water samples were tested in the approved Laboratory following standard methods of analysis [6]. Qualitative and quantitative analysis of pesticide residues in soil was carried out based on modified QuEChERS method for the extraction of pesticides from agricultural, ornamental and forestal soils [2]. For quantitative determination, GC-ECD, GC-FPD and GC-MS are used. Calibration standards, like internal standards were prepared from certified standard material.

2.2. Protocol in fixing Detection level of Pesticide contamination

As per standards, drinking water should be free from all pesticide residues or it should not be contaminated by any foreign matter. For quantifying the contamination levels, WHO has given the details with respect to Endosulfan the highly toxic pesticide and explained that a health-based value of 20 μgL^{-1} can be calculated on the basis of the Acceptable Daily Intake (ADI) of 0.006 mg/kg of body weight, with an allocation of 10% of the ADI to drinking-water, and with the assumption that a 60-kg adult consumes 2 liters of drinking-water per day. However, Endosulfan usually occurs at concentrations in drinking-water well below the level at which toxic effects can be expected to occur, and it is therefore not considered necessary to derive a guideline value for Endosulfan in drinking-water [13]. As it is a matter of great concern, the detection level of pesticide contamination is taken as 0.1 μgL^{-1} for water quality analysis. The Limit of Quantification (LOQ) set up for the analysis of soil samples are 0.01$mgKg^{-1}$, 0.05$mgKg^{-1}$, and 0.01 $mgKg^{-1}$ for Organochlorine, Organophosphorous and Synthetic pyrethroids respectively.

3. RESULTS AND DISCUSSIONS

Based on water quality analysis (Table 1) it is proved that pesticide residue is not present in water samples above the Limit of Quantification, 0.1 μgL^{-1} or to say that the water sources of Idukki district are at present not polluted from pesticide residues. The reasons may be,

1. Impact of banning of highly poisoned pesticides and strict monitoring from government agencies.

2. Awareness among the planters and quality control in plantations.
3. Favorable environmental conditions.

Among 38 nos of soil samples collected and tested, 18 nos of soil samples were contaminated by various persistent pesticide residues. The residual concentration of persistent pesticides found in samples with their identification code is given below (Fig.2).

Table 1: Test Results of Water Samples

Sl. No	Sample Identification	Month of collection	Location	EC	pH	Turbidity	TDS	Acidity	Alkalinity	Cl	TH	Ca	Mg	NO3	Fe	F	SO4	Alpha BHC,Beta BHC, Gamma BHC, Delta BHC, Alpha Endosulphan, Beta Endosulphan, Endosulphan Sulphate, Aldrin, Endrin, Heptachlor, Methoxychlor, 4,4' DDD, 4,4'DDT, Cu, Ph, Ni, Zn, Cd,Cr.
1	S 19	2013 Feb	Elappara	41.3	7.3	1.5	28.91	5	26	26	28	6.4	2.9	BDL	BDL	BDL	BDL	ND
2	S 23	2013 Feb	Kumali	68.1	7.3	1.7	47.67	5	32	20	52	11	5.8	BDL	BDL	BDL	BDL	ND
3	S 9	2013 Feb	Anakkara	69	7.4	1.1	48.3	4	30	24	50	13	4.4	BDL	0.05	BDL	BDL	ND
4	S 31	2013 Feb	Chakkupallam	83.4	7.4	2.3	58.38	5	44	26	64	13	7.8	BDL	BDL	BDL	BDL	ND
5	S 26	2013 Feb	Pampadumpara	39.1	7.3	1.8	27.37	5	30	20	22	4	2.9	BDL	0.05	BDL	BDL	ND
6	S 25	2013 Feb	Nedumkandam	57.9	7.3	1.4	40.53	5	30	28	40	9.6	3.9	BDL	BDL	BDL	BDL	ND
7	S 14	2013 Feb	Poopara	34.4	7.3	2.2	24.08	4	28	26	18	4	1.9	BDL	0.05	BDL	BDL	ND
8	S 35	2013 Feb	Udimbinchola	33.2	7.3	1.6	23.24	3	26	20	20	4	2.4	BDL	0.05	BDL	BDL	ND
9	S 68	2013 Mar	Peerumade	50.00	7.2	6.5	32.5	5	28	22	26	12	6.5	5	0.1	BDL	BDL	ND
10	S 69	2013 Mar	Kumily	70.23	6.9	2.1	45.65	5	32	26	30	8.5	4.3	6	0.05	BDL	BDL	ND
11	S 70	2013 Mar	Chakkupallam	43.31	7.1	5.1	28.15	4	26	30	30	17	8.6	1	0.3	BDL	BDL	ND
12	S 71	2013 Mar	Ayyappancoil	40.28	7	3.6	26.18	5	32	29	43	13	7.5	BDL	0.25	BDL	BDL	ND
13	S 72	2013 Mar	Nedumkandam	51.08	7	0.6	33.2	5	30	30	40	9.6	4.9	BDL	0.1	BDL	BDL	ND
14	S 73	2013 Mar	Udumbanchola	62.35	7.1	0.7	40.53	5	44	30	35	6.9	3.9	BDL	0.1	BDL	BDL	ND
15	S 74	2013 May	Munnar	44.77	6.8	1.9	29.1	4	30	18	34	9.4	4.8	6	0.1	BDL	BDL	ND
16	S 75	2013 May	Marayoor	33.20	6.6	0.1	23.24	3	30	28	42	9.4	4.8	4	BDL	BDL	BDL	ND
17	S 76	2013 May	Adimali	67.14	6.6	0.7	47	3	28	22	35	12	6.1	6	BDL	BDL	BDL	ND
18	S 77	2013 May	Devikulam	72.99	6.3	0.2	51.09	4	26	20	45	9.6	4.9	6	BDL	BDL	BDL	ND
19	SO 420	2013 May	Purapuzha	60.26	7.4	12.6	42.18	7	26	22	33	11	5.5	4	0.1	BDL	BDL	ND
20	SO402	2013 May	Munnar	55.81	7.3	0.7	39.07	6	32	26	43	6.4	3.1	2	0.2	BDL	BDL	ND
21	SO4026	2013 May	Vathikudy	38.21	7.2	5.2	26.75	3	30	30	30	7.5	4	2	0.3	BDL	BDL	ND
22	SO403	2013 May	Vellathuval	51.69	7.4	0.3	36.18	4	44	24	42	8	4.5	2	BDL	BDL	BDL	ND

