

RESEARCH ARTICLE

Editorial Process: Submission:09/06/2025 Acceptance:03/19/2026 Published:04/07/2026

Pesticide Exposure and the Risk of Ovarian Cancer among Postmenopausal Women in Rural Punjab, India

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Abstract

Objective: Punjab, a state in Northern India, has reported an alarming rise in cancer cases, which has been linked to the extensive use of pesticides in agriculture. Ovarian cancer, often diagnosed at late stages, lacks systematic screening within the population under the national program. The present study aimed to screen postmenopausal women for ovarian cancer and to evaluate pesticide exposure as a potential risk factor. **Methods:** A total of 1,327 postmenopausal women, residing in 48 villages for at least ten years, were screened annually for CA-125 levels. Women with CA-125 levels >35 U/mL were referred for transvaginal ultrasound. Demographic data were collected through a semi-structured questionnaire. For pesticide profiling, a case-control design was adopted. Blood samples were collected and analyzed for organochlorine and organophosphate residues using gas chromatography. **Results:** Among 1,327 postmenopausal women screened, 30 (2.3%) had elevated CA-125 levels (>35 U/ml); no ovarian cancers were detected during follow-up imaging and specialist evaluation. In the case-control analysis (24 cases; 42 controls), detectable pesticide residues were associated with a crude 6.7-fold increased odds of ovarian cancer (95% CI: 1.4–32.7). After multivariable adjustment for parity and education, Ethion (aOR = 6.29, 95% CI: 1.37–28.8) and DDE (aOR = 6.39, 95% CI: 1.35–30.3) remained associated, though confidence intervals were wide, reflecting small sample size. In agricultural participants, chlorpyrifos detections were more frequent among controls (OR = 0.12, $p = 0.008$). **Conclusion:** Although no ovarian cancer cases were detected during screening, the study highlights the prevalence of pesticide exposure among women in Punjab's Malwa region and its possible association with ovarian cancer risk. Routine population screening using CA-125 is not supported in light of current evidence and guidelines. Instead, strengthening diagnostic and registry systems in rural areas, reducing harmful exposures through safer agricultural practices, and conducting well-powered prospective studies with repeated exposure assessments are essential to clarify risks and inform targeted strategies in high-exposure settings.

Keywords: Endocrine disruptors- agricultural chemicals- environmental health- female reproductive system

Asian Pac J Cancer Prev, 27 (4), 1369-1376

Introduction

According to the Global Cancer Observatory (GLOBOCAN), an estimated 20 million new cancer cases and 9.7 million cancer-related deaths occurred worldwide in 2022 [1]. Within the South-East Asia Region (SEARO), India ranks third in cancer incidence and second in cancer-related mortality, highlighting its growing cancer burden.

Punjab, a leading agricultural state in India, played a pioneering role in the Green Revolution, which significantly enhanced food production through high-yielding crop varieties, advanced irrigation, and extensive use of chemical fertilizers and pesticides, earning Punjab the title of the “Breadbasket of India” [2]. However, this agricultural intensification has come at an environmental and human health cost.

The Malwa region, Punjab's cotton belt, despite comprising less than 15% of the state's geographical

area, accounts for approximately 75% of its pesticide consumption [3]. This disproportionate use of pesticides has raised concerns about long-term health risks, particularly cancer, among residents chronically exposed to these chemicals. Malwa has reported the highest cancer prevalence in Punjab, with 136 cases per 100,000 population, compared to the national average of 80 per 100,000 [4]. Several studies have attributed this increase, at least in part, to the widespread use of synthetic pesticides containing endocrine-disrupting chemicals (EDCs), which interfere with hormonal regulation and may contribute to cancers, including those affecting the female reproductive system [5-8].

Within the female reproductive system, cervical cancer is the only malignancy with systematic programmatic screening in India. In contrast, ovarian cancer, often diagnosed at advanced stages and primarily occurring post-menopause, lacks effective early detection strategies, resulting in poor survival outcomes. While established

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risk factors such as parity, family history, and genetic predisposition are well recognized, environmental exposures have received less attention. Limited but emerging evidence suggests that pesticide exposure, especially to endocrine-disrupting chemicals, may also contribute to ovarian cancer risk [9, 10]. Despite these concerns, systematic, population-level screening and awareness initiatives for ovarian cancer remain scarce [5].

