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Original Research Article

Assessment of agrochemical exposure in farmers through urinary residue analysis: a cross-sectional survey

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ABSTRACT

Background: The usage of pesticides has become widespread in agricultural sector to meet the rising demand for food production, especially in developing countries like India. Exposure to pesticides and lack of adequate protective measure leads to various health effects among agricultural workers. The study aims to evaluate pesticide exposure by analysing urine samples from farmers in Mysuru district of Karnataka.

Methods: A community-based cross-sectional study was conducted from November 2024 to January 2025 among 100 agricultural workers selected from three primary health centres (PHCs) (Suttur, Hadinaru and Kadakola). Data were gathered through a structured questionnaire, and urine samples were analyzed for the presence of pesticide residues. The statistical analysis involved both descriptive statistics and logistic regression.

Results: In the sample of 100 participants, pesticide residues were identified in 21% of the urine samples. Carbendazim and tricyclazole were detected most frequently (7% each). Unsafe practices regarding pesticide handling were prevalent, only 34% reported using personal protective equipment (PPE), and 53% stored pesticides in fields. Although pesticide usage was widespread, the low detection rates might be related to inconsistent exposure. Chronic health issues such as hypertension (14%) and diabetes (12%) were common among participants.

Conclusions: The findings show the internal exposure of agrochemicals among farmers and inadequate use of PPE. It is essential to enhance educational outreach, conduct regular health monitoring, and implement regulatory measures to protect the health of farming communities by incorporating occupational health into primary care and enhancing training on safe pesticide usage, PPE, and hygiene.

Keywords: Agrochemicals, Occupational exposure, Agricultural workers, Pesticide residues, Personal protective equipment

INTRODUCTION

Agriculture being a fundamental aspect of economic sustenance in numerous developing countries, including India, where a significant portion of the workforce is involved in farming and related sectors.[1] To address the rising demands for food production, the application of pesticides has become essential in contemporary agricultural methods.[2] Nonetheless, this heightened dependency on chemical pest management has led to serious health concerns, especially for agricultural workers who are directly exposed to these hazardous substances during the processes of mixing, spraying, and harvesting.[3]

Pesticides are chemical substances employed to eradicate insects, rodents, fungi, and weeds, as well as to inhibit pest growth. They encompass categories such as insecticides, herbicides, nematicides, fungicides, molluscicides, rodenticides, plant growth regulators, and various other compounds.[4] The overuse of pesticides presents a serious health concern since many farmers lack sufficient knowledge regarding safe application methods. Pesticides not only affect crops but also accumulate in other areas due to mismanagement, mishandling, or insufficient information leading to misuse and overapplication.[5] Humans are exposed to pesticides in either direct or indirect ways. When pesticides are applied to crops, individuals may come into direct contact with them, potentially affecting the skin, eyes, mouth, and respiratory system, leading to acute reactions such as headaches, irritation, vomiting, sneezing, and skin rashes. The impact of these pesticides on humans varies according to the length of exposure and the concentration levels.[6]

Biological monitoring through the analysis of pesticide metabolites found in urine provides a viable, non-invasive approach to assess internal exposure to pesticides.[7] Examining urinary biomarkers is particularly useful for detecting recent exposures to various categories of pesticides, such as organophosphates, carbamates, and triazoles.[8] However, there is a significant gap from Indian contexts, particularly concerning rural and semi-urban agricultural communities.[9] The study builds on current knowledge by measuring pesticide residues in the urine of farmers, serving as a direct indicator of internal exposure. By combining laboratory results with field data regarding pesticide application practices and safety behaviors, the study delivers a broader understanding of the factors influencing exposure.

The aim of the study is to measure internal exposure levels and highlight associated health risks, emphasizing the need for improved occupational health practices and more robust regulatory frameworks in agricultural settings.[10]

METHODS

Study design and study setting

A community-based cross-sectional study was carried out from November 2024 to January 2025 to assess pesticide exposure among agricultural workers in the Mysuru district. The research was conducted in villages falling under the jurisdiction of three PHCs: Suttur, Hadinaru, and Kadakola.

