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Original Research Article

PESTICIDE RESIDUES IN HUMAN BLOOD FROM PUNJAB, INDIA: BURDEN AND RISK ASSESSMENT

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ABSTRACT

This study was designed to assess the levels of pesticide residues in human blood and their relationship with certain health parameters in Punjab, India. A total of 300 samples were collected from both the urban and rural areas of the state between 2016 and 2017. The samples were analysed by gas chromatography and 29% were found to be contaminated with residues of at least one of four different pesticides (chlorpyrifos, malathion, p,p' DDE, lindane (gamma-hexachlorocyclohexane).The mean residues level of chlorpyrifos, malathion, p.p' DDE and lindane detected were 8.93, 0.37, 1.57 and 1.67 ng ml^{-1} respectively. The pesticide specific prevalence occurred in descending order; 21.0, 7.7, 3.0 and 0.7 % for chlorpyrifos, p.p' DDE, lindane and malathion respectively. In a similar manner, the percentage proportion of chlorpyrifos, p.p' DDE, lindane and malathion amongst the positive samples were 64.9, 23.7, 9.3 and 2.1 respectively. Pesticides levels analysed in relation to location of residence revealed statistically significant difference (p=0.001) between p,p' DDE detected in urban (2.40 ng ml^{-1}) and rural (0.33 ng ml^{-1}) areas. There was significant association (p=0.001) between the presence of p,p' DDE residues in blood and residential background with 11.7 % of urban participants having p,p' DDE in their blood compared to 1.7 % of rural inhabitants. Moreover, p,p' DDE was significant and positively correlated with BMI (P=0.021) with a correlation coefficient of 0.478. Higher proportion of chlorpyrifos residues in the analysed blood revealed a change in pattern of pesticides use from organochlorines to organophosphates.

Keywords: Human blood, Pesticide, Punjab, Residue

INTRODUCTION

Pesticides remain crucial in modern agriculture, offering protection against pests that threaten crop yields. Crops with broad, delicate foliage, such as cotton and tobacco, are particularly vulnerable and thus often heavily reliant on chemical controls (Kashyap *et al*., 2024). In many developing regions including parts of Africa (notably, Nigeria, Egypt and South Africa) and South Asia, the expanded use of agrochemicals has contributed to increased crop production, but also to mounting health and ecological concerns (Willenbockel *et al.,* 2022; Kashyap *et al.,* 2024). Despite their benefits, pesticides carry significant risks when misused, especially in contexts where farmers have limited awareness, inadequate training, or insufficient access to personal protective equipment (PPE) (Desye *et al*., 2024). The toxicity of a pesticide depends on its chemical class (e.g. organophosphates, carbamates, organochlorines), route of exposure (dermal, inhalational, ingestion), rates of biotransformation or detoxification, mode of application, function, and persistence in environmental/media compartments. (Willenbockel *et al*., 2022; Moreira *et al*., 2025). Internationally, WHO and FAO maintain a classification system for pesticide hazard (ranging from "extremely hazardous" to "slightly hazardous"), designed to guide regulation and safe use. High or prolonged exposures to the more hazardous pesticides can cause acute symptoms (nausea, headaches, respiratory distress, convulsions) and chronic outcomes (neurotoxicity, endocrine disruption,

carcinogenesis) (Kashyap *et al*., 2024; Moreira *et al*., 2025). Epidemiological and toxicological studies increasingly link chronic pesticide exposure to cancers (e.g. leukemia, non-Hodgkin lymphoma, prostate), as well as neurological, reproductive, and endocrine disorders (Willenbockel *et al*., 2022). At the same time, misuse of pesticides contributes to soil degradation, water contamination, and bioaccumulation through food chains (Pathak *et al*., 2022). These threats are magnified in low- and middle-income countries, such as India and Nigeria, where regulatory capacity is often constrained (Kashyap *et al*., 2024).

