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Soil Pesticide Residues in Orchard based Land Use Systems across Different Agro-climatic Zones of Himachal Pradesh

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A B S T R A C T

The soils were collected from different orchard 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. Apple orchard soils were found to contain highest ensdosulfan residues followed by HCH and DDT residues. In mango orchard soils dicofol was detected in addition to the apple soil contaminants. Further, the most common insecticide residues in Himachal soils are DDT, HCH, endosulfan, chlorpyrifos, dicofol, pyrethroids and chlorothalonil in the order of decreasing contamination.

Introduction

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 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). Thus, along with development of HVC crops, many second-generation issues are emerging.

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 (Zhang *et al.,* 2006; Wang *et al.,* 2007; Sharma *et al.,* 2015). 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). 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) and the world (Manirakiza *et al.,* 2003; Kannan *et al.,* 2003; Dem *et al.,* 2007). 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). 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). Therefore, to know the status of pesticide residues in orchard land use soils, and investigations were carried out for monitoring these residues in different agroclimatic zones of Himachal Pradesh.

Materials and Methods

The monitoring of pesticide residues in soils collected from fields with intensive crop production and without cultivation (uncultivated), 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.

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,

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

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 160^{o}C for 2 minutes, final temp. 260^{o}C @ 3.5^{o}C/min; temperature ECD: 300^{o}C, NPD: 270^{o}C; detector temperature was 260^{o}C; 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 estimation methods (Table 2) followed for different pesticides in the present study are given in table 2. The residues of dithiocarbamates were estimated as per the method of Dubey and Stan (1998). Dithiocarbamate residues were estimated according to method described by Dubey *et al.*, (1999) on CS_2 basis.

Results and Discussion

Pesticide residues in apple orchard soils

Pesticide residues were monitored in apple orchard soils collected from four locations viz., Kukumseri, Rekong Peo, Bajaura and Mashobra at two times i.e. before flowering and at harvest. The data presented in Table 3 reveal that in Kukumseri samples HCH isomers viz., α-HCH (0.002 mg/kg), β-HCH (0.004 mg/kg) and γ-HCH (0.016 mg/kg) were detected before flowering whereas, only endosulfan (0.019 mg/kg) was found at harvest stage.

At Rekong Peo, only chlorpyrifos (0.004 mg/kg) was detected before flowering, whereas, α-HCH (0.002 mg/kg), γ-HCH (0.004 mg/kg), p,p'-DDE (0.006 mg/kg), β-endosulfan (0.008 mg/kg) and endosulfan-sulphate (0.311 mg/kg) were detected at harvest time. The samples collected from Bajaura location contained no residue at flowering stage. However, at harvest stage the concentration of p,p'-DDE, β-endosulfan, p,p'-DDT, chlorpyrifos-methyl, and chlorpyrifos were detected as 0.002, 0.006, 0.003, 0.006 and 0.004 mg/kg, respectively.

At Mashobra, none of the soil samples were found contaminated with any pesticide before flowering, whereas, at harvest stage the residues of pesticides viz., α-HCH, β-HCH, γ-HCH, α-endosulfan, p,p'-DDE, β-endosulfan, endosulfan-sulphate, p,p'-DDT, chlorpyrifos and fenvalerate were detected as 0.004, 0.002, 0.003, 0.002, 0.001, 0.012, 0.023, 0.003, 0.005 and 0.011 mg/kg, respectively.

Pesticide residues in mango, plum and kinnow orchard soils of Himachal Pradesh

The pesticide residues at two sampling times i.e. before flowering and at harvest revealed that only β-endosulfan (0.002 mg/kg) was detected in mango orchard soil before flowering (Table 4). At harvest, however, α-HCH (0.001 mg/kg), γ-HCH (0.003 mg/kg), δ-HCH (0.053 mg/kg), dicofol (0.021 mg/kg), o,p'-DDE (0.013 mg/kg), α-endosulfan (0.037 mg/kg), p,p'-DDE (0.007 mg/kg), β-endosulfan (0.011 mg/kg), p,p'-DDD (0.003 mg/kg), o,p'-DDT (0.003 mg/kg), endosulfan-sulphate (0.030 mg/kg) and p,p'-DDT (0.009 mg/kg) were found.