Study population

The study population included agricultural workers aged 18 years and above from the selected PHC regions in Mysuru district, Karnataka, who had been involved in farming activities for a minimum duration of six months. Individuals from outside the district were excluded. Additionally, those who were unavailable during the data collection period or declined to provide informed consent were not included in the study. Written consent was taken from all the participants for the participation in the study.

Sample size calculation

The required sample size for the study was calculated using the formula.[11] The estimated prevalence (p=0.98) of pesticide detection was derived from the findings of a similar study by Hyland et al which reported comparable levels of pesticide exposure in agricultural workers.[12] Assuming a 95% confidence level, 3% absolute precision, the calculated sample size was 84. To account for potential incomplete response and data inconsistencies, a total of 100 participants were ultimately recruited.

Data collection

A structured questionnaire was developed; face validation was done and administered to the participants through in-person interviews. A total of 100 responses were collected. The questionnaire comprised two sections: (a) Socio-demographic and lifestyle characters (including age, gender, education, type of farming, duration of agricultural work, and habits such as smoking or alcohol use), (b) Chemical application practice (types of agrochemicals used, frequency and duration of pesticide application, use of PPE, methods of storage and disposal, and training on safe handling) and health problems experienced during agricultural work.

Biochemical analysis

To evaluate internal exposure to pesticides, biomonitoring was performed through urine samples collected from all participants in the study. Urine specimens were collected in sterile, leak-proof containers while maintaining hygienic practices. The samples were labelled and stored at -80°C after collection to ensure their integrity and prevent any degradation of analytes. All samples were transported to the lab under cold-chain conditions to uphold their stability during transportation. The analysis took place at a NABL accredited laboratory, which guaranteed adherence to quality and safety protocols.

Urine samples were examined for pesticide residues using liquid chromatography-mass spectrometry (LC-MS), a highly sensitive and specific technique capable of detecting trace concentrations of various pesticide metabolites. This method enabled quantification of commonly used agrochemicals among agricultural workers, such as insecticides, herbicides, and fungicides. The analytical targets included major compounds like bispyribac sodium, chlorpyrifos, quinolphos, carbendazim, hexaconazole, and tricyclazole.

Standards: Accurately dissolving 10±0.5 mg in 10 ml of methanol produced the stock solution of reference standards 1000µg/ml, which was then stored in a refrigerator. To prepare the intermediate stock standard preparation-I, 100 µl of each pesticide residue stock solution was taken, and the final volume was increased to 10 ml in order to obtain a concentration of 10 mg/kg for each ingredient. Then, using Intermediate stock solution-I, the Matrix match calibration standards were prepared, ranging from 5 ppb to 100 ppb (5 ppb, 10 ppb, 25 ppb, 50 ppb, 75 ppb and 100 ppb).

Limits of detection: The standard deviation approach was used to estimate the limit of detection (LOD), and the formula $3.3*\sigma/S$ was used to determine the slope of the calibration plot. Although their amounts were below the threshold for measurement, more than 100 other chemicals were found. The LC-MS results provided a direct measure of the internal pesticide burden, serving as the biochemical foundation for exposure assessment in this study.

Data analysis

The collected data was processed using IBM SPSS statistics version 22.[13] Statistical analysis such as descriptive statistics, univariate logistic regression and multivariate logistic regression analysis was done to determine the association between the presence of agrochemicals in urine with various factors. Crude odds ratio as well as adjusted odds ratio were calculated along with their respective 95% confidence interval (CI) levels and a $p<0.05$ was considered as statistically significant.

RESULTS

Table 1 shows that a total of 100 agricultural workers took part in the study, with the majority being males (81%) and predominantly married (93%). The majority were between the ages of 41 and 60, indicating an older workforce. The education levels were low, with 38% illiterate and few pursuing higher educations. The participants owned approximately 2.5 acres of land and lived in households with an average of four people and the lifestyle habits of the participants included smoking (16%), drinking (15%), and chewing tobacco (9%).

Table 2 shows that 66% of the participants were landowners, while others were employed as laborers. Common activities included weeding (73%), sowing (58%), applying pesticides (44%), and caring for animals (38%). A majority utilized insecticides for crops (66%), with 53% stored them in the field. While 74% stated they showered after working in the fields, only 14% had undergone chemical safety training, and merely 20% were knowledgeable about safe handling practices. These results underscore the necessity for enhanced education regarding pesticide application and farm safety.

