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Gas Chromatography Tandem Mass Spectrometry based Pesticides Assessment and their Association with Allergic Markers and Airways Obstruction in Pediatric Asthma

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ABSTRACT:

Background: Pesticide exposure in children, especially through inhalation, can worsen asthma and contribute to its development, often from indoor sources and residue on products.

Aim: The study examines pesticide levels (organophosphate, organochlorine, and pyrethroid groups) and their potential link to allergic marker (eosinophils and IgE levels) and airways obstruction (FEV1) in asthmatic children and controls.

Method: Total 100 asthmatic children and 100 age-sex matched controls were enrolled. Serum Pesticides levels were measured using gas chromatography tandem mass spectrometry and IgE was measured by immunoturbidity assay.

Result: Among 140 screened pesticides, four were identifiable which is belong from pyrethroid group and they are commonly used in mosquito coils, spray, and repellents in both asthmatic children and controls. Metofluthrin (2.9-fold), allethrin (24.6-fold), imiprothrin (2.6-fold) and transfluthrin (3.9-fold) were significantly higher in asthmatic children than control ($p<0.05$). We observed that increased eosinophil counts, serum IgE levels, and reduced FEV1 % in asthmatic children as compared to controls ($p<0.05$). Eosinophils and IgE levels were positively correlated with transfluthrin ($r=0.300$ $p=0.038$; $r=0.363$, $p=0.006$), metofluthrin ($r=0.401$, $p<0.0001$; $r=0.399$, $p<0.0001$), allethrin ($r=0.252$, $p<0.0001$; $r=0.474$, $p<0.0001$) and imiprothrin ($r=0.498$, $p<0.0001$; $r=0.401$, $p<0.0001$).

Conclusion: Exposure to household pesticides like transfluthrin, allethrin, metofluthrin, and imiprothrin in children not only triggers allergic reactions but also worsens asthma severity.

Introduction

Children can be exposed to pesticides through various sources, including pesticides spraying near residential areas, indoor use for pest control, residues on fruits, vegetables, and household products containing pesticides (mosquito coils, mosquito spray and mosquito repellents) [1,2].

Pesticides linked to aggravating asthma symptoms and potentially contributing to the development of asthma, especially in children with existing respiratory issues or allergies [3]. Exposure to pesticides can occur through inhalation, leading to irritation of the respiratory tract and inflammation in the airways [4].

In India, pesticides such as transfluthrin, allethrin, imiprothrin, and metofluthrin are commonly employed indoors in products like mosquito repellents, sprays, and coils to control diseases transmitted by mosquitoes, such as dengue and malaria. Inhaling pesticides can irritate the airways, trigger inflammation, and compromise lung function, which may manifest as wheezing, coughing, chest tightness, and difficulty in breathing—classic symptoms of asthma [5,6]. Certain pesticides contain chemicals that act as respiratory irritants or allergens, further exacerbating asthma symptoms.

Studies have shown that children exposed to these pesticides have a higher incidence of asthma and respiratory symptoms [2,7]. Both organophosphates and pyrethroids can irritate the airways, trigger inflammation, and compromise lung function, leading to symptoms such as wheezing, coughing, chest tightness, and difficulty breathing [8,9].

Pyrethroids are frequently used in mosquito repellents due to their effectiveness in repelling and killing mosquitoes [10,11] and are associated with potential respiratory effects, including exacerbation of asthma symptoms in some children.

Airway obstruction is defined as a forced expiratory volume in one second (FEV1) to forced vital capacity (FVC) ratio of less than 80% [12,13]. FEV1, eosinophils, and Immunoglobulin E (IgE) levels are vital markers in childhood asthma as they directly indicate airway obstruction, allergic inflammation, and immune response to allergens, respectively [14, 15].

As per the above content, the study was aimed to assess pesticide levels in asthmatic children and controls and explore their correlation with allergic markers (eosinophils, and IgE) and airways obstruction (FEV1 levels).

Methodology

Subjects' enrolment

A case-control study included 100 asthmatic children and 100 age-sex matched controls from the same geographical area with 5 to 15 years of age group. The asthma was diagnosed as per the Global Initiative for Asthma (GINA) guideline 2023 [16] from Department of paediatrics, Dr Ram Manohar lohia institute of medical sciences, Lucknow. The experimental work was done at department of biochemistry. The lung function test was done using an electronic spirometer (Spirolab, Italy) to evaluate severity of disease. The written informed consent and complete questionnaires was taken by all participant's parents or guardians for ethical consideration. The study was approved by institutional ethics committee (IEC No. 60/21).