The pilot study aimed to address this critical gap by conducting ovarian cancer screening among postmenopausal women in Talwandi Sabo, a block within the Bathinda district of Malwa, while also profiling pesticide exposure to explore its potential role as a risk factor. By elucidating the relationship between environmental toxins and cancer prevalence, this study seeks to generate evidence that can inform targeted public health interventions and policy decisions to reduce cancer risks in Punjab's agricultural communities.

Materials and Methods

The study was approved by the University Ethics Committee, registered under the competent Government regulatory authority. The study employed an integrated design combining (i) a prospective screening of postmenopausal women for ovarian cancer and (ii) a retrospective case-control analysis to assess pesticide exposure and socioeconomic determinants. The district is an essential part of the cotton-producing belt of the state. A major part of the block is rural (924 km²), while the remaining 35 km² is urban (3.6%); about 76% of the population resides in rural areas.

Screening for Ovarian Cancer: Prospective component Sample Size and Participants

The sample size for the ovarian cancer screening was determined using a Confidence Level (CL) of 95%, margin of error 3%, and a total population of 143,025 post-menopausal women in Talwandi Sabo. The calculated sample size with a non-response rate of 5% was rounded to 1,325 participants.

Participants were fully informed about the research objectives, symptoms of ovarian cancer, and the potential health risks associated with pesticide exposure. Written informed consent was obtained before blood sample collection, and all data were handled with strict confidentiality.

A total of 1,327 post-menopausal women who had been residing for at least ten years in 48 villages selected via multi-stage random sampling of the Talwandi Sabo block were enrolled. A pre-tested questionnaire was used to collect information on health status, reproductive history, nutritional profile, pesticide exposure, drinking water sources, dietary habits, lifestyle, and menstrual history.

Screening procedures and follow-up

The women were screened for CA-125, a tumor marker for ovarian cancer. 10 ml of venous blood was collected from the left hand of each participant using single-use syringes using standard infection prevention protocol.

Samples were transported in dry ice to the laboratory for analysis. Serum was separated via centrifugation (3,000 rpm for 15 minutes) and stored at -20°C. CA-125 levels were measured using the Enzyme-Linked Fluorescent Assay (ELFA) on a Minividas automated hormone analyzer (bioMérieux). The screening was repeated annually for three years.

Women with CA-125 levels above 35 U/mL were referred to a gynecologic oncologist for confirmatory evaluation. Women with persistently elevated results (>35 U/mL) were followed longitudinally. Each time a repeat positive result was observed, they were referred to a gynecologic oncologist for further evaluation. Instances of dropouts in subsequent years were also recorded. Although CA-125 is not recommended for population-wide screening due to its limited specificity and positive predictive value, we used it pragmatically in this pilot, given the high-exposure agricultural setting and the postmenopausal target group (Figure 1).

Pesticide Exposure Analysis -Case Control design

Because no ovarian cancer cases were identified prospectively, data on ovarian cancer cases were collected from civil hospitals. Only histologically confirmed cases were included. Date of diagnosis, FIGO stage, and treatment status at blood draw were abstracted from records. To reduce survivor bias, cases diagnosed within the previous two years were prioritized. Cases were restricted to postmenopausal women living in Talwandi Sabo. Addresses of eligible women were obtained from hospital records, and participants were subsequently approached through house-to-house visits. Demographic information and blood samples were collected only after obtaining written informed consent. The cases were then classified as agricultural (i.e., those involved in any kind of farming practices) and non-agricultural (i.e., those not involved in any form of agricultural practices).

Similarly, controls were identified from the same villages, frequency-matched on age (± 5 years) and menopausal status, and selected through random household sampling to minimize selection bias.

In other words, participants were classified into four groups: (i) agricultural cases women diagnosed with ovarian cancer who were engaged in farming, (ii) agricultural controls healthy women involved in farming with no history of cancer, (iii) non-agricultural cases women with ovarian cancer who were not involved in farming, and (iv) non-agricultural controls healthy women not engaged in farming and with no history of cancer. Response rates were recorded, and reasons for non-participation were documented. This classification enabled comparative analysis to explore potential links between environmental exposures and disease occurrence.