Table 3 reveals unsafe pesticide handling among participants. Over half did not retain unused (51%) or old (70%) pesticides, and 44% left empty containers in the field. PPE use was low, with masks being the most used (34%). Reports of eye (12%) and skin irritation (7%) were noted. Most used over 4 liters of chemicals (59%), often applied twice or more. While 76% washed sprayers after use, disposal of washed water was inconsistent. These findings emphasize the need for better training on safe pesticide handling and disposal.

Figure 1 shows that 14% of those working in agriculture had hypertension, while 12% were diagnosed with diabetes, highlighting a significant prevalence of chronic health issues. A number of participants reported skin-related problems, with 21% experiencing itching or infections, and smaller proportions suffering from rashes (2%) and dermatitis (2%). Respiratory concerns were relatively low, with just 5% of individuals experiencing wheezing. Moreover, 3% of workers indicated occurrences of dizziness or incontinence related to bowel or bladder function. These results suggest potential health impacts associated with workplace exposures and underscore the importance of regular medical screenings.

Among the 100 participants, the presence of various chemical compounds was identified in 21 urine samples, representing 21% of the study population as shown in Figure 2. Carbendazim and tricyclazole were the most commonly detected (7% each), followed by hexaconazole (4%) and bispyribac sodium (3%). Quinalphos and chlorpyrifos were not detected in any samples. The results highlight the need for improved safety practices among agricultural workers.

Table 4 shows the association between various sociodemographic and occupational factors and presence of pesticide residues in urine. P values from univariate model of health comorbidities, usage of pesticides and PPE, amount of chemicals used per acre, and frequency of chemical application were >0.25, hence multivariate logistic regression analysis was not done to those variables. There were some variations in association with age categories concerning the detection of pesticide residues. Individuals in the age groups of 31-40 and 51-60 showed higher adjusted odds ratios (0.254 and 6.025, respectively), but these associations lacked statistical significance (p>0.05). The highest odds were recorded in age group of 51-60, approaching significance (p=0.061). The presence of health comorbidities did not show a significant correlation with pesticide residues in urine. Factors such as pesticide application, the use of PPE, and the amount of time spent working in fields did not reveal statistically significant links with pesticide residue detection. The individuals who did not use PPE had higher unadjusted odds (OR=0.568), although this was not statistically significant. The amount of pesticide used per acre shows that risk increased with larger quantities applied. The frequency of application of chemicals suggested that individuals spraying more than once experienced varied levels of risk and spraying twice resulted in high unadjusted odds (OR=1.471) though it too was not statistically significant.

Table 1: Socio-demographic and lifestyle characters of study participants, (n=100).

Particulars	N
Age (in years)	
19-30	9
31-40	15
41-50	25
51-60	30
>60	21
Gender	
Male	81
Female	19
Marital status	
Married	93
Unmarried	6
Widowed	1
Religion	
Hindu	100
Educational status	
Illiterate	38
Primary and middle school	18
High school	30
PUC/diploma	9
Under graduation	5
Average family members (Mean±SD)	4±2.15
Average land owned (Mean±SD)	2.13±2.28 acres
Smoking	16
Alcohol	15
Tobacco chewing practice	9

Table 2: Details of agricultural work in field, (n=100).

Particulars	N
Ownership of land	
Owner	66
Labour	25
Both as owner and labour	9
Kind of work you do in field*	
Sowing	58
Weeding	73
Planting and seeding	29
Fertilizer application	28
Harvesting	38
Post-harvesting operation	29
Vegetables or oilseeds production	6

Continued.

Particulars	N
Animal care	38
Maintenance	37
Spraying pesticides	44
Others	9
Duration of work in the agricultural field (in years)	
<20	61
21-40	32
>40	7
Kind of chemicals used*	
Crop insecticides	66
Herbicides	25
Weedicides	45
Fungicides	4
Fumigants	0
Livestock/poultry insecticides	1
Others	7
Storage of pesticides	
Don't store	16
Home	28
Field	53
Others	2
Shower immediately after field work	
Always	74
Sometimes	6
Never	0
I'll not	20
Wash clothes separately	
Always	44
Sometimes	36
Never	14
I'll not	6
Took training regarding chemical use	14
Aware of safety guidelines for using agricultural chemicals	20

*Multiple options

Table 3: Pesticide handling and safety practices among agricultural workers, (n=100).