Estimation of eosinophil counts and immunoglobulin E (IgE) levels

Blood samples were collected in an EDTA and a plain vial via venipuncture. EDTA sample was used for the estimation of eosinophils count, whereas sample in plain vial was used for the estimation of IgE and pesticides levels. The eosinophils count was measured by using a 6-part haematology analyser (Alinity h-series). Serum IgE was estimated using a commercially available kit (DiaSy) by immunoturbidimetry assay on fully automated analyser (Beckman Coulter, AU480).

Estimation of pesticides levels

Standard and solvents procurement

A mixture of 140 pesticides included organophosphate, organochlorine, and pyrethroid groups standard was procured from Sigma Aldrich, Germany. The organic solvents like acetonitrile, glacial acetic acid, n-hexane, ethyl acetate, and chemicals i.e., PSA, magnesium sulphate, and sodium chloride of analytical mass grade were procured from Thermo fisher Scientific.

Standards and sample preparation

The initial stock solution of pesticides for 1 ppm was prepared for by using ethyl acetate. Subsequently, serial dilutions were prepared by stock solution in ethyl acetate to make the calibration curve standards of 10 ppb, 20 ppb, 50 ppb, 100 ppb, and 200 ppb, respectively. (Fig.1)

Pesticide extraction was done by using Liquid-Liquid

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Micro-Extraction approach. Total 1.0 mL of serum sample was taken and acidified with 1 mL chilled 2% glacial acetic acid in acetonitrile which allows proper extraction of maximum analytes and reduces the matrix effect. The sample was properly mixed by using a vortexed for 1 minute followed by the addition of 0.5 g magnesium sulphate and 0.2 g sodium chloride. Again, it was mixed and centrifuged at 8000 rpm for 10 minutes at 4ºC. The supernatant was taken out in a fresh tube and evaporated completely by using a nitrogen evaporator. The analytes were redissolved in 0.5 mL ethyl acetate and cleaned up by using 20 mg primary secondary amine (PSA). Tubes were vortexed and centrifuged at 8000 rpm for 5 minutes. The organic layer was taken out and injected for GC-MS/MS analysis [16].

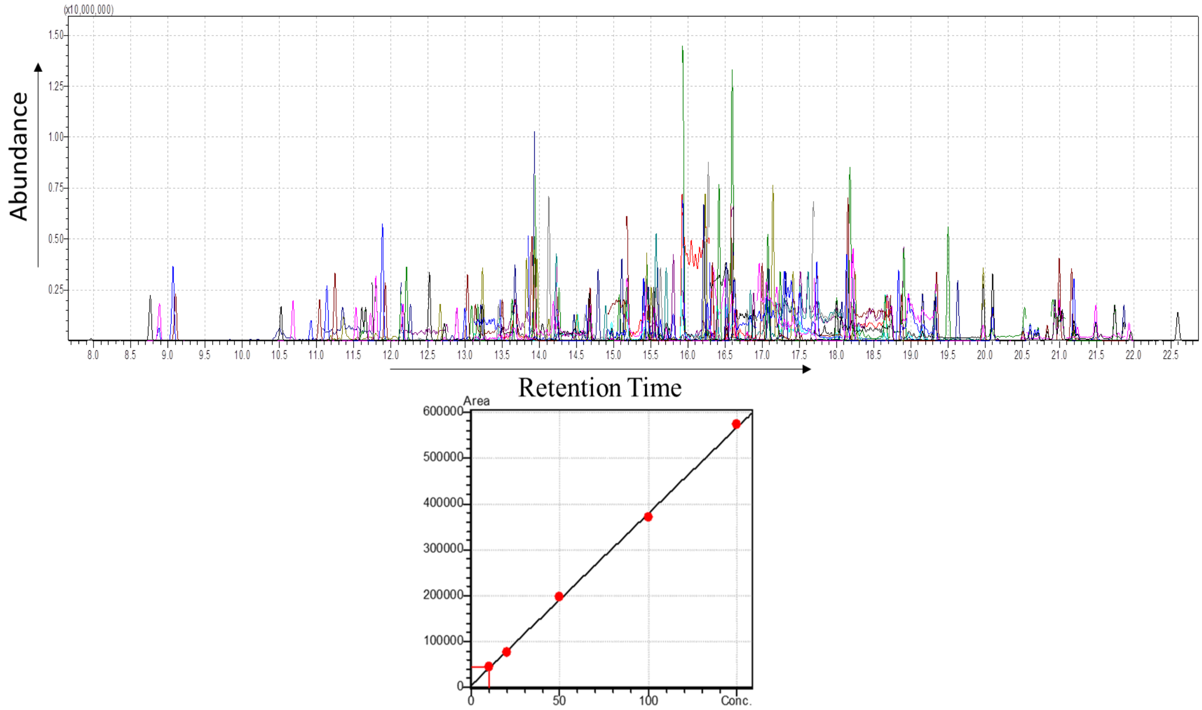

Fig. 1: Representative graph for screening and calibration curve of pesticides on Gas chromatography tandem mass spectrometry

