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Pesticide residues in soil in Olericulture based land use systems in different Agro-climatic zones of Himachal Pradesh

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Abstract
The soils were collected from different fields with intensive vegetable crop producing land use systems and uncultivated fields, from four agroclimatic zones of Himachal Pradesh *viz*., 1) sub tropical sub montane and low hills 2) temperate sub-humid mid-hills 3) wet temperate and high hills 4) dry temperate high hills cold desert, and pesticide residue study was carried out in Toxicology Laboratory, Department of Entomology and Apiculture, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. More than 90 per cent soil samples analysed from different zones of the state have shown presence of various pesticide residues *viz.*, DDT, HCH, endosulfan, chlorpyrifos, pyrethroids, dicofol and chlorothalonil. The orchard soils intercropped with cereals also showed the presence of HCH, DDT, endosulfan and dicofol residues. It can be concluded that the most common insecticide residues in Himachal soils are DDT, HCH, endosulfan, chlorpyrifos, dicofol, pyrethroids and chlorothalonil in the order of decreasing contamination. In vegetable soils, especially in cabbage, DDT was the major contaminant followed by endosulfan and dicofol. The tomato soils showed variably much higher concentration of HCH isomers as compared to its corresponding level in cabbage soils.

Keywords: Pesticide residue, HCH, DDT, chlorpyrifos, endosulfan, vegetable

Introduction
Himachal Pradesh is basically a horticultural and vegetable growing state, comprising of varied agroclimatic zones. It has made a tremendous progress in the production of fruit crops, especially apple. The area under fruit crops has been increased from 44,329 ha in 1971 to 202362 ha in 1998 which is about 43.02 per cent of the total area followed by vegetable crops (26.59%), intercropped cereals (22.39%) and uncultivated land (8.03%). Synthetic pesticides are still being the choice of farmers because these display a wide spectrum of activity. In Himachal Pradesh the annual consumption of pesticides is about 718 MT. However, the information provided by the department of Agriculture, Himachal Pradesh regarding the consumption of pesticides is different i.e. 239003 kg/lit (technical grade). Out of this the contribution of insecticides is 47.81 per cent followed by wedicides (34%) and fungicides (15.57%). Among different districts, Kangra district has been reported to consume maximum pesticides (16.40%) whereas minimum consumption was observed in district Bilaspur.

At present, out of the 145 pesticides registered in India about 40 are in use on various crops in the state and this consumption is increasing at alarming rate. In India and elsewhere in the world, synthetic pesticides have been very popular for their use by farmers because of their broad spectrum of activity, ease in storage, application, and high economic returns. Even though the consumption of pesticides in India is about 400 g/ha which is very low as compared to Europe 2 kg/ha and 10 kg/ha in Japan, yet there is a wide spread contamination of our feed and food commodities and environment with pesticides. Pesticides like DDT, HCH, HCB, dieldrin and endrin have a long history of use in the world for control of agricultural pests and are typical persistent organic pollutants (Wang *et al.*, 2007; Sharma *et al.*, 2015) [22, 21]. These are still routinely found in soil, water, air and even in the food chain (Gong *et al*. 2004; Barriada-Pereira *et al*. 2005; Concha-Grana *et al*. 2006) [12, 4, 7]. A number of reports have indicated the presence of different groups of pesticide residues in soils from several parts of India (Kumari *et al.*, 2004; Jayashree and Vasudevan, 2006; Bishnu *et al.*, 2008; Sharma *et al.*, 2015) [18, 16, 5, 21] and the world (Manirakiza *et al.*, 2003; Kannan *et al.*, 2003; Dem *et al.*, 2007) [19, 17, 8].

In a recent survey, it was found that the food commodities are not only contaminated with pesticide residues but these have also been detected in underground water and in all the major rivers of India which is quite alarming (Agnihotri 1999; Banshtu, 2015; Brar and Sharma, 2016) [1, 3, 6]. After (pesticides) application either as foliar spray or soil treatment, its major portion is retained on the surface of soil and remaining will be moved down and ultimately find its way into the aquatic system (Jain and Agnihotri 1986) [15].