23	SO404	2013 May	Kudayathoor	37.14	7.3	1.7	26.00	6	28	22	32	9.4	5.3	4	BDL	BDL	BDL	ND
24	SO405	2013 May	Kudayathur	40.00	7.2	1	28.00	7	38	28	45	6.7	3.9	2	BDL	BDL	BDL	ND
25	SO406	2013 May	Kudayathur	40.00	7.2	5.2	28.00	4	30	25	46	8	4.9	2	0.3	BDL	BDL	ND
26	SO407	2013 May	Idukki	62.86	7.1	0.6	44.00	5	44	23	65	9.2	5.3	4	0.1	BDL	BDL	ND
27	SO408	2013 May	Poopara	74.29	6.8	0.7	52.00	5	30	22	35	6.5	3.3	4	BDL	BDL	BDL	ND
28	SO409	2013 May	Kanthalloor	65.71	6.9	1.4	46.00	7	30	26	45	7.2	3.8	2	0.2	BDL	BDL	ND
29	SO410	2013 May	Udumbanchola	40.00	7	1.1	28.00	5	28	30	28	6.3	4.1	4	BDL	BDL	BDL	ND
30	SO411	2013 May	Ayyappancoil	36.76	7	17.5	25.73	4	26	24	28	8.9	4.7	8	BDL	BDL	BDL	ND
31	SO412	2013 May	Kalkoonthal	52.00	7.2	0.6	36.40	5	26	26	52	5.5	4.5	2	BDL	BDL	BDL	ND
32	SO413	2013 May	Elappara	58.57	7.1	1.9	41.00	6	32	24	50	9.8	3.5	BDL	0.1	BDL	BDL	ND
33	SO415	2013 May	Udumbannoor	38.67	7.3	1.2	29.00	4	30	20	64	6.4	4.1	0.5	0.1	BDL	BDL	ND
34	SO416	2013 May	Munnar	37.33	7.3	1	28.00	5	44	28	22	6.4	2.9	2	0.1	BDL	BDL	ND
35	SO417	2013 May	Kumily	39.00	7.4	3.6	29.25	5	30	20	40	11	5.8	1	0.2	BDL	BDL	ND
36	SO418	2013 May	Chakkupallam	50.67	7.4	2.2	38.00	6	22	20	18	13	4.4	26.6	0.1	BDL	BDL	ND
37	SO419	2013 May	Kudayathoor	38.55	7	1.7	28.91	7	23	22	20	13	7.8	BDL	0.1	BDL	BDL	ND
38	SO421	2013 May	Kumaramangala m	63.56	6.9	4.3	47.67	6	24	22	32	4	2.9	8.86	0.1	BDL	BDL	ND
39	SO422	2013 May	Vannapuram	64.40	6.7	2.2	48.3	4	22	24	24	9.6	3.9	2.2	0.1	BDL	BDL	ND
40	SO423	2013 May	Velliyamattom	35.67	6.8	1.6	26.75	5	30	29	32	4	1.9	8.86	BDL	BDL	BDL	ND
41	SO424	2013 Sept	Adimali	47.53	7.4	3.5	35.65	4	35	26	38	4	2.4	8.86	0.2	BDL	BDL	ND
42	SO425	2013 Sept	Rajakkad	30.67	7.5	1.7	23.00	6	24	20	22	4.3	2.4	11.1	0.2	BDL	BDL	ND
43	SO427	2013 Sept	Upputhara	36.00	7.2	2.0	27.00	5	30	24	29	3.4	2.1	8.86	0.05	BDL	BDL	ND
44	SO428	2013 Sept	Peerumade	60.00	7.3	2.3	45.00	6	24	26	38	6.4	3.1	7.15	0.1	BDL	BDL	ND
45	IDKB-031	2013 Sept	Kattappana	65.33	7.2	1.8	49.00	5	36	20	25	7.5	4	5	0.05	BDL	BDL	ND
46	IDKB-051	2013 Sept	Peermedu	50.37	7.5	1.4	37.78	6	45	28	38	8	4.5	4	0.2	BDL	BDL	ND
47	IDKO-011	2013 Sept	Karimkunnam	60.00	7.2	2.2	45.00	6	29	26	29	9.4	5.3	4	BDL	BDL	BDL	ND
48	IDKO-032	2013 Sept	Karimannur	55.04	6.9	6.7	41.28	5	38	20	34	6.7	3.9	5	BDL	BDL	BDL	ND
49	IDKO-052	2013 Sept	Devikulam	69.33	6.6	1.5	52.00	5	25	22	30	8	4.9	8.86	0.1	BDL	BDL	ND
50	IDKO-08	2013 Sept	Marayoor	74.67	7.1	1.7	56.00	5	23	26	38	7.4	5.3	17.7	0.05	BDL	BDL	ND
51	IDKO-09	2013 Sept	Vannappuram	39.00	7.1	4.7	29.25	5	34	30	43	6.5	3.3	4.48	0.1	BDL	BDL	ND
52	IDKO-13	2013 Sept	Rajakumari	95.33	6.9	2.3	71.50	6	30	29	35	7.2	3.8	17.7	0.05	BDL	BDL	ND
53	IDKO-14	2013 Sept	Santhanpara	86.67	7.4	1.8	65.00	3	25	30	39	6.3	4.1	17.7	BDL	BDL	BDL	ND
54	IDKO-16	2013 Octo	Nedumkandom	65.73	7.3	1.4	49.30	4	23	30	43	7.4	4	2	BDL	BDL	BDL	ND
55	IDKO-18	2013 Octo	Vathikudy	36.25	6.8	2.2	29.00	5	25	18	23	5.5	4.5	1	0.1	BDL	BDL	ND
56	IDKO-20	2013 Octo	Peruvanthanam	80.00	7.1	1.6	64.00	3	25	28	35	9.8	3.5	BDL	0.1	BDL	BDL	ND