Blood Sample Collection and Pesticide Detection

For both cases and controls, 5 ml of venous blood was collected from the left hand of each participant using single-use syringes using standard infection prevention protocol in serum separator tubes. The samples were stored at -20°C until further analysis. Quantification of organochlorine and organophosphate pesticide residues

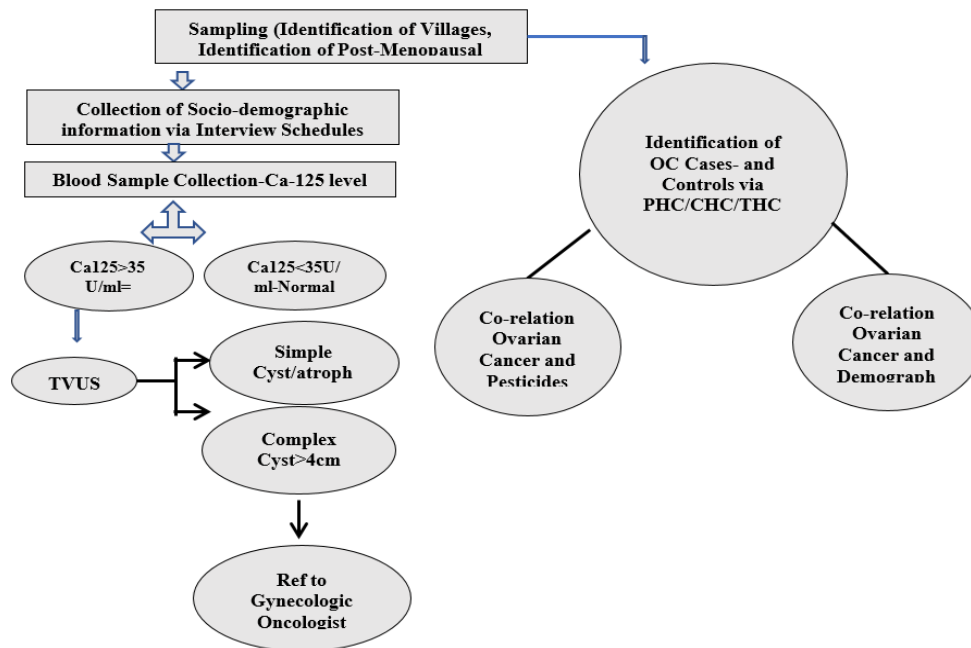


Figure 1. Flow Chart of the Methodology

was performed using gas chromatography, following the standardized protocol described by Mathur et al. [11].

Socioeconomic parameters, including reproductive history, dietary habits, occupation, education level, and family income, were analyzed using SPSS software. The chi-square test was employed to assess differences between cases and controls, with a p-value of <0.05 considered statistically significant. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate associations between pesticide exposure and ovarian cancer risk.

Results

Ovarian Cancer Screening

A total of 1327 post-menopausal women from 48 villages in the Talwandi Sabo block of Bathinda district, Punjab, were screened for serum CA-125 levels. Elevated CA-125 levels (>35 U/ml) were observed in 30 (2.3%) participants; however, no case of ovarian cancer was detected during the study. Nulliparity was significantly more common among women with elevated CA-125 compared to those with normal levels (6.7% vs 0.9%, $p < 0.05$) (Table 1).

Of the 30 women with elevated CA-125 levels, 26 underwent transvaginal ultrasound (TVUS), while 4 refused the procedure. The most common TVUS finding was atrophied ovaries (44.4%), followed by normal scans (33.3%) and simple ovarian cysts (13.8%). Other conditions identified included pyometra, para-ovarian cysts, fibroid uterus, and ascites. Annual follow-up scans revealed cyst enlargement in one individual, with a simple cyst in the left ovary increasing from 20×17 mm to 26×20 mm, and a new cyst (15×11 mm) appearing near the right ovary. During the project period, two women with atrophied ovaries and elevated CA-125 levels succumbed

to abdominal tuberculosis.

Pesticide Residue Analysis in Ovarian Cancer Cases and Controls

Demographic data for the two groups (i.e., ovarian cancer cases and controls) are outlined in Table 2. Illiteracy was more common in controls than cases (76.2% vs 58.3%, $p < 0.05$). Parity also differed significantly between cases and controls. Women with 1–2 births had a threefold higher risk of ovarian cancer compared to those with ≥ 3 births (OR \approx 3.3, 95% CI: 1.17–9.49, $p < 0.05$). This finding aligns with existing evidence that higher parity confers a protective effect against ovarian cancer. A crude 6.7-fold increased risk of ovarian cancer was observed among individuals with detectable pesticide levels in their blood (95% CI: 1.4–32.7, $p < 0.05$).