Analytical instrumentation

The screening of pesticides in serum samples was done using Shimadzu Nexa 3000 Gas Chromatography equipped with Nexa mass spectrometry. The column dura bond (DB) 5ms with dimension (30m×0.25 mm×0.25µm) was used for proper separation of 140 pesticides. Initially, the serum samples were screened in full scan mode and all the peaks were matched from National Institute of Standards and Technology (NIST) library. All the pesticides were quantified by using Multiple reaction monitoring (MRM) mode with oven temperature starting from 50^0C, raised to 250^0C at a rate of 10^0C and final reached to 300^0C hold for 2 minutes. For mass spectrometry, the interface temperature was set to 250^0C and ion source temperature was maintained to 300^0C. 1 µL injection volume was injected into Autosampler AOC-20is in the split less liner mode. The total run time was 45 min per sample. Quantitation of all the pesticides in each sample was done by spiking the known concentration and calculating the recovery and matrix match calibration. Out of 140 screened pesticides only 4 pesticides were detected in blood samples of asthmatic children. Notably, metofluthrin, allethrin, imiprothrin, and transfluthrin were detected (fig. 2a to 2d; Supp. Table 1).

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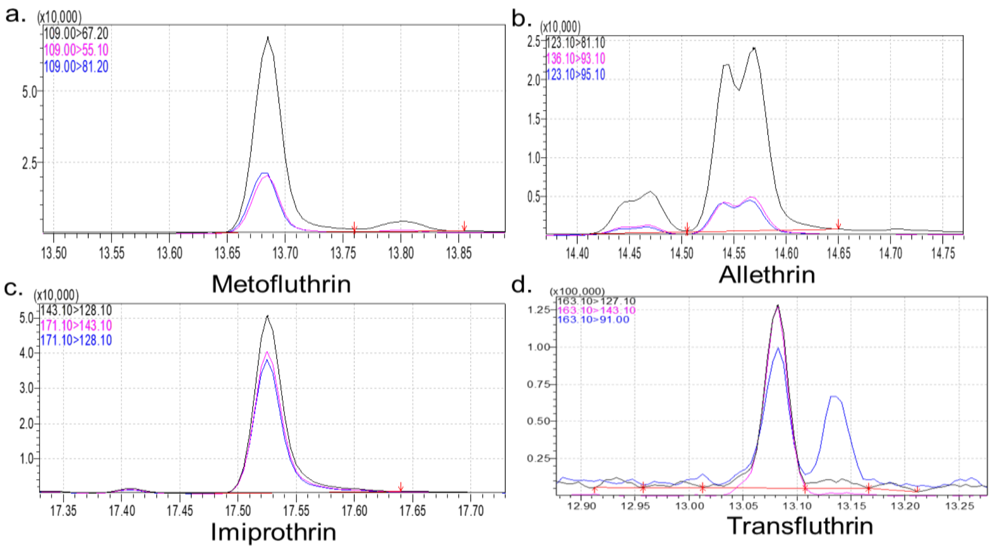

Fig. 2: Extracted Chromatogram of detected pesticides: a) Metofluthrin, b) Allethrin, c) Imiprothrin, d) Transfluthrin

Data analysis

The demographical data was presented in number and percentage. The variable data was presented in median and quartile range (quartile 25% and quartile 75%). The p-value was calculated using both the chi-square and Mann-Whitney tests. The pearson correlation was used to see association between two variables. The heatmap graph was prepared by using GraphPad. The data was analysed by using SPSS version 23, Chicago, USA. The p-value less than 0.05 was considered as statistically significant.

Result

Heatmap of detected household pesticides in asthmatic children and control

Four identified, pyrethroids pesticides (metofluthrin, allethrin, imiprothrin, and transfluthrin which is commonly used in mosquito repellents, spray, and coils) in both asthmatic children and the control group. The heatmap shows the concentration of these pesticides in different samples. In this heatmap, the x-axis represents the pesticides name and y-axis represents the different samples. A colour gradient was employed by ranging the concentration of pesticides from low (green colour) to high (red colour). Notably, metofluthrin, allethrin, imiprothrin, and transfluthrin were detected in 40-100% of the population, indicating widespread exposure across the tested samples. (Fig.3)