57	IDKO-22	2013 Octo	Vandipperiyar	0.00	7.2	1.5		3	26	22	26	6.4	4.1	BDL	0.1	BDL	BDL	ND
58	IDKO-24	2013 Octo	Vandanmedu	73.75	7	1.7	59.00	4	32	20	28	7.3	4	BDL	BDL	BDL	BDL	ND
59	IDKO-25	2013 Octo	Upputhara	82.10	6.9	2.8	65.68	4	30	22	32	8.1	3.6	BDL	0.2	BDL	BDL	ND
60	IDKO-28	2013 Octo	Arakulam	36.94	6.8	2.3	29.55	5	44	26	35	8.6	3.4	BDL	0.2	BDL	BDL	ND
61	IDKO-30	2013 Octo	Thodupuzha Municipality	46.85	6.9	1.8	37.48	6	30	30	36	9	3.2	4.43	0.05	BDL	BDL	ND
62	IDKO-39	2013 Octo	Adimali	36.25	6.9	5.0	29.00	7	30	24	31	7.4	3.9	17.7	0.1	BDL	BDL	ND
63	IDKO-40	2013 Octo	Munnar	70.00	6.7	2.2	56.00	5	28	22	34	9.5	3	4.43	0.05	BDL	BDL	ND
64	IDKO-43	2013 Octo	Vazhathoppu	50.66	7.1	1.6	40.53	4	26	28	45	9.9	2.8	44.3	0.2	BDL	BDL	ND
65	IDK012	2013 Octo	Thodupuzha	46.20	7.2	1.6	36.96	5	28	25	25	10	2.6	35.4	BDL	BDL	BDL	ND
66	IDK03	2013 Octo	Muttom	37.98	7	1.5	30.38	4	32	23	23	7.4	3.7	8.86	BDL	BDL	BDL	ND
67	IDK04	2013 Octo	Arakkulam	90.31	7.7	2.8	72.25	4	28	26	38	7.2	3.6	BDL	0.1	BDL	BDL	ND
68	IDK05	2013 Octo	Vannapuram	57.50	7.1	1.1	46.00	5	30	20	30	8.1	3.6	BDL	0.05	BDL	BDL	ND
69	IDK06	2013 Octo	Karimannoor	46.25	7	2.3	37.00	4	26	24	30	8.6	3.4	4	0.1	BDL	BDL	ND
70	IDK07	2013 Octo	Vazhathope	56.25	7	1.8	45.00	5	32	26	24	9	3.2	2	0.05	BDL	BDL	ND
71	IDK08	2013 Octo	Kattappana	86.46	7.2	6.5	69.17	6	30	20	43	7.6	3.7	4	BDL	BDL	BDL	ND
72	IDK09	2013 Octo	Elappara	82.88	6.4	2.2	66.30	6	44	28	55	9.5	3	8	BDL	BDL	BDL	ND
73	IDK10	2013 Octo	Peruvanthanam	46.25	6.2	1.6	37.00	5	30	26	45	9.9	2.8	2	0.1	BDL	BDL	ND
74	IDKO2	2013 Octo	Karimkunnam	87.71	7.2	1.5	70.17	6	30	20	43	10	2.6	2	0.1	BDL	BDL	ND
75	1010313	2013 Mar	Elappara	66.50	6.3	1.7	46.55	3	28	22	46	8.1	3.7	4	0.1	BDL	BDL	ND
76	2010313	2013 Mar	do	56.14	6.8	6.0	39.30	4	26	26	54	11	2.4	8	0.1	BDL	BDL	ND
77	3010313	2013 Mar	do	37.14	6.9	8.0	26.00	7	26	30	39	11	2.2	BDL	0.03	BDL	BDL	ND
78	4010313	2013 Mar	do	64.29	7.1	11	45.00	5	32	29	47	12	2	1	0.2	BDL	BDL	ND
79	5010313	2013 Mar	do	55.71	7.1	1.4	39.00	6	30	30	48	8.5	3.4	BDL	0.1	BDL	BDL	ND
80	6010313	2013 Mar	Chenkara	92.86	7.1	0.2	65.00	5	44	30	59	8.5	3.4	1	0.1	BDL	BDL	ND
81	7010313	2013 Mar	Anavilasam	45.97	6.9	1.6	32.18	4	36	18	43	9.5	3	2	0.2	BDL	BDL	ND
82	8020313	2013 Mar	Chakkupallam	60.23	7	0.8	42.16	5	34	28	43	9.9	2.8	4	0.1	BDL	BDL	ND
83	9020313	2013 Mar	Nedumkandam	41.43	6.9	1.5	29.00	3	32	22	35	10	2.6	BDL	0.1	BDL	BDL	ND
84	10020313	2013 Mar	do	83.14	7	1.7	58.2	4	30	20	34	8.9	3.3	2	0.2	BDL	BDL	ND
85	11020313	2013 Mar	do	39.10	6.7	1.1	27.37	5	30	22	47	11	2.4	1	0.1	BDL	BDL	ND
86	12030313	2013 Mar	poopara	57.90	6.7	2.3	40.53	3	28	26	39	11	2.2	1	0.2	BDL	BDL	ND
87	13030313	2013 Mar	Moolathara, Poopara	34.40	6.6	1.7	24.08	5	26	30	36	9.2	3.1	2	0.2	BDL	BDL	ND
88	14030313	2013 Mar	Thalakkulam, Poopara	33.20	7.2	1.4	23.24	3	36	24	36	8.1	3.6	6	0.2	BDL	BDL	ND
89	15030313	2013 Mar	Pampadumpara	46.43	7.2	0.8	32.5	5	26	22	25	8.6	3.4	1	0.1	BDL	BDL	ND