Organophosphate Pesticide Residue Analysis of Cases and Controls- Agriculture

Among agricultural participants (Table 3), 13 of 14 OPs were detected in cases, compared to 10 in controls. The mean concentrations of Monocrotophos (12.1 ± 36.3 ppb vs. 0.51 ± 1.7 ppb), Malathion (1.7 ± 5.0 ppb vs. 1.35 ± 2.5 ppb), Malaoxon (8.5 ± 14.8 ppb vs. not detected), Ethion (0.79 ± 0.67 ppb vs. 0.26 ± 0.57 ppb), Fenitrothion (14.3 ± 14.7 ppb vs. 4.6 ± 10.5 ppb), Dimethoate (111.9 ± 193.8 ppb vs. 9.9 ± 22.0 ppb), Atrazine (0.087 ± 0.105 ppb vs. 0.02 ± 0.06 ppb), Parathion methyl (19.2 ± 40.3 ppb vs. not detected), and Phorate (245.5 ± 736.4 ppb vs. not detected) were higher in cases compared to controls. Chlorpyrifos detections were less frequent in cases than controls (OR = 0.12, $p = 0.008$).

With respect to detection frequencies, Ethion was detected in 9 of 14 cases (64.3%) versus 4 of 20 controls (20%), Fenitrothion in 8 of 15 cases (53.3%) versus 3 of 15 controls (20%), and Atrazine in 5 of 14 cases (35.7%)

Table 1. Demographic Characteristics of Postmenopausal Women (with Normal CA125 Levels and Elevated CA125 levels) from Talwandi Sabo Block, Punjab, (Age group 40-70)

Demographic Characteristics	Numbe (n=1327)(%)	Normal CA125 (n =1297)	Elevated CA125 (n = 30)	Odds ratio (95% CI)	p- value
Education					
Illiterate	984 (74.15)	961 (74.09)	23 (76.66)	0.8 (0.27-2.4)	1.0
Primary Education	202 (15.22)	199 (15.34)	3 (10.00)	0.5 (0.1-2.3)	0.45
Secondary Education+	141 (10.62)	137 (10.56)	4(13.33)	Reference	
Age at menarche					
<13	126 (9.49)	123 (9.48)	3 (10.00)	1.17 (0.34-4.03)	1.00
13	318 (23.96)	309 (23.82)	9 (30.00)	1.39 (0.62-3.14)	1.00
>13	883 (66.54)	865 (66.69)	18 (60.00)	Reference	-
Parity					
0	14 (1.05)	12 (0.92)	2 (6.66)	5.8 (1.19-28.94)	0.06
1-3	842 (63.45)	827 (63.76)	15 (50.00)	0.6 (0.3-1.3)	1.00
4-6	471 (35.49)	458 (35.31)	13 (43.33)	Reference	
Age at menopause					
<45	125 (9.41)	123 (9.48)	2 (6.66)	Reference	
45-49	756 (56.97)	742 (57.20)	14 (46.66)	0.86 (0.19-3.8)	1.00
50-54	421 (31.72)	408 (31.45)	13 (43.33)	0.5 (0.11-2.2)	0.5
>55	25 (1.88)	24 (1.85)	1 (3.33)	0.39 (0.03-4.47)	1.00
Occupation					
Agriculture	1134 (85.45)	1108 (85.42)	26 (86.6)	1.5 (0.46-5.11))	1.00
Non-agriculture	193 (14.55)	189 (14.57)	3 (10)		
Diet Followed					
Vegetarian	1222 (92.08)	1192 (91.90)	30 (100)	-	-
Non-vegetarian	105 (7.91)	105 (8.09)	0		
Tobacco Consumption					
No	1302 (98.11)	1272 (98.07)	30 (100)	-	-
Yes	25 (1.88)	25 (1.92)	0		

versus 1 of 16 controls (6.3%).

Malaoxon (1/10 cases, 0/18 controls), Parathion methyl (5/15 cases, 0/15 controls), Phorate (1/16 cases, 0/14 controls), and Phorate sulfone (1/16 cases, 0/14 controls) were detected only among ovarian cancer cases.