The state of the Himachal Pradesh specialises in the genre of horticulture. Fruits grow in HP covering an absolute area of 2.07 Lac hectares. Himachal Pradesh has made a tremendous progress in production of fruits during the last two decades. The total production of fruits in the state is not less than 5.00 Lac MTs. Nonetheless there is a speedy progress in biological control measures, yet pesticidal application cannot be dispensed and still it remains as one of the major weapons in the hands of farmers to control pests. Due to market driven demand, to increase the intensity of production customarily farmers have been using agrochemicals with a high dosage to meet the this demand and enhance income through increased production. The situation seems to be goaded in the years to come due to ever increasing demographic growth and dearth of cultivable land. These pesticides can enter ground water resources and surface run-off during rainfall, thus causative of environmental contamination. Because of their widespread use, these are detected soil, water and air (Murugan *et al.*, 2013; Sharma *et al.*, 2015; Bakshi, 2016) [20, 21, 2]. Thus, along with development of HVC crops, many second-generation issues are emerging.

A major fraction of any agricultural pesticide, no matter how applied, eventually finds its way to the soil and it is in the soil that much of the ultimate decomposition takes place. It is obvious therefore, why a great deal of attention paid to study the status of pesticide residues in soils of Himachal Pradesh. Therefore, to know the status of pesticide residues in soils under vegetable land use systems, investigations were carried out for monitoring these residues in different agroclimatic zones of Himachal Pradesh.

Materials and Method

The monitoring of pesticide residues in soils collected from fields with intensive vegetable crop production and uncultivated land use systems, selected for sampling from four agro-climatic zones of Himachal Pradesh *viz*., 1) sub tropical sub montane and low hills 2) temperate sub-humid mid-hills 3) wet temperate and high hills and 4) dry temperate high hills cold desert were carried out in Toxicology Laboratory, Department of Entomology and Apiculture, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. Composite soil samples were drawn from each zone having two identified locations and four land use patterns at two times i.e. before flowering/ before harvest and at harvest of crop by using X and N system of sampling at 0-15 cm depth. The physico-chemical properties of soil in different zones are given in table 1.

Table 1: Physico-chemical properties of soils collected from Himachal Pradesh

Zone	pH	Per cent organic matter
Dry temperate, high hills, cold desert (Zone 4)	7.12	8.24
	66.88	5.84
	66.50	7.34
Wet temperate and high hills (Zone 3)	6.15	10.34
	66.17	10.39
	66.82	4.13
Temperate sub-humid mid-hills (Zone 2)	7.00	8.17
	66.80	8.53
	66.66	8.99
Sub-tropical sub-mountane and low hills (Zone 1)	7.22	10.65
	77.21	2.95
	77.83	8.53

Residue Analysis

Soil containing pesticide residues absorbed on florisil, eluted with hexane and acetone (9:1), clean up on silicagel with 15 ml mixture of hexane and acetone in 9:1 ratio (v/v) was quantified on Gas chromatograph. The soil sample (1 kg) brought from fields were air dried, mixed thoroughly and sieved through 20 mm mesh sieve. From each sieved sample two-sub samples of 15 g each were drawn for further use.