Globally, acute pesticide poisoning is estimated to cause around one million incidents annually (Willenbockel *et al*., 2022; Shekhar *et al*., 2024). Biomonitoring works that detect pesticide residues or metabolites in human matrices (blood, urine, adipose tissue, breast milk) underscore on-going exposure even among non-agricultural populations (Sharma *et al*., 2015; Moreira *et al*., 2025). Similarly, studies of Indian pesticide sprayers report altered biomarkers of oxidative stress, acetylcholinesterase inhibition, and inflammation in comparison to non-exposed persons (Thakur *et al*., 2020).

In India, especially the state of Punjab, well known agricultural state, pesticide use has grown substantially over recent decades. Although residues of some legacy persistent organic pollutants (POPs) have declined due to bans (Bedi *et al*., 2015a), the contemporary use of more acutely toxic compounds (organophosphates, carbamates) has remained widespread (Bedi *et al*., 2015b, Kashyap *et al*., 2024). In Punjab, pesticide residues (e.g. cypermethrin, chlorpyrifos, DDE) have been detected in dairy milk samples, revealing dietary exposure pathways (Gill *et al*., 2020). Given this exposure background, quantifying pesticide residues in human blood and investigating associations with health risk factors is critical to inform policy and promote safer agricultural practices in pesticide-intensive regions. Assessing pesticide concentrations in human blood offers insight into the body's cumulative burden of these toxic substances. Accordingly, the present study aimed to evaluate pesticide residue levels in human blood and their association with health indicators in the population of Punjab, India.

MATERIALS AND METHODS

SAMPLING

A total of 300 blood samples were collected in 2016/2017 from human population of Punjab from both high-risk population (rural areas) and low-risk population (urban areas) after taking the approval/consent from the sample donors. Before the commencement of sampling, approval of the ethics committee of Dayanand Medical College and Hospital (DMCH), Ludhiana, Punjab, was obtained. One hundred and eighty (180) samples were collected from donors attending the Dayanand Medical College and Hospital (DMCH) Urban Centre at Shimla Puri, Ludhiana District of Punjab. The remaining 120 samples were collected from donors visiting DMCH Rural Centre at Pohir, Ludhiana District of Punjab. Five millilitres (5ml) of blood was collected from each donor in a heparinised vacutainer tube and transported in an ice pack to the laboratory and stored at -20^0C until analysed. All the chemicals used were of analytical reagent (AR) grade, and were obtained from E. Merck India Ltd and Sd-fine India Ltd. Information on age, sex, dietary habits (vegetarian/non-vegetarian), height, weight and history of any health disorders was registered on the designed questionnaire. Information on the use of pesticides for pest control in fields was also obtained.

PESTICIDE STANDARDS

High-purity analytical standards of organochlorines (OCs), organophosphorus (OPs) and synthetic pyrethroids pesticides (SPs) were purchased from Sigma-Aldrich and Rankem Ltd and used for recovery tests and quantification of residues in samples.

EXTRACTION AND CLEAN-UP OF PESTICIDE RESIDUES IN HUMAN BLOOD

Pesticide extraction from blood samples followed a modified protocol based on Gill *et al*. (1996). Blood samples were thawed, vortexed, and 1 ml aliquots were transferred into 15 ml centrifuge tubes. After equilibration at room temperature for 15 minutes, 1 ml of glacial acetic acid was added, followed by vortexing for 1 minute. The analytes were extracted with 5 ml of hexane/dichloromethane (9:1, v/v), vortexed for 1 minute, then centrifuged at 2500 rpm for 5 minutes. The organic layer was carefully collected, and the extraction was repeated twice with 5 ml of hexane/dichloromethane. The combined organic extracts were treated with 1 ml of concentrated sulfuric acid, vortexed for 1 minute to remove lipids, and then centrifuged at 1600 rpm for 2 minutes to separate phases. The organic layer was isolated, and any residual sulfuric acid phase was further extracted with 1.5 ml of hexane/dichloromethane. The combined organic phase was concentrated to 0.5 ml for clean-up.