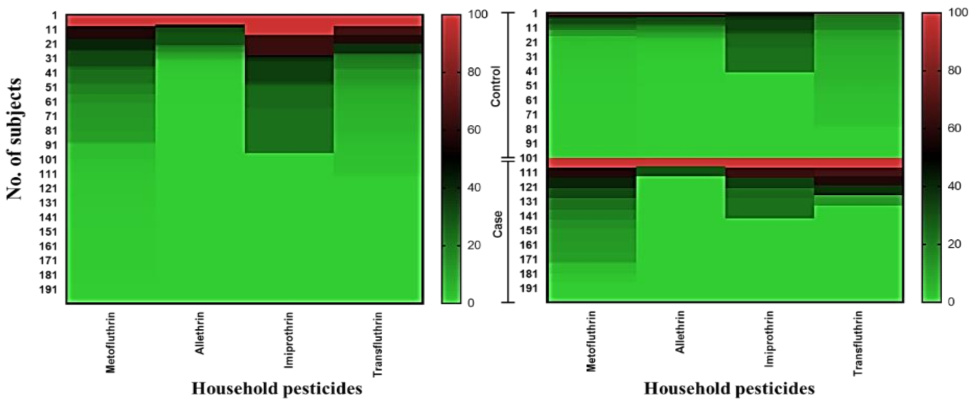

Fig.3: Heat-map graph of detected pesticides. The red colour indicates the high levels of pesticide (61 to 100%), black colour indicated the moderate pesticide levels (40 to 60%), and green colour represents mild pesticides level (0 to 40%)

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Demographical and allergic markers

The demographical and biochemical variables of study population was mentioned in table 1. No significant differences were found in age (years) (p=0.087) and gender (p=0.199) between the groups, indicating the adequate matching. The levels of eosinophils were significantly higher by 3.2-fold, and IgE levels were higher by 9.1-fold in asthmatic children (p < 0.0001). However, the FEV1 median:78.00 (71.00-82.00) was significantly reduced in asthmatic children than the control 98.50 (95.00-99.00), p<0.0001.

Table 1: Demographical and allergic marker status of study population

Variables	Asthmatic children (N=100) N, (%)	Controls (N=100) N, (%)	p-value
Age in Years (Mean±SD)			
Range (years)	8.00±5.00	9.00 ±3.00	0.087
	5-13	6-12	
Gender			
Male	52(52.0)	61(61.0)	0.199
Female	48(48.0)	39(39.0)	
Family history			
Yes	59(59.0)	20(20.0)	<0.0001*
No	41(41.0)	80(80.0)	
Allergic markers Median (Q1-Q3)			
FEV1 (L)	78.00 (71.00-82.00)	98.50 (95.00-99.00)	<0.0001*
Eosinophils (%)	9.50 (8.00-15.00)	3.00 (2.00-4.00)	<0.0001*
IgE (IU/mL)	534.50 (252.38-999.00)	58.60 (39.70-121.70)	<0.0001*

*Abbreviations: FEV1: Forced expiratory volume in 1 second, IgE: Immunoglobulin E. The chi-square test, student t-test and mann-whitney test were used to calculate the p-value. *p-value <0.05 was considered as statistically significant.*

Household Pesticides significantly higher asthmatic children as compare to controls

Pyrethroids i.e., metofluthrin (2.9-fold), allethrin (24.6-fold), imiprothrin (2.6-fold), and transfluthrin (3.9-fold) were significantly higher in asthmatic children than the control with p<0.05, respectively. (Table 2)

Table 2: Status of Pesticide levels in asthmatic children and controls

Pesticides (µg/L)	Asthmatic children (N=100) Median (Q1-Q3)	Controls (N=100) Median (Q1-Q3)	p-value
Metofluthrin (n=100,73)	19.54 (18.83-20.58)	6.65 (5.65-8.76)	<0.0001*
Allethrin (n=89,12)	47.23 (25.06-64.98)	1.92 (0.89-2.95)	0.001*
Imiprothrin (n=66,41)	4.77 (3.60-6.21)	1.87 (1.03-2.45)	0.001*
Transfluthrin (n=93,32)	5.80 (5.25-6.97)	1.50 (0.34-2.38)	<0.0001*

*The mann-whitney test were used to calculate the p-value. *p-value <0.05 was considered as statistically significant.*

Correlation between household pesticides and allergic markers in asthmatic children

The transfluthrin (r=-0.309; p<0.0001), metofluthrin (r=-0.343; p<0.0001), allethrin (r=-0.463, p<0.0001), and imiprothrin (r=-0.413; p<0.0001) showed a negative correlation with FEV1 levels. However, eosinophil counts and IgE levels were positively correlated with the levels of transfluthrin (r=0.300 p=0.038; r=0.363,