These sub samples were analyzed for organochlorines, organophosphates, pyrethroids, cyclodienes and some fungicides (mancozeb and carbendazim). From the processed soils samples, 3-5 sub samples of 15g each were taken for spiking and technique standardization. Soil samples of 15g each were fortified at 1 ppm. These samples were processed and peak areas were used to calibrate the integrator using blank for listing quantities of pesticides used in sample. At each level recovery was calculated as follow,

$$\text{Recovery (\%)} = \frac{\text{Amount added}}{\text{Amount recovered}} \times 100$$

Homogenized soil sample of 15g was blended with 0.3g florisil and 0.3g charcoal in mortar until free flowing. The free flowing soil, florisil and charcoal mixture were placed into sintered column, having 1 g anhydrous sodium sulphate at its base. After slight tapping, the packed material was eluted with 100 ml of hexane and acetone, (9:1). Eluent was evaporated to dryness in rotary evaporator at 40-50oC. Residues were re-dissolved in 5 ml n-hexane for clean up. The n-hexane containing pesticide residues and plant material was loaded on 1 g activated silica gel. The column was eluted with 15 ml of 10 per cent acetone in hexane. The eluent was evaporated in rotary evaporator to dryness. Residues were re-dissolved in 5ml n-hexane and 1µl of it was injected into G.C. Pesticide residues were detected using Gas Chromatography (Hewlett Packard 5890 Series II with Agilent 3396 III Integrator) with Ultra Performance Capillary column Cross-linked Methyl Silicon Film thickness: 0.33 microns, Int. diameter: 0.20 mm, length: 25 metre 160ºC for 2 minutes, final temp. 260ºC @ 3.5ºC/min; temperature ECD: 300ºC, NPD: 270ºC; detector temperature was 260ºC; Injection temp.

Gas flow- Iolar Nitrogen @ 4 ml/min., septa purge @ 2 ml/min., make up gas 25 ml/min, Hydrogen 1 ml/min. The residues of dithiocarbamates were estimated as per the method of Dubey and Stan (1998) [10]. Dithiocarbamate residues were estimated according to method described by Dubey *et al.* (1999) [9] on CS_2 basis. The residues estimation methods followed for different pesticides in the present study are given in table 2.

Table 2: Various residues estimation methods

Sr. No.	Name of pesticide	Residues estimation method	Reference
1.	DDT	Colorimetric	Schechter and Haller (1945)
2.	Parathion	Colorimetric	Averell and Norris (1948),
3.	Benezene hexachloride	Colorimetric	Schechter and Hornstein (1952)
4.	Aldrin	Colorimetric	O'Donnell *et al.* (1954)
5.	Dieldrin	Colorimetric	O'Donnell *et al.* (1955)
6.	Dieldrin	GC-ECD	Gutenmann and Lisk (1963)
7.	Disyston	Colorimetric	Schummann and Olson (1964)
8.	γHCH (Hexachlorocyclohexane)	TLC/GC	Kovacs (1965)
9.	Carbaryl	Spectrophotometer	Benson and Finocchiaro (1965)
10.	Dimethoate and thimet	GC emission spectroscopic	Bache and Lisk (1966)
11.	Carbofuran	GC-NPD	Cook *et al.* (1969)
12.	Disulfoton	GLC	Zweig and Sharma (1972)
13.	Carbofuran	Colorimetric	Gupta and Dewan (1973)
14.	DDT	TLC	Balinov (1973)
15.	Organophosphorus	Colorimetric	Jain *et al.* (1974)
16.	Benomyl and Methyl N (2. Benzimidazole) carbamate	GC-ECD	Rouchaud and Decallone (1974)
17.	OP	TLC	Katkar and Barve (1976)
18.	Chlorophenol	GC	Bartoletti and Binecchio (1977)
19.	Propyzamide	GC-ECD	Gousowski (1980)
20.	Metribuzin	GC-N-specific Alkali flame ionization detector	Jarczyk (1983)
21.	Quinalphos, disulfoton, monocrotophos	TLC	Mirashi *et al.* (1985)
22.	Benomyl and Methyl N (2. Benzimidazole) carbamate	Voltametric determination	Kavetskii and Andrienko (1986)
23.	Fluzifop-butyl	GLC-N-specific detector	Clegg (1987)
24.	Dichlobenil	HPLC	Schmidt *et al.* (1988)
25.	Pyrethroids	GC	Ming *et al.* (1989)
26.	Methyl-parathion	HPLC	Kaur *et al.* (1998)
27.	Butachlor	GC-ECD	Prakash *et al.* (2000)
28.	DDT	ELISA	Maestroni *et al.* (2001)
29.	Atrazine	ELISA	Kramer *et al.* (2001)
30.	Triazine and chloroaectanilide	GC-NPD or GC-MS	Vryzas *et al.* (2002)