Clean-up was carried out per USEPA Method 3620B (2003), employing florisil as an adsorbent in column chromatography. Florisil was activated at 130°C overnight and cooled in a desiccator before use. A 12 mm internal diameter, 20 cm length column was packed with 1 g of florisil topped with 0.5 g of anhydrous sodium sulfate, pre-eluted with hexane. The extract was transferred onto the column and eluted with 10 ml of hexane for organochlorines, or with 10 ml of hexane/dichloromethane (1:9, v/v) for organophosphates. The eluent was further purified with

sequentially increasing amounts of diethyl ether in hexane (6%, 15%, 50%), each 10 ml. The collection was evaporated to dryness, and residues were reconstituted in a 2 ml mixture of n-hexane (HPLC grade) and acetone (HPLC grade) for subsequent analysis by GC-ECD for OCs and GC-FTD for OPs.

RECOVERY STUDIES FOR PESTICIDE RESIDUES IN BLOOD

The method used for extraction and estimation of pesticide residues in blood samples was validated by calculating the recovery from blood samples spiked with known concentration of pesticide standards at 0.1mgkg^{-1}. The mean recovery values of spiked samples ranged from 79.0 % to 92.4 %. Repeatability of the method was also estimated by calculating the relative standard deviation of the recovery values, which were found to be below 10%. The limit of detection ranged from 1.0 ng g^{-1} for OCPs and SPs to 2.0 ng g^{-1} for OPs.

DATA ANALYSIS

Statistical analyses were performed using Microsoft Excel and SPSS 16.0. The pesticides residue levels found in blood were studied and analysed in relation to location of residence (urban and rural), gender, age, dietary habits, body mass index (BMI), source of drinking water, occupation, tobacco smoking, and spraying activity of the donors to find out whether these parameters are associated in some ways with residue levels in human blood. Values of $P \leq 0.05$ were considered statistically significant.

RESULTS

The mean age of participants was 43.8 years with a range of 9-82 years. The mean BMI was 28.80 with a range of 13.24 to 42.25. Of the total number of participants, 172 were females while 128 were males. Only three participants reported taking protective measures while spraying pesticides inside or outside their homes. The results revealed that 29% of the 300 samples analysed were contaminated with residues of at least one of the four different pesticides detected. Two organochlorine pesticides were detected, viz: Lindane (γ-HCH) and p,p' DDE with a range of ND-120 ng ml^{-1} and ND-60 ng ml^{-1}, respectively. Likewise, two organophosphorus pesticides, chlorpyrifos and malathion with a range of ND-189 ng ml^{-1} and ND-62 ng ml^{-1} respectively, were also found in the blood samples. (Table I).

TABLE I: LEVELS OF PESTICIDE RESIDUES (NG ML^{-1}) IN HUMAN BLOOD (N=300)

Pesticide	Mean±SD	Range	Positive (%) samples	Percentage contribution
Chlorpyrifos	8.93 ± 25.40	ND-189	63 (21)	64.9
Malathion	0.37 ± 4.60	ND-62	2 (0.7)	2.1
p,p' DDE	1.57 ± 6.47	ND-60	23 (7.7)	23.7
Lindane	1.67 ± 11.47	ND-120	9 (3.0)	9.3

ND = Not determined

These pesticides levels were studied in relation to demographic characteristics of the donor to find out correlation of these parameters with residue levels in human blood (Table II-III). Table II shows the mean residue levels of pesticides in blood samples from urban areas and rural areas. There was no significant difference in the residue levels of chlorpyrifos between the two locations (p= 0.471).

In terms of presence or absence of chlorpyrifos residues, there was no significant association between residential background and chlorpyrifos contamination (p= 0.107). The table also revealed that malathion was detected only in samples from rural areas. However, residues of p,p' DDE was detected both in urban and rural areas and this difference was found to be significant (p=0.001) . There was also significant association (p= 0.001) between the presence of p,p' DDE residues in blood and residential background.