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p=0.006), metofluthrin (r=0.401, p<0.0001; r=0.399, p<0.0001), allethrin (r=0.252, p<0.0001; r=0.474, p<0.0001), and imiprothrin (r=0.498, p<0.0001; r=0.401, p<0.0001). (Table 3)

Table 3: Correlation of pesticides with allergic markers in asthmatic children

Allergic markers	**Relative coefficient (r), p-value**
Metofluthrin (µg/L)	
FEV1 (L)	r=-0.44, p<0.0001*
Eosinophils (%)	r=0.40, p<0.0001*
IgE (IU/mL)	r=0.39, p<0.0001*
Allethrin (µg/L)	
FEV1 (L)	r=-0.46, p<0.0001*
Eosinophils (%)	r=0.45, p<0.0001*
IgE (IU/mL)	r=0.47, p<0.0001*
Imiprothrin (µg/L)	
FEV1 (L)	r=-0.41, p<0.0001*
Eosinophils (%)	r=0.49, p<0.0001*
IgE (IU/mL)	r=0.40, p<0.0001*
Transfluthrin (µg/L)	
FEV1 (L)	r=-0.39, p<0.0001*
Eosinophils (%)	r=0.31, p=0.038*
IgE (IU/mL)	r=0.36, p=0.006*

*Abbreviations: r= Pearson correlation, FEV1: Forced expiratory volume in 1 second, IgE: Immunoglobulin E. The pearson correlation was used to see the correlation between variables. *p-value <0.05 was considered as statistically significant.*

Association of pesticides with disease severity

The scattered plot showed that high levels of metofluthrin, allethrin, imiprothrin, and transfluthrin were observed in severe airways obstructive asthmatic children and also indicates that increased pesticide levels are associated with increase airways obstruction in asthmatic children. (Fig. 4a to 4d)

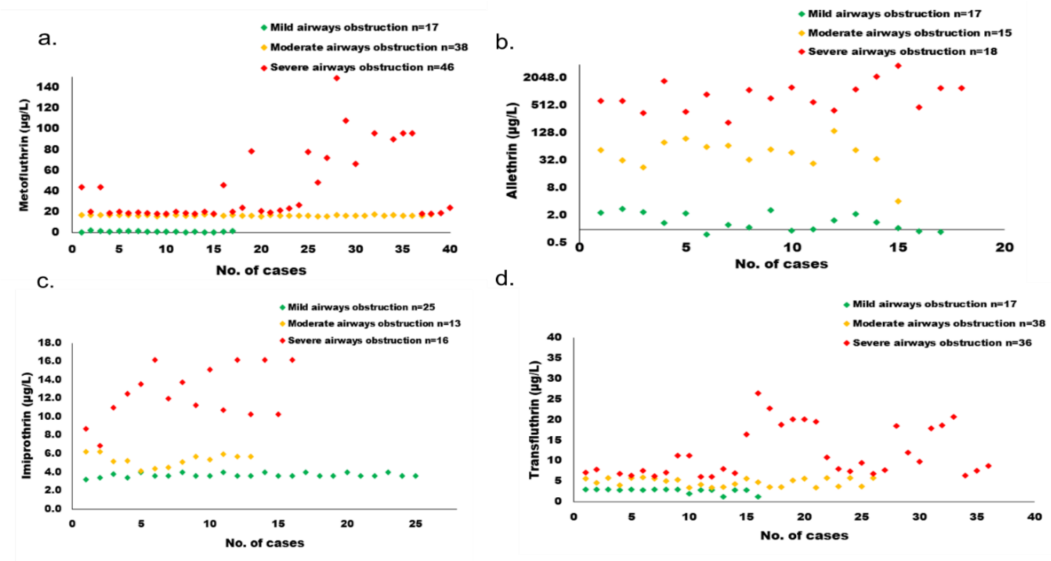

Fig.4: Scattered plot showing the association between the correlated pesticides and the severity of asthma

Discussion

Pyrethroid pesticides uses to control a wide range of pests like mosquitoes, etc, and their effect primarily depend on the duration of exposure. They contain highly volatile compounds which enters the body through inhalation, and cause airways inflammation via oxidative stress [17]. The disease susceptibility depends on the exposure of the environmental factors (pesticides), so the current study assessed the levels of pesticides i.e., organophosphate, organochlorine, and pyrethroids in asthmatic children and normal children (controls) and to assess their association with allergy markers (eosinophils, and IgE) and airways obstruction marker (FEV1). In our study we found that eosinophil counts and IgE levels were significantly higher and FEV1 was significant reduced in asthmatic children than controls ($p<0.05$).