Results and Discussion

Pesticide residues in cabbage soils

The pesticide residues in cabbage growing soils collected from Rekong Peo, Bajaura and Dhaulakuan areas are presented in Table 3. The data reveal that in Rekong Peo soil samples dicofol (0.015 mg/kg), α-endosulfan (0.005 mg/kg), β-endosulfan (0.013 mg/kg) and endosulfan-sulphate (0.136 mg/kg) were present before harvest where as at harvest p,p'-DDE (0.007 mg/kg), endosulfan-sulphate (0.003 mg/kg), p,p'-DDT (0.003 mg/kg), chlorpyrifos (0.362 mg/kg) and o,p'-DDD (0.296 mg/kg) were detected. The dicofol (0.003 mg/kg), o,p'-DDE (0.014 mg/kg), p,p'-DDE (0.002 mg/kg), β-endosulfan (0.003 mg/kg) and p,p'-DDD (0.003 mg/kg) were the main contaminants in soils of Bajaura before harvest stage, whereas, at harvest the residues of dicofol, p,p'-DDE, p,p'-DDD and p,p'-DDT were detected at concentration of 0.004, 0.006, 0.003 and 0.007 mg/kg, respectively in soil samples. In Dhaulakuan area, residues were not detected before harvest whereas, at harvest the residues of δ-HCH, p,p'-DDE, chlorpyrifos-methyl, chlorpyrifos and α-methrin were determined as 0.009, 0.012, 0.004, 0.004 and 0.015 mg/kg, respectively in soil samples.

Pesticide residues in tomato soils

Soil samples collected from tomato growing areas of Solan and Bilaspur districts reveal that samples from Bilaspur district contained α-HCH (0.003 mg/kg), γ-HCH (0.003 mg/kg), δ-HCH (0.252 mg/kg), o,p'-DDE (0.001 mg/kg), p,p'-DDE (0.002 mg/kg), β-endosulfan (0.003 mg/kg) and p,p'-DDD (0.003 mg/kg) before harvest, whereas, at harvest the residues of α-HCH, β-HCH, γ-HCH, δ-HCH, p,p'-DDE, p,p'-DDD and p,p'-DDT were detected with their respective concentrations of 0.003, 0.001, 0.003, 0.253, 0.006, 0.003 and 0.007 mg/kg (Table 4). In the soil samples of district Solan, the residues of α-HCH, γ-HCH, α-endosulfan, p,p'-DDE, β-endosulfan, p,p'-DDD, p,p'-DDT, chlorpyrifos-methyl, chlorpyrifos, chlorothalonil and o,p'-DDD were determined with their respective concentration of 0.005, 0.003, 0.008, 0.002, 0.003, 0.003, 0.012, 0.006, 0.004, 0.004 and 0.020 mg/kg at harvest, whereas before harvest, residues were below detectable level.

Pesticide residues in pea, French bean and chilly soils

Representative soil samples of pea, French bean and chilly cropped fields were monitored from Kukumseri, Mashobra and Jachh, respectively. In pea cropped soil, dicofol (0.003 mg/kg) and β-endosulfan (0.001 mg/kg) were present before harvest, whereas, at harvest the residues of α-HCH, β-HCH, γ-HCH, δ-HCH, α-endosulfan, p,p'DDE, β-endosulfan, op-DDT, endosulfan-sulphate, p,p'-DDT, chlorpyrifos-methyl, chlorpyrifos, o,p'-DDD and α-methrin were determined as 0.004, 0.005, 0.003, 0.003, 0.002, 0.006, 0.005, 0.006, 0.003, 0.003, 0.006, 0.004, 0.008 and 0.007 mg/kg, respectively (Table 5). The french bean soil of Mashobra, were found free from pesticide residues before harvest whereas, at harvest the soils contained residues of p,p'-DDE (0.003 mg/kg), β-