90	16030313	2013 Mar	do	65.21	7.2	1.6	45.65	4	32	28	31	9	3.2	2	0.2	BDL	BDL	ND
91	17030513	2013 May	Kailasanad, Udumbumchola	40.21	7.2	1.5	28.15	5	30	25	35	9.3	3.1	3	0.25	BDL	BDL	ND
92	18030513	2013 May	Kallupalam, do	37.40	7.1	1.5	26.18	3	44	23	49	9.5	3	2	0.2	BDL	BDL	ND
93	19030513	2013 May	Namari, do	47.43	7.1	3.5	33.2	7	30	26	55	9.9	2.8	8	0.2	BDL	BDL	ND
94	20030513	2013 May	Thalakkulam	57.90	6.7	2.3	40.53	4	30	20	43	10	2.6	4	0.2	BDL	BDL	ND
95	21040513	2013 May	Kattappana	41.57	7	1.8	29.1	6	28	24	48	9.3	3	4	0.2	BDL	BDL	ND
96	22040513	2013 May	Vallakkadav, Kattappana	33.20	6.7	1.4	23.24	4	26	26	49	11	2.4	3	0.15	BDL	BDL	ND
97	23040513	2013 May	Moonnilavu, Thodupuzha	67.14	6.8	2.2	47.00	5	26	20	26	11	2.2	3	0.15	BDL	BDL	ND
98	24060513	2013 May	Adimali, Munnar	72.99	6.8	1.6	51.09	3	32	28	35	12	2	2	0.1	BDL	BDL	ND
99	25060513	2013 May	Kallar, Munnar	60.26	7.1	3.5	42.18	4	30	26	37	9.7	2.9	4.43	0.13	BDL	BDL	ND
100	26060513	2013 May	Vallathooval, Anachal	55.81	7.1	4.8	39.07	5	44	20	49	9.8	2.9	13.3	0.18	BDL	BDL	ND