The soils of plum orchards of Solan area, contained residues of γ-HCH (0.003 mg/kg) and p,p'-DDE (0.033 mg/kg) before flowering and p,p'-DDE (0.006 mg/kg), p,p'-DDT (0.003 mg/kg) and chlorpyrifos (0.004 mg/kg), at harvest stage. The kinnow orchard soils of Dhaulakuan area were found contaminated with chlorpyrifos-methyl (0.006 and 0.004 mg/kg), at both the stages of sampling. At Jachh, the residues of β-HCH (0.003 mg/kg) and β-endosulfan (0.006 mg/kg) were found before flowering and no residues of other pesticides were detected at harvest. The experiment conducted for monitoring the pesticides residues in orchard soils (apple, plum, mango and kinnow) indicated that the apple and mango soils were contaminated with DDT, HCH and endosulfan residues (Table 5). Apple orchard soils were found to contain highest endosulfan (0.006-0.319 mg/kg) followed by HCH (<0.002-0.022 mg/kg) and DDT (<0.001-0.006 mg/kg) residues in four different locations (Kukumseri, Rekong Peo, Bajaura and Mashobra) of Himachal Pradesh. Like apple soils, mango orchard soils also accumulated the highest mean contents of Σ-endosulfan (0.073 mg/kg) followed by Σ-HCH (0.057 mg/kg), Σ-DDT (0.034 mg/kg) and dicofol (0.021 mg/kg). The occurrence of high level of endosulfan residues in apple and mango orchard soils has reflected the use of this insecticide in regular interval on the crops for the control of pests. The plum soils contained more Σ-DDT (0.022 mg/kg) than γ-HCH (0.003 mg/kg) residues and only lower residue levels of β-HCH (0.003 mg/kg) and β-endosulfan (0.006 mg/kg) were found in kinnow soils. The present findings are in conformity with the findings of Harris and Sans (1969, 1971) 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). 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), who also suggested a continuing decline in Σ-DDT residues. The results also showed that unlike organochlorine pesticides, the presence of organophosphorus and pyrethriod compounds were present least in apple, mango, plum and kinnow soils. Among organophosphorus insecticides, only chlorpyrifos was detected in apple, plum and kinnow orchards with highest mean residues of 0.010, 0.004 and 0.005 mg/kg Σ-chlorpyrifos, respectively. Though number of pyrethroids have been recommended for the control of fruit pests, yet only the fenvalerate (0.011 mg/kg) and that too in apple sample of Mashobra was detected (Table 5).

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 6 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.

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
	6.88	5.84
	6.50	7.34
Wet temperate and high hills (Zone 3)	6.15	10.34
	6.17	10.39
	6.82	4.13
Temperate sub-humid mid-hills (Zone 2)	7.00	8.17
	6.80	8.53
	6.66	8.99
Sub-tropical sub-mountane and low hills (Zone 1)	7.22	10.65
	7.21	2.95
	7.83	8.53

Table.2 Various residues estimation methods

Sr. No.	Name of pesticide	Residues estimation method
1.	DDT	Colorimetric
2.	Parathion	Colorimetric
3.	Benezene hexachloride	Colorimetric
4.	Aldrin	Colorimetric
5.	Dieldrin	Colorimetric
6.	Dieldrin	GC-ECD
7.	Disyston	Colorimetric
8.	γHCH (Hexachlorocyclohexane	TLC/GC
9.	Carbaryl	Spectrophotometer
10.	Dimethoate and thimet	GC emission spectroscopic
11.	Carbofuran	GC-NPD
12.	Disulfoton	GLC
13.	Carbofuran	Colorimetric
14.	DDT	TLC
15.	Organophosphorus	Colorimetric
16.	Benomyl and Methyl N (2. Benzimidazole) carbamate	GC-ECD
17.	OP	TLC
18.	Chlorophenol	GC
19.	Propyzamide	GC-ECD
20.	Metribuzin	GC-N-specific Alkali flame ionization detector
21.	Quinalphos, disulfoton, monocrotophos	TLC
22.	Benomyl and Methyl N (2. Benzimidazole) carbamate	Voltametric determination
23.	Fluzifop-butyl	GLC-N-specific detector
24.	Dichlobenil	HPLC
25.	Pyrethroids	GC
26.	Methyl-parathion	HPLC
27.	Butachlor	GC-ECD
28.	DDT	ELISA
29.	Atrazine	ELISA
30.	Triazine and chloroaectanilide	GC-NPD or GC-MS