endosulfan (0.002 mg/kg), endosulfan-sulphate (0.009 mg/kg) and p,p'-DDT (0.004 mg/kg). At Jachh, the chilly growing soils contained only p,p'-DDE (0.002 mg/kg), before harvest and chlorpyrifos-methyl (0.004 mg/kg) at harvest stage.

All the vegetable soils (cabbage, tomato, pea and french bean) collected from different locations of Himachal Pradesh have shown higher accumulation of organochlorine pesticide residues, especially DDT, HCH, endosulfan and dicofol. In cabbages soils, their occurrence was Σ-DDT (0.012-0.306 mg/kg), Σ-endosulfan (<0.002 to 0.087 mg/kg) and dicofol (<0.004 – 0.015 mg/kg). Among HCH isomers, δ-HCH (0.009 mg/kg) was detected only in Dhaulakuan samples. The tomato soils showed variably much higher concentration of Σ-HCH (0.008-0.259 mg/kg) as compared to its corresponding level in cabbage soils, while other two insecticides Σ-DDT (0.015-0.037 mg/kg) and Σ-endosulfan (0.003-0.011 mg/kg)) were found in low level. The contamination of pesticide residue in pea soils were Σ-HCH (0.015 mg/kg), Σ-DDT (0.027 mg/kg), Σ-endosulfan (0.008 mg/kg) and dicofol (0.003 mg/kg). In french bean soils, the contaminants were Σ-DDT (0.007 mg/kg) and Σ-endosulfan (0.011 mg/kg), while in chilly soils, only DDT metabolite p,p'-DDE (0.002 mg/kg) was found (Table 6). Regarding organophosphorus and synthetic pyrethroids residues, their presence was observed minimum as compared to organochlorine insecticides. Among organophosphorus insecticides, studied for residue analysis only chlorpyrifos was noticed in all the vegetable samples. Its residues were found highest in cabbage soils from <0.010 to 0.362 mg/kg followed by tomato and pea having <0.010 to 0.010 mg/kg and chilly 0.004 mg/kg. The two soils, cropped with cabbage and pea collected from Dhaulakuan and Kukumseri were found contaminated with α-methrin (0.015 and 0.007 mg/kg), respectively.

The present findings are in conformity with the findings of Harris and Sans (1969, 1971) [13, 14] who reported that apple orchard soils had the highest organochlorine residues in the cropping practices. They reported both DDT and dicofol in orchard soils. The higher residues of organochlorines as compared to present findings have been reported by Frank *et al.* (1976) [11]. According to them the most frequently found insecticides were DDT, TDE and their metabolites DDE which were not longer in use. Apple and peach orchards had the highest mean residues of 43.3 and 9.22 ppm of Σ-DDT, respectively. Other organochlorine insecticides found were endosulfan, endrin and methoxychlor residues were below 1 ppm with the exception of endosulfan. The lower residue levels may be due to the complete restriction on their use in public health and on fruit crops. Different orchards were studied by Harris and Sans (1969, 1971) [13, 14], who also suggested a continuing decline in Σ-DDT residues.