Similarly, Table II indicated that the mean residue levels of chlorpyrifos in the 128 blood samples from males is 14.47 ng ml^{-1} compared to 7.04 ng ml^{-1} for the 172 samples from female subjects. However, there was no significant difference in the residue levels of chlorpyrifos between the two sexes (p=0.147). There was no significant association between gender and chlorpyrifos contamination (p=0.142).). There was also no significant association (p= 0.603) between the presence of p,p' DDE residues in blood and gender. Lindane was detected in both sexes, without a statistically significant difference between the two sexes (p= 0.669). Also, there was no association between gender and lindane contamination (p= 1.000). There was no significant difference between vegetarian and non-vegetarian population for the residue levels of p,p' DDE (p=0.891) and lindane (p= 0.814), while significant differences exist for Chlorpyrifos (p=0.033) and malathion (p= 0.044). There were no statistically significant associations between the presence or absence of these four pesticides with dietary habits (Chlorpyrifos, p=0.061; malathion, p= 0.043; p,p' DDE, p=0.266 and lindane, p= 0.983).

Participants in the present study used one of three sources of drinking water, viz. hand pump, municipal water supply and submersible pumps. Comparison of mean residue levels based on sources of drinking water showed that there were no significant differences among the three sources (p> 0.05).

TABLE II: MEAN RESIDUE LEVELS AND STANDARD DEVIATION (NG ML^{-1}) OF PESTICIDES IN HUMAN BLOOD IN RELATION TO SOME PARAMETERS (MEAN±SD (%))

Parameters	Pesticides			
	Chlorpyrifos	Malathion	p,p' DDE	Lindane
Residential background				
Urban (n=180)	8.07 ± 24.41 (18.3)	ND	2.40± 7.92[a](11.7)[b]	2.78 ± 14.72(5)
Rural (n=120)	10.23 ± 26.87(25)	0.93 ± 7.24(1.7)	0.33 ± 2.88(1.7)	ND
Gender				
Male (n=128)	11.47 ± 30.12(25)	0.88 ± 7.00(1.6)	1.57 ± 5.60(8.6)	1.35 ± 9.45(3.1)
Female (n=172)	7.04 ± 21.12(18)	ND	1.58± 7.1(7.0)	1.90± 12.79(2.9)
Dietary habit				
Vegetarian (n=200)	5.85 ± 18.26(17.9)	ND	1.54 ± 6.95(6.5)	1.78 ± 11.15(3)
Non-vegetarian (n=96)[d]	15.19 ± 35.06[c](27.5)	1.13 ± 7.97(2)	1.65 ± 5.41(10.1)	1.44 ±12.15 (3)
Tobacco				
User (n=122)	11.87 ± 21.97(31.8)	2.27 ± 10.67(4.5)	3.68 ± 10.52(13.6)	ND
Non-user (n=178)	8.70 ± 25.67(20.1)	0.22 ± 3.72(0.4)	1.41 ± 6.04(7.2)	1.80 ± 11.91(3.2)
Outdoor pesticides spray				
Sprayer (n=68)[e]	7.26± 19.14(20.6)	ND	3.26 ± 10.45(11.8)	3.24 ± 14.27[f](7.4)[g]
Non-sprayer (n=230)	9.50 ± 27.08(21.3)	0.49 ± 5.24(0.9)	1.04 ± 4.65(6.1)	1.22 ± 10.54(1.7)
Indoor pesticides spray				
Sprayer (n=185)	9.84 ± 29.11(20)	0.34 ± 4.56(0.5)	1.83 ± 6.45(4.5)	2.65± 14.51(4.3)
Non-sprayer (n=112)[h]	7.67 ± 18.12(23.2)	0.45 ± 4.73(0.9)	1.10 ± 6.53(9.2)	ND
Sources of water				
Hand Pump (n=7)	5.99 ± 11.58 (28.6)	ND	ND	ND
Municipal (n=169)	7.96 ± 24.76 (17.8)	ND	1.67± 6.00 (9.5)	2.86 ±15.14 (4.7)
Submersible (n=124)	10.42 ± 26.84 (39.2)	0.90 ±7.12 (1.6)	1.53± 7.26 (5.6)	0.14 ± 1.53 (0.8)

[a] p=0.001, [b] p=0.001, [c] p=0.033, [d] missing data=4, [e] missing data=2, [f] p=0.018, [g] p=0.032
[h] missing data=3, ND=not determined

Blood sample donors were divided into six age groups, viz. < 20-30, 31-40, 41-50, 51- 60, 61-70 and > 70 years (Table III). However, statistical analysis of the samples showed that there were no significant differences (p > 0.05) among the six age groups in the levels of contamination of each of the four pesticides detected in human blood in this study. Also, tests of associations revealed that age was not associated (p> 0.05) with each of the four pesticides found.