Table.3 Pesticide residues in apple orchard soils of Himachal Pradesh

Location	Sampling time	Residues (mg/kg)										
		α-HCH	β-HCH	γ -HCH	α-endosulfan	p,p'-DDE	β -endosulfan	endosulfan sulphate	p,p'-DDT	chlorpyrifos-methyl	chlorpyrifos.	fenvalerate
Kukumseri	Before flowering	0.002	0.004	0.016	ND	ND	ND	ND	ND	ND	ND	ND
	At harvest	ND	ND	ND	ND	ND	0.019	ND	ND	ND	ND	ND
												ND
Rekongpeo	Before flowering	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.004	
	At harvest	0.002	ND	0.004	ND	0.006	0.008	0.311	ND	ND	ND	ND
Bajaura	Before flowering	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	At harvest	ND	ND	ND	ND	0.002	0.006	ND	0.003	0.006	0.004	ND
Mashobra	Before flowering	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	At harvest	0.004	0.002	0.003	0.002	0.001	0.012	0.023	0.003	ND	0.005	0.011

* ND – Not detectable

Table.4 Pesticide residues in mango, plum and kinnow orchard soils of Himachal Pradesh

n	Crop	Residues (mg/kg)														
		Sampling time	α-HCH	β-HCH	γ – HCH	δ-HCH	dicofol	O,p'-DDE	α-endosulfan	p'p'-DDE	β – endosulfan	p'p'-DDD	o'p'-DDT	endosulfan sulphate	p'p'-DDT	chlorpyrifos-methyl	chlo
r	Mango	BF	ND	ND	ND	ND	ND	ND	ND	ND	0.002	ND	ND	ND	ND	ND	
		AH	0.001	ND	0.003	0.053	0.021	0.013	0.037	0.007	0.011	0.003	0.003	0.030	0.009	ND	
	Plum	BF	ND	ND	0.003	ND	ND	ND	ND	0.033	ND	ND	ND	ND	ND	ND	
		AH	ND	ND	ND	ND	ND	ND	ND	0.006	ND	ND	ND	ND	0.003	ND	0
	Kinnow	BF	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.006	
		AH	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.004	
	Kinnow	BF	ND	0.003	ND	ND	ND	ND	ND	ND	0.006	ND	ND	ND	ND	ND	
		AH	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

ND=Not detectable; BF=Before flower; AH=After harvest

Table.5 Average residues of various pesticides in orchard soils

Crop	∑HCH	∑DDT	Dicofol	∑Endosulfan	∑Chlorpyrifos	∑Pyrethoids
Apple						
i) Kukumseri	0.022	<0.001	ND	0.019	<0.10	ND
ii) Rekongpeo	0.006	0.006	ND	0.319	0.004	ND
iii) Bajaura	<0.002	0.005	ND	0.006	0.010	ND
iv) Mashobra	0.009	0.004	ND	0.037	0.005	0.011*
Range	(<0.002-0.022)	(<0.001 - 0.006)	ND	(0.006-0.319)	(BDL - 0.010)	ND
Mango						
v) Bilaspur	0.057	0.034	0.021	0.073	<0.10	ND
Plum						
vi) Solan	0.003***	0.022	ND	<0.002	0.004	ND
Kinnow						
vii) Jachh	0.003**	<0.001	ND	0.006	<0.10	ND
viii) Dhaulakuan	<0.002	<0.001	ND	<0.002	0.005	ND

* Fenvalerate

** β-HCH BDL: Below detectable limit

*** γ-HCH

Table.6 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	cypermethrin	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.7 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

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 7 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).

In conclusion, 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. In the present study, 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. Apple orchard soils were found to contain highest ensdosulfan residues followed by HCH and DDT residues. In mango orchard soils dicofol was detected in addition to the apple soil contaminants.

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