Cases and controls differed significantly with respect to Ethion exposure ($p < 0.05$), with an OR of 7.2 (95% CI: 1.53–33.84). However, the confidence interval was wide, indicating imprecision due to the small number of exposed participants. In multivariable logistic regression adjusting for parity and education, Ethion (aOR=6.29, 95% CI: 1.37–28.8, $p=0.018$) and DDE (aOR=6.39, 95% CI: 1.35–30.3, $p=0.020$) were associated with higher odds of ovarian cancer.

Organochlorine Pesticide (OC) Residue Analysis of Cases and Controls – Agriculture

Out of the 16 organochlorine compounds (OC) analyzed among cases and controls, 14 were detected in the cancer cases, while 12 were identified in the control group (Table 4). No Significant association was observed between the serum levels of organochlorines and risk of ovarian cancer ($p>0.05$). Although mean concentrations of Endosulfan (13.98 ± 22.4 ppb vs.

3.26 ± 10.5 ppb), Heptachlor (2.95 ± 9.3 ppb vs. 1.23 ± 3.7 ppb), Lindane (Gamma-HCH: 0.028 ± 0.09 ppb vs. not detected), Chlordane (0.11 ± 0.34 ppb vs. not detected), Chlorobenzilate (4.35 ± 3.8 ppb vs. not detected), and Vinclozolin (3.11 ± 5.4 ppb vs. not detected) were higher in cases than in controls, these differences were not statistically significant (all $p > 0.05$). DDE showed an adjusted association as above.

In non-agricultural women participants, of the 11 OCs and 6 OPs tested, 3 pesticides were detected in cases, and 16 pesticides in controls (Table 6). A small sample size remains an important limitation in this group.

Discussion

The state of Punjab, India, has long reported a high incidence of cancer, with most residents belonging to lower socio-economic groups that lack the resources to bear the economic burden of cancer treatment. In the present study, 2.3% of postmenopausal women had elevated CA125 levels. Although CA125 is regarded as a biomarker for ovarian cancer, it is not recommended for population screening due to poor specificity and predictive value [12]. In the study, no ovarian cancer cases were

Table 2. Frequency Distribution of Select Characteristics among the Ovarian Cancer Case and Control Population in the Study Area

Variable	Cases (n=24)	Controls (n=42)	OR (95%CI)	P-value
Age				
40-49	3 (12.5)	11 (26.2)	Reference	
50-59	5 (20.8)	12 (28.6)	1.5 (0.29-7.94)	0.614
60-69	12 (50.0)	16 (38.1)	2.75 (0.62-12.08)	0.180
70-79	4 (16.7)	3 (7.1)	4.88 (0.68-34.96)	0.114
Education				
Illiterate	14 (58.3)	32 (76.2)	0.25 (0.06-0.99)	0.048
Primary	3 (12.5)	6 (14.3)	0.28 (0.04-1.82)	0.184
Secondary	7 (29.2)	4 (9.5)	Reference	
Family Income				
<3,000	12 (50.0)	40 (95.2)	0.1 (0.0-1.05)	0.055
3,000-5,000	9 (37.5)	1(2.3)	3 (0.14-64.26)	0.482
>5,000	3 (12.5)	1 (2.3)	Reference	
Occupation				
Agriculture	18 (75)	23 (54.8)	2.47 (0.82-7.48)	0.107
Non-agriculture	6 (25)	19 (45.2)	Reference	
Age at menopause				
<45	2 (8.3)	5 (11.9)	Reference	
45-49	12 (50)	23 (54.8)	1.3 (0.22-7.75)	0.770
50-54	6 (25)	6 (14.3)	2.5 (0.34-18.33)	0.367
>55	4 (16.7)	8 (19.0)	1.25 (0.16-9.53)	0.829
Age at Menarche				
<12	0	1 (2.4)	0.59 (0.02-15.48)	0.755
12-13	8 (33.3)	12 (28.6)	1.21 (0.41-3.56)	0.732
> 13	16 (66.7)	29 (69.0)	Reference	
Parity				
0	0	0	3 (0.05-161.86)	0.589
1-2	15 (62.5)	14 (33.3)	3.33(1.17-9.49)	0.024
≥3	9 (37.5)	28 (66.7)	Reference	
Diet Followed				
Vegetarian	19 (79.2)	31 (73.8)		
Non-vegetarian	5 (20.8)	11 (26.2)	0.74 (0.22-2.47)	0.626
Tobacco Consumption				
No	21 (87.5)	41 (97.6)		
Yes	3 (12.5)	1 (2.4)	5.86 (0.57-59.81)	0.136
Pesticides Detected in Blood				
Yes	22 (91.6)	26 (61.9)	6.7(1.4-32.7)	0.014
No	2 (8.4)	16 (38.1)		

detected through follow-up imaging, underscoring the low yield of CA-125–based screening in a general rural population.