Particulars	N
Unused chemicals	
Don't keep	51
Keep in field	39
Keep in home	3
Others	1
Old stocks	
Don't keep	70
Keep in field	19
Keep in home	3
Throw outside	6
Others	2
Empty containers	
Don't keep	16
Keep in field	44
Keep in home	8
Burn	14

Continued.

Particulars	N
Nearby stream	2
Sell	9
Throw outside	9
Kind of PPE used*	
Mask	34
Gloves	8
Sunglass	5
Boots	3
Safety cloth	2
Helmet	2
Others	4
Irritation experienced during mixing/spraying of chemicals*	
Eye	12
Skin	7
Mouth	1
Others	4
Amount of chemicals used	
0-2 ltrs	13
2-4 ltrs	6
>4 ltrs	59
Don't know	22
Frequency of chemical application	
1 time	12
2 times	39
3 times	4
More	23
Don't know	22
Type of sprayer used	
Motorised sprayer	33
Knapsack sprayer	37
Hand-held applicator	2
Battery sprayer	1
Others	12
None	23
Ever spilled chemicals on body	
Yes	16
No	84
Wash sprayer after use	
Yes	76
Disposal of washed water?* (n=76)	
Nearby stream	14
Field	17
Others	45

*Multiple options.

Table 4: Univariate and multivariate logistic regression for associations between selected variables and detection of pesticide residues in urine samples.

Variables	Pesticide residues detected in urine, N (%)		Unadjusted odds ratio	95% CI	P value	Adjusted odds ratio	95% CI	P value
	Yes, (n=21)	No, (n=79)						
Age (in years)								
19-30	3 (33.3)	6 (66.7)	1.231	0.238-6.358	0.804	1.00	--	0.069
31-40	1 (6.7)	14 (93.3)	8.615	0.944-78.667	0.056	0.254	0.024-2.724	0.258

Continued.

Variables	Pesticide residues detected in urine, N (%) Yes, (n=21)	No, (n=79)	Unadjusted odds ratio	95% CI	P value	Adjusted odds ratio	95% CI	P value
41-50	4 (16)	21 (84)	3.231	0.809-12.910	0.097	6.251	0.484-80.796	0.160
51-60	5 (16.7)	25 (83.3)	3.077	0.836-11.323	0.91	6.025	0.917-39.569	0.061
>60*	8 (38.1)	13 (61.9)	1.00	--	0.173	3.076	0.654-14.476	0.155
Health comorbidity								
Yes	7 (25)	21 (75)	1.381	0.490-3.890	0.541	--		
No	14 (19.4)	58 (80.6)						
Pesticide usage								
Don't use	4 (23.5)	13 (76.5)	0.837	0.242-2.896	0.779	--		
Use	17 (20.5)	66 (79.5)						
PPE used								
Don't use	14 (25)	42 (75)	0.568	0.207-1.557	0.271	--		
Use	7 (15.9)	37 (84.1)						
Duration of work in field (in years)								
<20*	9 (14.8)	52 (85.2)	1.00	--	0.125	1.00	--	0.934
21-40	9 (28.1)	23 (71.9)	4.333	0.827-22.694	0.083	1.518	0.164-14.038	0.713
>40	3 (42.9)	4 (57.1)	1.917	0.356-10.322	0.449	1.336	0.136-13.157	0.804
Amount of chemicals used/acre								
0-2 ltrs*	1 (7.7)	12 (92.3)	1.00	--	0.664	--		
2-4 ltrs	1 (16.7)	5 (83.3)	3.529	0.364-34.185	0.276			
>4 ltrs	14 (23.7)	45 (76.3)	1.471	0.138-15.689	0.749			
Frequency of chemical application								
1 time*	2 (16.7)	10 (83.3)	1.00	--	0.160	--		
2 times	9 (23.1)	30 (76.9)	1.471	0.239-9.043	0.677			
3 times	3 (75)	1 (25)	0.980	0.282-3.404	0.975			
More	2 (8.7)	21 (91.3)	0.098	0.008-1.163	0.066			