Eosinophils are essential contributors to both allergic and non-allergic asthma, primarily due to the function of their basic proteins, such as eosinophil cation protein (ECP) and eosinophilic peroxidase (EPO). These proteins have the capacity to incite allergic responses, irrespective of the trigger, thereby perpetuating airway inflammation and hyperreactivity [18-20].

Exposure to these chemicals triggers a Th2 immune response, inducing the production of eosinophils release inflammatory mediators i.e., IL-5 cytokines that activate and stimulate the growth of eosinophils [21,22] and also prompt B cells to undergo class switching, leading to increased production of allergen-specific IgE antibodies [1,23].

Overall, the combination of airway inflammation, bronchoconstriction, mucus production, and asthma exacerbations probably triggered by pesticides exposure can acutely worsen airway inflammation and bronchoconstriction, resulting in a rapid decline in lung function and FEV1% in children with asthma [24,25].

In our study the pesticides i.e., metofluthrin, allethrin, imiprothrin, and transfluthrin were significantly elevated in asthmatic children than controls ($p<0.05$). The metofluthrin, allethrin, imiprothrin, and transfluthrin are also belongs from pyrethroid group and highly volatile compounds, most commonly used as a mosquito repellent, mosquito spray, and mosquito coils in households [23,26]. These substances are commonly employed to combat mosquito-borne diseases prevalent in tropical and subtropical regions, such as India. The vapours emitted by these substances can trigger asthma attacks. However, they are also known for their potential adverse health impacts and have been linked to effects on the epithelial cells of the human nasal and lung mucosa [27].

Research indicates that metofluthrin, allethrin, imiprothrin, and transfluthrin function as respiratory irritants, capable of damaging the bronchial mucosa and heightening airway sensitivity to stimuli. This heightened sensitivity can increase the risk of developing asthma or exacerbate existing asthma conditions [28,29].

In our study we have observed that levels of metofluthrin, allethrin, imiprothrin, and transfluthrin were positively correlated with eosinophil and IgE whereas negatively correlated with FEV1 levels, which indicated that these chemicals act as a respiratory irritant and trigger allergy.

In our previous case-control study, transfluthrin was found to significantly increase the risk of asthma (OR: 3.08, $p < 0.0001$). Additionally, it showed correlations with IgE ($r = 0.363$, $p = 0.006$), eosinophils ($r = 0.300$, $p = 0.038$), and hs-CRP ($r = 0.324$, $p = 0.049$). The FEV1% status in transfluthrin detected children had severe obstruction airways than the moderate and mild [16].

Studies also suggested that the wide spectrum organophosphate pesticide are also widely used throughout the world for agricultural, residential settings, and public health purposes, mainly to enhance food production. However, its exposure has been associated with respiratory symptoms and exacerbations in individuals with pre-existing asthma.

The study conducted by Rodgers and Xiong on rat model involved administering oral pesticides and then reconstituting it with bone marrow-derived mast cells. They found that this process restored malathion's capability to enhance macrophage activity, trigger mitogenic responses, and induce mast cell degranulation. In essence, the study suggests that minimal exposure to malathion can activate the numerous inflammatory mediators which is associated with aryl hydrocarbon receptor (AHR). This implies that pesticides, even in small amounts, have the potential to initiate a cascade of inflammatory responses mediated by AHR. Such activation may contribute to various health issues linked to inflammation, emphasizing the significance of monitoring and minimizing pesticide exposure to safeguard health [30].

Another study was conducted by Segura et al. on female guinea pigs and rabbits, which demonstrated that the increased lung resistance index (LRI) induced by another pesticides, a response totally depends on biotransformation of parathion to paraoxon through the P450 enzymatic reaction. They also demonstrated that low dose of parathion induced the airways hyperresponsiveness. One potential explanation for pesticides called parathion-induced airway hyperresponsiveness to histamine is that parathion's inhibition of Acetylcholine enhances the cholinergic effect of histamine [31]. However, further investigation is needed to understand the mechanisms underlying this interaction. But in our study, the organophosphates were not detectable in asthmatic children and the control samples. Because children can spend up to 90% of their time indoors, the focus on addressing indoor pollutants holds particular significance. Since children spend a substantial portion of their time indoors, often in settings like homes, schools, and daycare facilities, minimizing exposure to indoor pollutants becomes paramount for protecting their respiratory health.

Indoor environments harbour a plethora of potential asthma triggers, including allergens like pest control product and household cleaning products. These pollutants can exacerbate respiratory symptoms, trigger asthma attacks, and contribute to the development of asthma in susceptible individuals.