Analysis of Variance (ANOVA) revealed that there were no statistically significant differences in the concentration of each of the four pesticides detected among all the BMI categories (chlorpyrifos (p=0.998), malathion (p=0.825), p,p' DDE (0.378) and lindane (p=0.592)). Likewise, there was no association between the presence of each of the pesticides with BMI (chlorpyrifos (p=0.605), malathion (p=0.846), p,p' DDE (0.836) and lindane (p=0.747)). However, p,p' DDE was significantly positively correlated with BMI (P=0.021) with a correlation coefficient of 0.478.

Blood donors for this study were grouped into six broad occupational categories (artisans, businesspeople, farmers, housewives, medical workers and others) based on shared characteristics and similarities for analytical convenience. Table III shows that out of the 300 participants from whom samples were collected and analysed, 11 were farmers, 23 businesspeople, 5 each from artisans and medical workers, 145 housewives and 111 from others (babysitters, retirees, drivers, children, the unemployed, security operatives, railway workers, teachers, etc.).

DISCUSSION

The prevalence of p,p' DDE shows the restricted use of DDT in Punjab (Bedi *et al*., 2015b). Also, the detection of p,p' DDE despite the restriction may indicate the long-term persistence of DDE metabolites in the human body. Technical grade DDT consists primarily of p,p' DDT and some o,p' DDT. In the human body, p,p' DDT is slowly dechlorinated too, p' DDD and p,p' DDE (dichlorodiphenyldichloroethane and dichlorodiphenyldichloroethylene). (WHO, 1989). Metabolism of DDT in the human body leads to conversion into DDE and DDD metabolites. (WHO, 1989).

TABLE III: MEAN RESIDUE LEVELS AND STANDARD DEVIATION (NG ML^{-1}) OF PESTICIDES IN HUMAN BLOOD IN RELATION TO DEMOGRAPHIC PARAMETERS (MEAN±SD (%))

Parameters	Pesticides Chlorpyrifos	Malathion	p,p' DDE	Lindane
Age				
<20-30 (n=74)	9.24 ± 21.0 (25.7)	ND	ND	2.88 ±16.11 (5.4)
31- 40 (n=48)	4.79 ± 15.89 (12.5)	2.33 ± 11.38 (4.2)	1.35± 6.43 (6.2)	ND
41-50 (n=86)	9.23 ± 29.01 (19.8)	ND	1.81 ± 5.49 (11.6)	1.59 ± 10.33 (3.5)
51-60 (n=55)	10.33 ± 30.68 (21.8)	ND	2.55 ± 8.07 (10.9)	1.27± 9.44 (1.8)
61-70 (n=24)	11.58 ± 27.64 (25)	ND	3.79 ±12.81 (12.5)	3.33 ±16.33 (4.2)
>70 (n=13)	9.69 ± 25.01 (23.1)	ND	1.54 ± 5.55 (7.7)	ND
Body mass index				
Underweight (< 18.5)(n=20)	8.64 ± 20.60 (30)	ND	0.50 ± 2.24 (5.0)	ND
Normal weight (18.5 -24.9) (n=122)	9.13 ± 23.01 (20.5)	0.41 ± 4.53 (0.8)	1.06 ± 4.33 (6.6)	1.48 ± 10.88 (2.5)
Overweight (25–30)(n=95)	8.52 ± 28.96 (17.9)	0.65 ± 6.36 (1.1)	1.76 ± 6.19 (9.5)	2.87 ±15.84 (4.2)
Obese (>30) (n=63)	9.26± 23.80 (23.8)	ND	2.63± 10.18 (7.9)	0.75± 4.31 (3.2)
Occupation				
Artisans (n=5)	9.81± 9.33 (60)	12.40 ± 27.73 (20)	2.80 ± 6.26 (20)	3.40 ± 7.60 (20)
Business people (n=23)	4.38 ± 8.95 (21.7)	ND	ND	ND
Farmers (n=11)	4.66 ± 11.54 (18.2)	ND	0.91 ±3.02 (9.1)	ND
House Wives (n=145)	7.14 ± 22.26 (16.6)	ND	1.85 ± 7.64 (8.3)	2.14 ±13.85 (2.8)
Medical Workers (n=5)	7.14 ± 22.26 (40.0)	ND	ND	ND
Others* (n=111)	12.36 ± 32.14 (24.3)	0.45 ± 4.75 (0.9)	1.62 ± 5.86 (8.1)	1.56 ±10.14 (3.6)