The mean concentration levels of organophosphates such as Monocrotophos, Malathion, Malaoxon, Ethion, Fenitrothion, Dimethoate, and the herbicide Atrazine were higher among ovarian cancer cases compared to controls. Some pesticides (e.g., Malaoxon, Parathion methyl, Phorate, and Phorate sulfone) were detected only in cases, although based on very small numbers. Despite bans on many of these pesticides, their detection in blood samples

highlights their continued use, environmental persistence, and potential health risks. Similarly, mean levels of organochlorines, including Endosulfan, Heptachlor, Lindane, Chlordane, Chlorobenzilate, and Vinclozolin were also higher in cases than controls. However, we also observed contradictory patterns; for example, Chlorpyrifos was more frequently detected among controls in agricultural participants (inverse association), whereas an apparently elevated OR in non-agricultural women had very wide confidence intervals.

Few studies have evaluated environmental chemical
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Table 3. Organophosphate Pesticide Residue Analysis (ppb) among Ovarian Cancer Cases and Controls-Agriculture

Pesticide	Cases			Controls			Odds Ratio (95% CI)	p-value
	N	N (%) of samples detected	Mean + SD	N	N (%) of samples detected	Mean + SD		
Chlorpyrifos	15	5 (33)	96.93 (174.25)	20	16 (80)	1222.42 (1181)	0.12 (0.02-0.57)	0.008
Monocrotophos	15	1 (6.66)	12.09 (36.28)	18	1 (5.55)	0.51 (1.7)	1.2 (0.06-21.2)	0.89
Malathion	12	1 (8.3)	1.66 (4.99)	18	6 (33)	1.35 (2.54)	0.18 (0.01-1.75)	0.14
Malaoxon	10	1 (10)	8.52 (14.75)	18	0	-	5.8 (0.21-157.5)	0.29
Ethion	14	9 (64.3)	0.786 (0.67)	20	4 (20)	0.26 (0.57)	7.2 (1.53-33.84)	0.01
Fenitrothion	15	8 (53.3)	14.29 (14.67)	15	3 (20)	4.62 (10.5)	4.5 (0.9-23.13)	0.06
Dimethoate	10	1 (10)	111.92 (193.8)	10	2 (20)	9.87 (22.04)	0.44 (0.03-5.88)	0.53
Phosphamidon	8	0	-	15	7 (46.6)	6.35 (7.95)	0.06 (0.003-1.36)	0.07
Parathion methyl	15	5 (33)	19.17 (40.25)	15	0	0	16.2(0.8-325)	0.06
Paraoxon methyl	11	2 (18)	3.34(6.64)	12	1 (8)	5.55 (18.42)	2.4 (0.18-31.5)	0.49
Phorate	16	1 (6.25)	245.47 (736.4)	14	0	0	2.8 (0.1-74.5)	0.53
Phorate sulfoxide	11	1 (9.1)	49.25 (147.7)	14	5 (35.7)	510.38 (607.5)	0.1 (0.01-1.84)	0.10
Phorate sulfone	16	1 (6.25)	344.41 (1033.23)	14	0	-	2.8 (0.1-74.5)	0.53
Atrazine	14	5 (35.7)	0.087 (0.105)	16	1 (6.3)	0.02 (0.06)	8.3 (0.8-83.2)	0.07

exposures in relation to ovarian cancer. While Inoue-Choi et al. [13] found no association between atrazine in drinking water and postmenopausal ovarian cancer risk, Sharma et al. [14] reported significantly higher levels of β -HCH, endosulfan-I, endosulfan-II, p'p'-DDT, and p'p'-DDE in ovarian cancer cases compared to controls.

These chemicals have been reported as neurotoxic, immunotoxic, cytotoxic, acutely hazardous, potential carcinogens, and acetylcholinesterase inhibitors, in addition to being linked with adverse birth outcomes [15-17].