Pesticide residues in uncultivated fields

Pesticide residues were also monitored in uncultivated field soils from eight locations *viz*., Kukumseri, Rekong Peo, Bajaura, Mashobra, Bilaspur, Solan, Dhaulakuan and Jachh. The data presented in Table 7 show that in Kukumseri samples, α-HCH (0.002 mg/kg), β-HCH (0.009 mg/kg), γ-HCH (0.003 mg/kg), dicofol (0.025 mg/kg), α-endosulfan (0.005 mg/kg) and p,p'-DDE (0.003 mg/kg) were found. At Rekong Peo location, the residues of γ-HCH (0.002 mg/kg), δ-HCH (0.002 mg/kg), dicofol (0.006 mg/kg), o,p'-DDE (0.004 mg/kg), α-endosulfan (0.004 mg/kg), p,p'-DDE (0.002 mg/kg), β-endosulfan (0.016 mg/kg) and endosulfan-sulphate (0.029 mg/kg) were detected. In the samples collected from Bajaura location, the residues of dicofol (0.004 mg/kg), α-endosulfan (0.003 mg/kg), p,p'-DDE (0.049 mg/kg), β-endosulfan (0.002 mg/kg), p,p'-DDD (0.070 mg/kg) and o,p'-DDT (0.015 mg/kg) were obtained whereas, in samples collected from Mashobra the residues of p,p'-DDD (0.196 mg/kg) and α-methrin (0.026 mg/kg) were recorded and in Bilaspur area, the residues of α-HCH, γ-HCH, dicofol, p,p'-DDE, p,p'-DDD, o,p'-DDT and p,p'-DDT were detected at concentrations of 0.003, 0.013, 0.003, 0.126, 0.035, 0.015 and 0.153 mg/kg, respectively. The soil samples from Solan were found contaminated with α-HCH (0.008 mg/kg), γ-HCH (0.004 mg/kg), p,p'-DDE (0.005 mg/kg), β-endosulfan (0.003 mg/kg), p,p'-DDT (0.006 mg/kg), chlorpyrifos-methyl (0.005 mg/kg), p,p'-DDD (0.008 mg/kg), cypermethrin (0.097 mg/kg), α-methrin (0.009 mg/kg) and β-cyfluthrin (0.034 mg/kg). The Dhaulakuan soils were observed to contain the residues of γ-HCH (0.003 mg/kg), α-endosulfan (0.006 mg/kg) and p,p'-DDE (0.005 mg/kg). However, in the soils of Jachh the residues of δ-HCH, p,p'-DDD, o,p'-DDT and chlorpyrifos were detected as 0.001, 0.010, 0.003 and 0.004 mg/kg, respectively.

The data presented in Table 8 show that all samples collected from different locations of Himachal Pradesh contained residues of HCH, DDT, endosulfan and dicofol. The concentrations of Σ-DDT residues varied from 0.003-0.329; Σ-HCH, from <0.002 to 0.016; Σ-endosulfan <0.002 to 0.049 and dicofol (<0.004 to 0.025 mg/kg). Among pyrethroids, cypermethrin (0.097 mg/kg), β-cyfluthrin (0.034 mg/kg) and α-methrin (0.009 mg/kg) were detected in Solan soils while Mashobra soil was found to be contaminated with α-methrin (0.026 mg/kg).

Conclusions

In the present investigations, more than 90 per cent soil samples, analysed from different zones of the state, have shown presence of various pesticide residues *viz*., DDT, HCH, endosulfan, chlorpyrifas, pyrethroids dicofal and chlorothalonil. The frequency of their occurrence was recorded in the order; DDT 25.35%> HCH 21.12% >endosulfan 20.42% > chlorpyrifos 14.78% > dicofol 10.56% > pyrethroids 6.33% and chlorothalonil 1.40%. Among HCH isomers, γ-HCH was detected in all the locations followed by α-HCH, δ-HCH and β-HCH, which were found in 7, 6 and 4 locations, respectively. In case of DDT, the metabolite p,p'-DDE was encountered more frequently in all the locations while p,p'-DDT (parent compound) was detected in 6 locations. Among organophosphorus insecticides only chlorpyrifos could be detected in seven locations except Bilaspur. The contamination of synthetic pyrethroids has also been found at low level. Among these α-methrin was the major contaminant followed by cypermethrin, β-cyfluthrin and fenvalerate. The only fungicide chlorothalonil 0.004 and 0.058 mg/kg was detected in Solan and Jachh soils, respectively. In vegetable soils, especially in cabbage, DDT was the major contaminant followed by endosulfan and dicofol. The tomato soils showed variably much higher concentration of HCH isomers as compared to its corresponding level in cabbage soils.