*(child, retiree, babysitters, student's driver, job, unemployed, teachers, service, security, railways), ND=not determined

Though DDT use is banned in India, lack of suitable alternative for malaria control made India to seek and obtain permission to use up to 10,000 tons of DDT per year for its vector control programs (WHO 2006, Bedi *et al*., 2015b).

The absence of active and fresh-use metabolites of DDT (p,p' DDT and o,p' DDT) indicates very limited or no use of DDT in public health programmes in the region of the present study. DDT levels detected in this study were several times lower than in the studies carried out in Punjab which detected total DDT at mean levels of 23.60 (Bedi *et al*., 2015b) and 4.77 (Sharma *et al.*, 2015). Mathur *et al.* (2005) found p,p' DDE in 95% of the samples analysed and reported a much higher mean value for p,p' DDE which was 45 ng ml^{-1} even as their works were concentrated in Bathinda and Ropar districts of Punjab which are surrounded by agricultural fields where pesticide use is greater than other parts of Punjab. The study subjects for the current study were mostly drawn from Ludhiana, the industrial hub of Punjab. In addition, the above-mentioned levels are still much lower compared to the corresponding levels of 7170, 271, 950 and 743 ng/ml reported from different parts of India (Dua *et al*., 2001; Kumar *et al*., 2006). Furthermore, residues of DDT observed in India were lower than those recorded in Romania (2420 ng/ml), Spain (4895.8 ng/ml) and Sweden (836.1 ng/ml) (Glynn *et al*., 2000; Dirtu *et al*., 2006; Porta *et al*., 2008). However, Mishra *et al.* (2011) reported in a study conducted in Assam, India, that there was predominance of p,p' DDT metabolites in human blood samples in that state because of environmental conditions such as excessive rainfall, high humidity and warmer climates mostly throughout the year which favours the transmission of malaria and hence the increased use of DDT in mosquito control.

Hexachlorocyclohexane, previously called BHC (benzene hexachloride), is a mixture of eight isomers, of which five are found in the crude product (α, β γ, δ and ε,). Only the γ isomer or lindane has powerful insecticidal properties. (USEPA, 2003). The mean level of the only HCH isomer

detected in the present study (γ-HCH) is lower than reported by Bedi *et al*. (2015b) for the other isomers, namely, α-HCH at 1.11 ng ml^{-1} and β-HCH at 5.89, and much lower than those found by Mathur *et al* (2005) who detected γ -HCH in 100% of the samples at a mean level of 22.7 ng ml^{-1}. This might be attributed to regulatory restrictions, shift to alternative pesticides, increased awareness and precaution and environmental degradation. Gamma-HCH is most commonly used and is more resistant to biological and chemical degradation under aerobic conditions. It appears in the list of pesticides for restricted use (the use of lindane formulations generating smoke for indoor use is prohibited; it can be used for the control of insect pests of field crops) (Mathur *et al*. 2005).