To best of our knowledge no studies have been found regarding association of asthma with detected household pesticides' exposure in human samples. Further, we will explore the potential role of the remaining chemicals such as allethrin, metofluthrin and imiprothrin with their mechanisms and also look at the association of these chemicals with allergy markers. Acknowledging some limitations of the study is essential, including the fact that exposure time and frequency to these pesticides was only assessed through serum pesticide levels, without consideration of inhalation amount might be due to parents' unawareness of their consequences.

Conclusion

This research establishes a link between pesticides exposure and asthma incidence. The study found that asthmatic children had significantly reduced FEV1 values and raised eosinophil counts and IgE levels indicating obstruction of airways. It also revealed that elevated levels of specific pesticides in asthmatic children, including pyrethroids (metofluthrin, allethrin, imiprothrin, and transfluthrin) were significantly associated. In India, pesticides such as transfluthrin, allethrin, imiprothrin, and metofluthrin are commonly employed indoors in products like mosquito repellents, sprays, and coils to control diseases transmitted by mosquitoes, such as dengue and malaria. However, the inhalation of these volatile pesticide chemicals by children has been linked to allergic reactions and heightened disease severity. To establish a comprehensive risk profile for children, it is essential to evaluate various other indoor exposures. This will enhance the preventive scope of the study.

Author Contributions

SS: Experimental work, preparation of the original manuscript draft, data curation

JV: Help in pesticide standardization

MRK: Conceptualization, review and editing manuscript.

AS: Formal analysis.

SS: Clinical details and samples

VT: Conceptualization and fund acquisition

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Supp. Table 1: Name of 140 screened pesticides in asthmatic children and control samples

Name	**Retention time (minutes)**	**Target ions**
(E)-Chlorfenvinphos	14.458	323.00>267.00
(Z)-Chlorfenvinphos	14.662	323.00>267.00
1,1-Dichloro-2,2-bis(4-ethylphenyl) ethane	16.264	223.20>167.10
2,4'-Methoxychlor	17.405	227.10>121.10
2-Phenylphenol	9.055	170.10>141.10
4,4'-Dichlorobenzophenone	14.117	139.00>111.00
4,4'-methoxychlor olefin	17.065	238.10>223.10
Acequinocyl	21.153	342.20>188.10
Acrinathrin-1	18.905	181.10>152.10
Acrinathrin-2	19.115	181.10>152.10
Aldrin	13.922	262.90>191.00
Allethrin	14.47	123.10>81.10
alpha-BHC	11.03	180.90>144.90
alpha-Endosulfan	15.389	194.90>125.00
Anthraquinone	13.922	180.10>152.10
Azinphos-ethyl	19.491	132.10>77.00
Azinphos-methyl	18.894	160.10>132.10
beta-BHC	11.515	180.90>144.90
beta-Endosulfan	16.507	194.90>160.00
Bifenthrin	18.17	181.10>166.10
Bromfenvinfos-methyl	14.672	294.90>109.00
Bromfenvinphos	15.437	266.90>159.00
Bromophos	14.252	330.90>315.90
Bromophos-ethyl	15.065	358.90>302.90
Bromopropylate	18.237	340.90>182.90
Carbophenothion	17.076	157.00>45.00
Carfentrazone-ethyl	16.989	340.10>312.10
Chlorbenside	15.097	125.00>89.00
Chlorfenson	15.56	175.00>111.00

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Chlorobenzilate	16.408	139.00>111.00
Chloroneb	8.874	206.00>141.00
Chlorpropham	10.51	127.10>65.00
Chlorpyrifos	13.818	196.90>168.90
Chlorpyrifos-methyl	12.877	285.90>93.00
Chlorthal-dimethyl	13.924	298.90>220.90
Chlorthiophos-1	16.2	256.90>239.00
Chlorthiophos-2	16.619	324.90>268.90
Chlorthiophos-3	16.619	324.90>268.90
Chlozolinate	14.604	330.90>258.90
cis-Chlordane	15.39	374.80>265.90
cis-Nonachlor	16.614	406.80>299.90
cis-Permethrine	19.964	183.10>153.10
Coumaphos	20.091	362.00>109.00
Cyfluthrin-1	20.499	163.10>127.10
Cyfluthrin-2	20.597	163.10>127.10
Cyfluthrin-3	20.659	163.10>127.10
Cyfluthrin-4	20.701	163.10>127.10
Cyhalothrin-1	18.77	208.00>181.00
Cyhalothrin-2	18.96	208.00>181.00
Cypermethrin-1	20.828	163.10>127.10
Cypermethrin-2	20.929	163.10>127.10
Cypermethrin-3	20.988	163.10>127.10
Cypermethrin-4	21.029	163.10>127.10
delta-BHC	12.247	180.90>144.90
Deltamethrin-1 (Tralomethrin deg.-1)	22.12	180.90>151.90
Deltamethrin-2 (Tralomethrin deg.-2)	22.581	180.90>151.90
Diazinon	11.915	304.10>179.10
Dieldrin	15.917	276.90>241.00
Disulfoton	12.133	153.00>125.00
Edifenphos	17.132	173.00>109.00
Endosulfan ether	12.653	240.90>205.90
Endosulfan sulfate	17.229	271.80>236.90
Endrin	16.316	262.90>191.00
Endrin aldehyde	16.783	249.80>214.90
Endrin ketone	18.123	316.90>244.90
EPN	18.198	169.10>140.90