Table 3: Pesticide residues in cabbage soils of Himachal Pradesh

Location	Sampling time	Residues (mg/kg)*												
		δ- HCH	dicofol	o,p'-DDE	α- endosulfan	p,p'-DDE	β- endosulfan	p,p'-DDD	endosulfan sulphate	p'p'-DDT	chlorpyrifos- methyl	chlorpyrifos	o'p'-DDD	α-methrin
Rekongpeo	Before harvest	ND	0.015	ND	0.005	ND	0.013	ND	0.136	ND	ND	ND	ND	ND
	At harvest	ND	ND	ND	ND	0.007	ND	ND	0.003	0.003	ND	0.362	0.296	ND
Bajaura	Before harvest	ND	0.003	0.014	ND	0.002	0.003	0.003	ND	ND	ND	ND	ND	ND
	At harvest	ND	0.004	ND	ND	0.006	ND	0.003	ND	0.007	ND	ND	ND	ND
Dhaula Kuan	Before harvest	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	At harvest	0.009	ND	ND	ND	0.012	ND	ND	ND	ND	0.004	0.004	ND	0.015

ND – Not detectable

Table 4: Pesticide residues in Tomato soils of Himachal Pradesh

Location	Residues (mg/kg)													
	Sampling time	α-HCH	ß-HCH	γ - HCH	δ- HCH	o'p'-DDE	α –endosulfan	p,p'-DDE	ß-endosulfan	p'p'-DDD	p'p'-DDT	chlorpyrifos-methyl	chlorpyrifos	o'p'-DDD	chlorothalonil
Bilaspur	Before harvest	0.003	ND	0.003	0.252	0.001	ND	0.002	0.003	0.003	ND	ND	ND	ND	ND
	At harvest	0.003	0.001	0.003	0.253	ND	ND	0.006	ND	0.003	0.007	ND	ND	ND	ND
Solan	Before harvest	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	At harvest	0.005	ND	0.003	ND	ND	0.008	0.002	0.003	0.003	0.012	0.006	0.004	0.020	0.004

ND – Not detectable

Table 5: Pesticide residues in pea, french bean and chilly soils of Himachal Pradesh

Location	Crop	Residues (mg/kg)														
		Sampling time	α-HCH	ß-HCH	γ– HCH	δ- HCH	dicofol	α –endosulfan	p'p'-DDE	ß-endosulfan	o'p'-DDT	endosulfan sulphate	p'p'-DDT	chlorpyrifos-methyl	chlorpyrifos	o'p'-DDD	α- methrin
Kukumseri	Pea	Before harvest	ND	ND	ND	ND	0.003	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND
		At harvest	0.004	0.005	0.003	0.003	ND	0.002	0.006	0.005	0.006	0.003	0.003	0.006	0.004	0.008	0.007
Mashobra	French bean	Before harvest	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		At harvest	ND	ND	ND	ND	ND	ND	0.003	0.002	ND	0.009	0.004	ND	ND	ND	ND
Jachh	Chillies	Before harvest	ND	ND	ND	ND	ND	ND	0.002	ND	ND	ND	ND	ND	ND	ND	ND
		At harvest	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.004	ND	ND	ND