Out of the total pesticide residues found in human blood, the highest contribution was observed for chlorpyrifos. The preponderance of chlorpyrifos at higher mean level on the one hand, and the relatively much lower levels of the organochlorines on the other point to a trend resulting from a shift to the use of less persistent and less dangerous organophosphorus pesticides (Bedi *et al*., 2015b; Sharma *et al*., 2015). Chlorpyrifos, which is the fourth highest pesticide people are exposed to in India, was earlier detected in 85% of the samples at mean level of 66.2 ng ml^{-1} and ranged from ND–496.5 ng ml^{-1} in 20 whole blood samples analysed in Punjab (Mathur *et al*., 2005). It is a moderately persistent insecticide effective against mosquito and fly larvae, cabbage root fly and aphids. It has become one of the most widely applied insecticides in homes and restaurants against cockroaches and termites (Bedi *et al*., 2015b).

Malathion detected in the this study was much lower compared to the report of Mathur *et al* (2005) which found that about 70% of the whole blood samples collected from Punjab were contaminated with malathion at mean levels of 30.1 ng ml^{-1}, and the concentrations ranged from ND to 75.3 ng $ml^{-1.}$ Malathion is a widely used contact insecticide and acaricide for the control of aphids, red spider mites, leaf hoppers and thrips on a wide range of vegetable and other crops. It is also used to control insect vectors like mosquitoes.

The detection of malathion in the rural areas is likely due to occupational exposure of farmers and agricultural workers, environmental contamination of soil, water and air, and limited access to proper protective gear.

The level of p,p' DDE found in this study is much less than the 5.67 ng ml^{-1} reported by Dhananjayan *et al.* (2012) in a study conducted in rural Karnataka.

The absence of statistically significant differences between males and females in relation to concentration of pesticide residues was consistent with earlier works conducted in Punjab (Bedi *et al*., 2015b; Sharma *et al*., 2015) and in rural Karnataka (Dhananjayan *et al*., 2012). However, there are previous studies from various countries which have shown higher prevalence of pesticide residues in females as compared to males (Charlier & Plomteux 2002; Lino & Silveria 2006; Luzardo *et al*. 2006). This might be due to the higher percentage of body fat associated with women, which can store liphophilic pesticides like organochlorines.

The absence of statistically significant association between the occurrences of the four pesticides detected in this study with dietary habits agrees with Bedi *et al.* (2015b) and Sharma *et al.* (2015).

Comparison of the pesticide residue levels in blood of humans with tobacco chewing and smoking habit and those with no chewing and smoking habit revealed that the mean residue levels of the three pesticides detected in the group that engaged in the habit of smoking or chewing tobacco were slightly higher as compared to those with no habit of tobacco chewing and smoking. This may be attributed to the fact that people with tobacco-chewing habits may have direct oral exposure to the pesticides during spraying on the crops and in the fields.

In contrast with the results from this study, Bedi *et al. (*2015b) reported statistically significant difference in the levels of total dichlorordiphenyltrichloroethane (DDT) among different age groups of humans. Correlation analyses, considering only the positive samples among the 300 samples, revealed that there were no significant ($p > 0.05$) correlations between age and each of the four pesticides detected in this study. Non-significant positive correlations were found for chlorpyrifos p,p' DDE and lindane. However, increasing age in relation to higher pesticide residue levels have been reported earlier by many researchers (Bates *et al*., 2004; Dirtu *et al*., 2006). This implies the bioaccumulation of pesticide residues in the body over time. The significant positive correlation of p' DDE with BMI could be attributed to the liphophilic nature of organochlorine pesticides

CONCLUSION

Organochlorine residues levels in human blood in the present study are low probably due to restrictions imposed on its usage coupled with increase in demand for organophosphate and synthetic pyrethroids in the study area. Higher proportion of OPs residues in the blood reveal a change in pattern of pesticides use from organochlorines to these pesticides. Mean residues level of p,p' DDE in urban resident was found to be significantly higher than that of the rural areas, probably due to dietary habits, and sources, environmental exposure and occupational exposure because of work in industries that use or produce DDT. Similarly, there was also significant association between the presence of p,p' DDE residues in blood and residential background. Moreover, p,p' DDE was significantly positively correlated with BMI. Further studies on the effects of these pesticides on genetic material of humans and animals are hereby recommended.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest

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