Table 2: Pesticide Residue Analysis for Soil Samples

Name of Pesticides	Arithmetic Mean(mgKg-1)	µgKg-1)
Endosulfan-I	0	0.0
Endosulfan II	0.00633333	6.3
Endosulfan sulfate	0.086278	86.3
Total Endosulfan	0.092611	92.6
P,P'- DDE	0.014222	14.2
P,P' – DDD	0.0051	5.1
P,P' – DDT	0.0000	0.0
Total DDT	0.0193	19.3
Chlorpyriphos	0.0465	46.5
Quinalphos	0.02616667	26.2
Ethion	0.03955556	39.6
Total organophosphorous	0.1122	112.2
Total pesticide residue in soil samples	0.224111	224.11

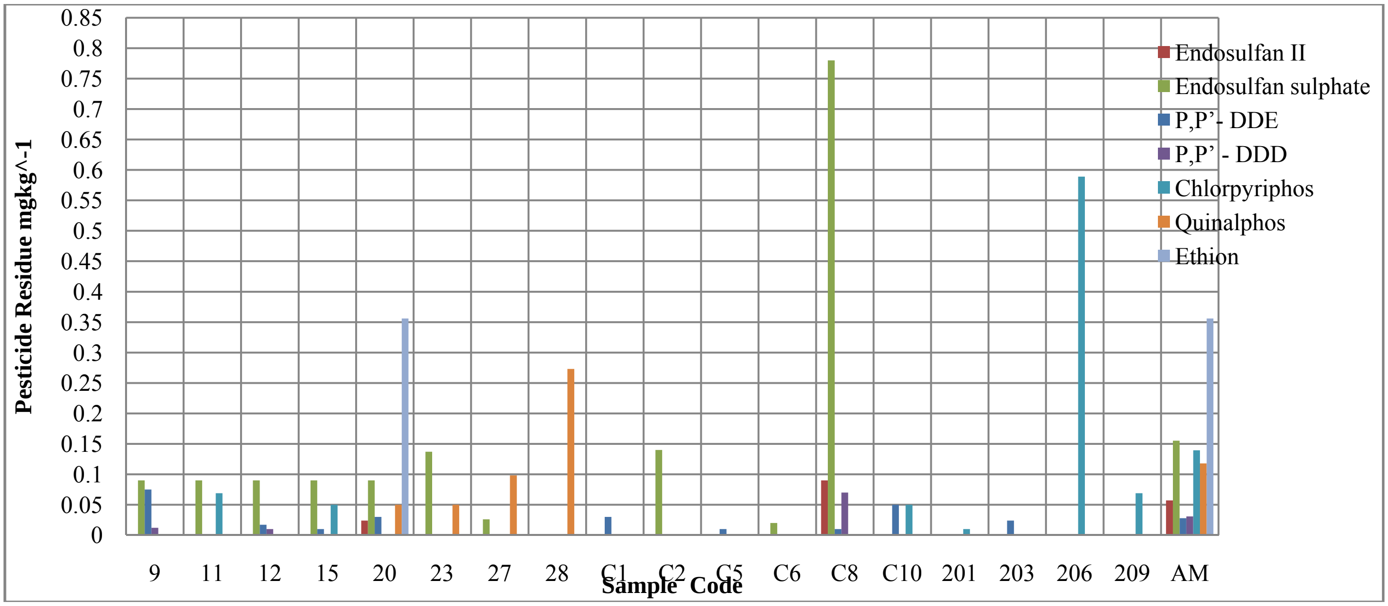

Fig. 2: Concentration of Pesticide Residues in soil samples

The test results were critically analysed and interpreted following the earlier reports and research data. A total of 4 organochlorine residues were identified, confirmed and quantified (fig.2). The analysis shows that there is a probability of getting endosulfan in soils of Idukki district cardamom plantations at 31.6 % within a range of 0-0.87 $mgKg^{-1}$ and a mean value of 0.093 $mgKg^{-1}$ as shown in (Table 2). DDT, another OC pesticide are present in 29 % of the soil samples in the range of 0.01 - 0.087 $mgkg^{-1}$ with a mean value of 0.0193 $mgKg^{-1}$. Organophosphorous pesticides Chlorpyriphos, Quinalphos and Ethion were present in 21 % of the samples within a range of 0.01- 0.589 $mgKg^{-1}$ and a mean value of 0.1122 $mgKg^{-1}$. The probability of contamination of the soil in the cardamom plantations by any of these pesticides is as high as 82 %. The test of hypothesis was carried out to establish the experimental results and its predictions. The test of hypothesis at 5 % significance level and degree of freedom 17 shows that the residues of endosulfan, DDT and organophosphorous pesticides are available in the soil at 0.10 $mgKg^{-1}$,0.03 $mgKg^{-1}$, 0.12 $mgKg^{-1}$ respectively.

4. INVERSE DISTANCE WEIGHTED INTERPOLATION AND MAPING OF CONTAMINATED AREAS