Ethion has been observed to be significantly associated with an increased risk of ovarian cancer in those practicing farming. In this study, Ethion was detected in 64% of cases versus 20% of controls, although the wide confidence

interval reflects imprecision due to small sample size. In the liver, ethion is metabolized into its active form, ethion monoxon, which can circulate through the bloodstream and reach various organs, including the brain. There, it inhibits the cholinesterase enzyme, potentially leading to neurological disorders [18]. Despite these toxicological effects, no direct evidence has confirmed ethion exposure as a cancer risk factor in humans. Although it is not classified as a carcinogen, the World Health Organization (WHO) designates ethion as a moderately hazardous chemical. Indian Agricultural Research Institute (IARI) has recommended against its use on cotton crops, which are widely cultivated in Punjab [19].

Chlorpyrifos exposure was significantly associated with ovarian cancer risk among non-farming women.

Table 4. Organochlorine Pesticide Residue Analysis (ppb) among Ovarian Cancer Cases and Controls-Agriculture

Pesticide	Cases			Controls			Odds Ratio (95% CI)	p-value
	N	No (%) of samples detected	Mean + SD	N	No % of samples detected	Mean + SD		
Endosulphan	15	6 (40)	13.975 (22.37)	21	9 (42.8)	3.26 (10.5)	0.9 (0.23-3.4)	0.8
Aldrin	15	1 (6.6)	1.635 (5.17)	20	6 (30.0)	1.27 (3.02)	0.16 (0.01-1.57)	0.1
Endrin	14	9 (64.28)	2.583 (2.6)	18	8 (44)	6.83 (10.5)	2.2 (0.5-9.4)	0.3
Heptachlor	16	2 (12.5)	2.95 (9.32)	20	2 (10)	1.23 (3.7)	1.2 (0.1-10.2)	0.8
Alpha HCH	16	0	-	20	1 (9.09)	3.95 (13.)	0.39 (0.01-10.3)	0.5
Beta HCH	16	5 (31.25)	10.20 (21.57)	20	11 (55)	33.13 (79.6)	0.37 (0.09-1.4)	0.1
Delta HCH	16	1 (7)	0.02 (0.07)	20	1 (5)	0.21 (0.7)	1.2 (0.07-21.9)	0.8
Gamma HCH	16	1 (10)	0.028 (0.09)	20	0	-	3.96 (0.1-104.0)	0.4
Methoxychlor	15	2 (13.3)	0.74 (2.14)	20	5 (25)	1.75(3.02)	0.46 (0.07-2.7)	0.39
Hexachlorobenzene	16	0	-	21	7 (33.3)	1.37 (2.14)	0.05 (0.003-1.11)	0.06
Chlordane	15	1 (6.66)	0.114 (0.34)	21	0	-	4.4 (0.16-116.9)	0.37
Chlorobenzilate	15	3 (20)	4.35 (3.82)	21	0	-	12.0 (0.5-252.7)	0.1
Vinclozolin	15	1 (6.66)	3.11 (5.39)	21	0	-	4.4 (0.16-116.9)	0.37
DDD	15	3 (20)	0.397 (0.937)	20	8 (40)	1.37 (1.8)	0.37 (0.079-1.76)	0.2
DDE	15	12 (80)	33.87 (68.56)	20	20 (100)	252.8 (551.8)	0.08 (0.004-1.7)	0.11
DDT	15	4 (26.66)	2.58 (7.46)	20	16 (80)	6.37 (10.6)	0.1 (0.01-0.44)	0.003

Table 5. Organochlorine Pesticide Residue (ppb) in Non-agricultural Cases and Controls