ND - Not detectable

Table 6: Average residues of various pesticides in vegetable soils

Crop	∑HCH	∑DDT	Dicofol	∑Endosulfan	∑Chlorpyrifos	∑Pyrethroids
Cabbage						
i) Rekongpeo	<0.002	0.306	0.015	0.087	0.362	ND
ii) Bajaura	<0.002	0.028	0.003	0.003	ND	ND
iii) Dhaulakuan	0.009*	0.012	ND	ND	0.008	0.015**
Range	(<0.002-0.009)	(0.012-0.306)	<0.004-0.015	(<0.002-0.087)	(<0.010-0.362)	ND
Tomato						

iv) Bilaspur	0.259	0.015	ND	0.003	<0.010	ND
v) Solan	0.008	0.037	ND	0.011	0.010	ND
Range	(0.008-0.259)	(0.015-0.037)	ND	(0.003-0.011)	(<0.010-0.010)	ND
Pea						
vi) Kukumseri	0.015	0.027	0.003	0.008	0.010	0.007**
French bean						
vii) Mashobra	<0.002	0.007	ND	0.011	<0.010	ND
Chillies						
viii) Jachh	<0.002	0.002***	ND	<0.002	0.004	ND

* Delta HCH; ** Alphametrin; ***p,p'-DDE

Table 7: Pesticide residues in uncultivated field soils of Himachal Pradesh

Location	Residues (mg//kg)																		
	α-HCH	ß-HCH	γ - HCH	δ- HCH	dicofal	o,p'-DDE	α endosulfan	p,,p'-DDE	ß endosulfan	p,p'-DDD	o,p'-DDT	endosufan sulphate	p,p'-DDT	chlorpyrifos-methyl	chlorpyrifos	o,p'-DDD	cyper methrin	α Merthrin	ß-Cyfluthrin
Kukumseri	0.002	0.009	0.003	ND	0.025	ND	0.005	0.003	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Reckong Peo	ND	ND	0.002	0.002	0.006	0.004	0.004	0.002	0.016	ND	ND	0.029	ND	ND	ND	ND	ND	ND	ND
Bajaura	ND	ND	ND	ND	0.004	ND	0.003	0.049	0.002	0.070	0.015	ND	ND	ND	ND	ND	ND	ND	ND
Mashobra	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.196	ND	ND	ND	ND	ND	ND	ND	0.026	ND
Bilaspur	0.003	ND	0.013	ND	0.003	ND	ND	0.126	ND	0.035	0.015	ND	0.153	ND	ND	ND	ND	ND	ND
Solan	0.008	ND	0.004	ND	ND	ND	ND	0.005	0.003	ND	ND	ND	0.006	0.005	ND	0.008	0.097	0.009	0.034
Dhaulakuan	ND	ND	0.003	ND	ND	ND	0.006	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Jachh	ND	ND	ND	0.001	ND	ND	ND	NS	ND	0.010	0.003	ND	ND	ND	0.004	ND	ND	ND	ND

ND - Not detectable

Table 8: Average pesticide residues in uncultivated soils

Crop	∑HCH	∑DDT	Dicofol	∑Endosulfan	∑Chlorpyrifos	∑Pyrethoids
Kukumseri	0.014	0.003	0.025	0.005	<0.010	<0.010
Recongpeo	0.004	0.006	0.006	0.049	<0.010	<0.010
Bajaura	<0.002	0.134	0.004	0.005	<0.010	<0.010
Mashobra	<0.002	0.196	<0.004	<0.002	<0.010	0.026**
Bilaspur	0.016	0.329	0.003	<0.002	<0.010	<0.010
Solan	0.012	0.019	<0.004	0.003	0.005	0.140*
Dhaulakuan	0.003	0.005	<0.004	0.006	<0.010	<0.010
Jachh	0.001	0.013	<0.004	<0.002	0.004	<0.010
Range	(<0.002-0.016)	(0.003-0.329)	(<0.004-0.025)	(<0.002-0.049)	(<0.010-0.005)	(<0.010-0.140)

BDL: Below detectable limit; * 0.097 cypermethrin + 0.009 alpha-methrin + 0.034 cyfluthrin; ** α- Methrin

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