The interpolation and probable contaminated area are identified by Inverse Distance Weighted (IDW) method based on deterministic interpolation technique. Interpolation can be used to estimate elevation, rainfall, temperature, chemical dispersion, or other spatially-based phenomena. Deterministic interpolation techniques can be divided into two groups, global and local. Global techniques calculate predictions using the entire dataset. Local techniques calculate predictions from the measured points within neighborhoods, which are smaller spatial areas within the larger study area.

Inverse Distance Weighted (IDW) interpolation explicitly implements the assumption that, things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. The weights are represented in terms of optimal power (p). The value of p is determined by minimizing the root mean square prediction error (RMSPE). The RMSPE is the statistic that is calculated from cross- validation. In cross-validation, each measured point is removed and compared to the predicted value for that location. The RMSPE is a summary statistic quantifying the error of the prediction surface. The RMSPE is plotted for several different powers for the same dataset. A curve is fit to the points (a quadratic Local Polynomial equation), and from the curve the power that provides the smallest RMSPE is determined as the optimal power. As p increases, the weights for distant points decrease rapidly. If the p value is very high, only the immediate few surrounding points will influence the prediction. Geostatistical Analyst uses power functions greater than 1. The shape of the area trying to create is to be fixed based on the nature of data upon which the prediction is to be carried out. If there are no directional influences on the weighting of data, the shape to be considered as a circle. If directional influences such as water flow is to be represented in the data, then the neighborhood is considered as an ellipse with the major axis parallel to the direction of flow. Define the maximum and minimum number of locations to be considered and divide the neighborhood into sectors and the maximum and minimum constraints will be applied to each sector.