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Ethion	16.563	153.00>97.00
Etofenprox	20.955	163.10>135.10
Fenamiphos	15.497	303.10>195.10
Fenchlorphos	13.225	284.90>269.90
Fenitrothion	13.488	277.00>260.00
Fenpropathrin	18.16	181.10>152.10
Fenson	14.214	141.00>77.00
Fenthion	13.888	278.00>109.00
Fenvalerate-1	21.735	225.10>119.10
Fenvalerate-2 (Esfenvalerate)	21.953	225.10>119.10
Fluazifop-P-butyl	16.223	282.10>91.00
Flucythrinate	21.185	199.10>157.10
Fluvalinate-1	9.98	250.10>55.00
Fluvalinate-2	21.655	250.10>55.00
Fonofos	11.875	137.10>109.10
gamma-BHC (Lindane)	11.712	180.90>144.90
Heptachlor	13.202	271.80>236.90
Heptachlor-exo-epoxide	14.676	352.80>262.90
Hexachlorobenzene	11.126	283.80>248.80
Imiprothrin	16.469	123.00>81.20
Iodofenphos	15.56	376.90>361.80
Isazofos	12.154	257.00>162.00
Isodrin	14.494	192.90>157.00
lambda-Cyhalothrin	19.148	181.10>152.10
Leptophos	18.862	376.90>361.90
Malathion	13.662	173.10>99.00
Metalaxyl (Mefenoxam)	13.16	249.20>190.10
Methacrifos	8.753	208.00>180.00
Metofluthrin	13.691	109.00>67.20
Mevinphos	7.957	127.00>109.00
Mirex	19.321	271.80>236.80
o,p'-DDD	15.919	235.00>165.00
o,p'-DDE	15.17	246.00>176.00
o,p'-DDT	16.584	235.00>165.00
p,p'-DDD	16.584	235.00>165.00
p,p'-DDE	15.791	246.00>176.00
p,p'-DDT	17.303	235.00>165.00

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Parathion	13.958	139.00>109.00
Parathion-methyl	12.986	263.00>109.00
Pentachloroanisole	11.236	264.80>236.80
Pentachlorobenzene	9.088	249.90>214.90
Pentachlorothioanisole	13.621	295.80>262.90
Permethrin-1	19.77	183.10>153.10
Permethrin-2	19.9	183.10>153.10
Phenothrin	18.731	183.10>153.10
Phorate	10.914	260.00>75.00
Phosalone	18.824	182.00>111.00
Phosmet	18.141	160.00>77.00
Piperonyl butoxide	17.677	176.10>131.10
Pirimiphos ethyl	14.23	304.10>168.10
Pirimiphos-methyl	13.443	290.10>125.00
Profenofos	15.698	338.90>268.90
Prothiofos	15.62	266.90>238.90
Pyraclofos	19.622	194.00>138.00
Pyrazophos	19.338	221.10>193.10
Pyridaphenthion	17.991	340.00>199.10
Quinalphos	14.78	146.10>118.00
Resmethrin-1	17.724	143.10>128.10
Resmethrin-2 (Bioresmethrin)	17.724	143.10>128.10
Sulfotep	10.673	322.00>202.00
Sulprofos	16.874	156.00>141.00
tau-Fluvalinate-1	21.858	250.10>55.00
tau-Fluvalinate-2	21.927	250.10>55.00
Tefluthrin	12.2	177.00>127.10
Terbufos	11.789	231.00>128.90
Tetrachlorvinphos	15.179	328.90>109.00
Tetradifon	18.722	226.90>199.00
Tetramethrin	18.062	164.10>107.10
pheTolclofos-methyl	13.02	264.90>249.90
trans-Chlordane	15.131	374.80>265.90
Transfluthrin	13.077	163.10>127.10
trans-Nonachlor	15.453	406.80>299.90
trans-Permethrine	20.091	183.10>153.10
Triazophos	16.831	257.00>162.00