Pesticide	Cases			Controls			Odd's ratio (95% CI)	p-value
	N	No (%) of] samples detected	Mean (SD)	N	No % of samples detected	Mean (SD)		
Endosulfan	6	0	-	18	2 (11.11)	0.15 (0.57)	0.5 (0.02-12.1)	0.67
Dieldrin	5	0	-	15	3 (20)	0.209 (0.5)	0.19 (0.01-7.4)	0.48
Endrin	5	0	-	18	18 (100)	7.07 (6.23)	0.002 (0.0-0.13)	0.003
Alpha HCH	6	0	-	18	1 (5.56)	0.066 (0.21)	0.89 (0.03-24.9)	0.95
Beta HCH	6	0	-	18	1 (5.56)	0.273 (0.86)	0.89 (0.03-24.9)	0.95
Delta HCH	6	0	-	18	3 (16.67)	0.184 (0.45)	0.34 (0.02-7.57)	0.49
Gamma HCH	6	0	-	18	1 (5.56)	0.072 (0.23)	0.89 (0.03-24.9)	0.95
Total HCH	6	0	-	18	3 (16.67)	0.59 (1.73)	0.34 (0.02-7.57)	0.49
Chlordane	5	0	-	16	1 (6.25)	0.31 (0.75)	0.94 (0.03-26.64)	0.97
Methoxychlor	5	1 (20)	3.51 (4.96)	15	0	-	10.3 (0.35-299.9)	0.17
DDD	6	0	-	18	2 (11.11)	0.27 (0.79)	0.5 (0.02-12.07)	0.68
DDT	6	2(33.33)	11.25(13.3)	18	4 (22.22)	0.48 (0.95)	1.75 (0.23-13.3)	0.59
Total DDT	6	2(33.33)	11.25(13.3)	18	4(22.22)	0.75(1.58)	1.75 (0.23-13.3)	0.59

However, given the small sample size, larger-scale studies are warranted. Moreover, in the overall agricultural analysis, Chlorpyrifos was more common in controls, suggesting no consistent relationship. It is a widely used organophosphate pesticide known to inhibit acetylcholinesterase and convert into a more toxic form, chlorpyrifos oxon. Although not classified as carcinogenic by the USEPA, some studies have linked its exposure to lung, colorectal, and potentially ovarian cancers [20-22]. Despite international restrictions, India has no plans to phase out its use.

Hexachlorocyclohexane (HCH) and dichlorodiphenyl-trichloroethane (DDT) are two of the major organochlorine pesticides (OCPs) extensively used in India for more than half a century [23]. The total content of HCH (Mean levels, 29.09 ppb) observed in the controls of the present study was found to be relatively lower in comparison to a previous study conducted among the population of Punjab (Mean levels, 57.1 ppb) [11]. Though this could be attributed to HCH being banned or severely restricted for use, residues of this persist in blood, soil, and other environmental media are of public health concern [23].

The mean levels of DDE detected in the controls of the present study (168.31 ppb) were substantially higher in comparison to an earlier study, which reported mean levels of 20.88 ppb in the adult population of the Bhatinda district of Punjab [24].

Although the precise exposure thresholds for endocrine-disrupting chemicals (EDCs) to cause cancer remain unclear, it can be speculated that during menopause, when ovarian function declines, the ovary may become more susceptible to the effects of exogenous chemicals such as EDCs. Thus, a combination of long-term pesticide exposure and physiological changes in postmenopausal women may cross a threshold, contributing to ovarian cancer manifestation [9]. Farr et al. (2004) also suggested that pesticides can disrupt reproductive hormones or exert toxic effects on the ovary, potentially delaying menopause

and increasing cancer risk [25].

The present study, therefore, highlights the need for further investigation into the link between pesticide exposure, menopausal delay, and ovarian cancer risk.

This study provides preliminary insights but has certain constraints, including hospital-based case recruitment, reliance on single blood samples for exposure measurement, and the potential for residual confounding. These factors, together with the limited sample size, highlight its exploratory nature and the need for larger prospective studies. In line with current screening guidance, routine population screening with CA-125 is not supported. Instead, strengthening cancer diagnostic services and registry systems in rural areas, alongside efforts to reduce harmful exposures through safer agricultural practices, farmer education, and promotion of eco-friendly alternatives, should be prioritized. Well-powered prospective studies with repeated exposure assessment and robust confounder control are essential to clarify whether risk-stratified surveillance has value in high-exposure settings

Author Contribution Statement

Study conceptualization and design: RS; Data collection and analysis: NS; Manuscript writing and analysis: RS; Manuscript proofreading and scientific contributions: SM, RD. Data Availability: Available on request

Acknowledgements

The authors would like to express deep gratitude to the village heads and the women participants for their cooperation and participation in the study.

Funding Statement

The study was funded by the Rajiv Gandhi Centre for Biotechnology (RGCB), Department of Biotechnology

(DBT), Ministry of Science and Technology, Government of India.

Ethical Declaration

The study was approved by the Amity University, Noida, India's ethical committee

Conflict of Interest

There is no potential conflict of interest.

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