For the present study**,** **t**he sample values for various parameters obtained from random locations are interpolated to create continuous surfaces. The Interpolation is done based on deterministic global technique fixing, the Idukki district boundary as limitation. The pesticide residues in known points and the soil characteristics which has influence in pesticide concentration viz. pH of soil, % finer (< 75 microns) and the elevation of the sampling points were taken to interpolate the unknown values of non sampling points. The chemical composition prediction was obtained for the entire district and is represented in the maps with proper legend using Quantum GIS Desktop (QGIS) software.

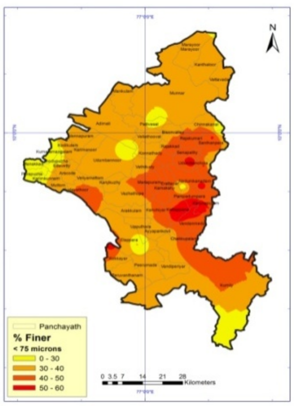

Fig. 3: Soil sensitive area

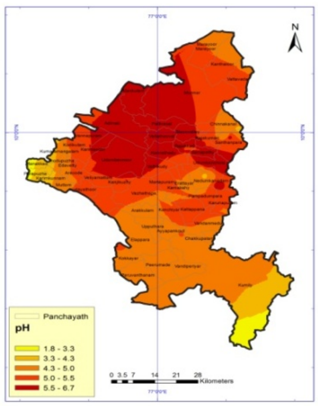

Fig. 4: Soil pH

The spatial distribution of pesticide application shows that soil in Kattappana, Udumbanchola and Nedumkandam panchayaths (Fig 3) is very sensitive and hence adhesion of pesticide residue and high risk of bound pesticide residue in identified. At the same time in panchayaths like Nadumkandam, Udumbanchola, Rajakkkad, Konnathady, Munnar and the surrounding area (Fig.4) the soil pH is favourable for faster degradation and hence expecting low concentration of pesticide residues without affecting the environmental cycle. Santhanpara, Kattappana, and surrounding pachayats are within the high risk zone of organophosphorous pesticide residue at the rate of 0.2-0.35mgKg^{-1} (Fig.5). Santhanpara panchayath is also within the high risk zone to Endosulfan residue and predicted concentration ranges from 0.3-0.5mgKg^{-1} (Fig.6).

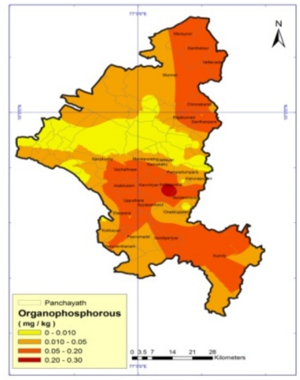

Fig. 5: Pollution due to Organophosphorous pesticides

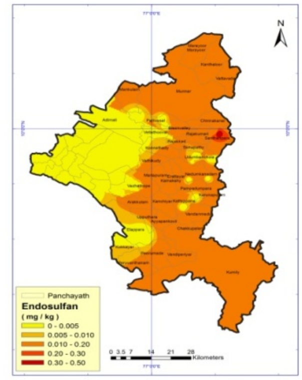

Fig. 6: Pollution due to Endosulfan

5. CONCLUSIONS

1. The water sources in Idukki district is found to be protected from toxic pesticide residues.
2. Endosulfan which is a banned toxic pesticide is still in use and residue is observed at high concentrations in Santhanpara panchayath.
3. Soil is very sensitive and the degradation of pesticides is at a faster rate due to forestal soil properties and climatic conditions.
4. Udumbanchola Taluk is mostly under high risk of pesticide residue and hence strict monitoring and control is to be implemented there.
5. Decontamination of soil by intensive soil cultivation and intensive fluctuation of soil humidity without applying agro-chemicals for a long-lasting soil decontamination of persistent organic chemicals is highly recommended in this case [14].

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