*Reference group

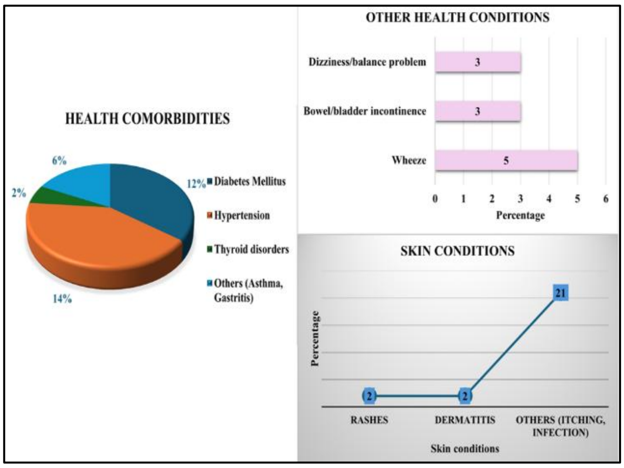

Figure 1: Health status of agricultural workers, (n=100).

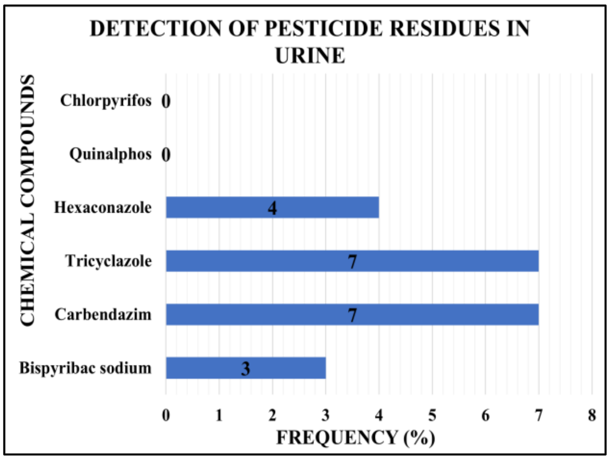

Figure 2: Detection of pesticide residues in urine samples of agricultural workers, (n=100).

DISCUSSION

The study examined the frequency and trends of pesticide exposure among agricultural laborers in the Mysuru district through the analysis of urinary residues. The finding of pesticide residues in 21% of the urine samples from participants highlights a significant occupational health issue within this group.

The most frequently detected substances, carbendazim and tricyclazole, are systemic fungicides commonly employed in paddy and horticultural farming in southern India. Several factors may contribute to this relatively low detection rate, such as the short biological half-lives of many pesticides, which cause rapid excretion; the timing of urine sample collection in relation to pesticide exposure; and potential seasonal variations in environmental persistence and pesticide application intensity. These results are consistent with those of Summaiya et al who found detectable levels of DAP metabolites in urine causing long-term exposure among agricultural workers of India.[14] These observations emphasize the global importance of biomonitoring as a method for evaluating internal pesticide exposure and the necessity for focused interventions.

The study participants were predominantly male (81%), middle-aged to older individuals, with limited educational backgrounds. These characteristics are representative of farming populations in many developing regions, paralleling observations made by Ghosh et al from northern India.[9]

The lack of formal education and limited involvement in training programs likely contributed to inadequate knowledge of chemical safety; only 14% reported having received training related to chemical handling, and just 20% were aware of safety protocols. Practices surrounding pesticide use, including the types of chemicals utilized, storage methods, and protective measures, showed considerable variability, with numerous unsafe behaviors. For example, 53% of respondents indicated storing pesticides in the fields, while only 44% stated they always washed their clothes separately after exposure.

Such practices heighten the risk of dermal and inhalational absorption, as evidenced by Kim et al who identified poor hygiene and storage methods as significant risk factors for pesticide-related toxicity.[6] The use of PPE was significantly low; only 34% reported wearing masks, and even fewer used gloves or boots.

This aligns with observations made by Hyland et al who noted similar patterns among Latino farmworkers in the United States and by Summaiya et al where lack of personal protection when handling pesticides, bare-handed mixing of pesticide formulations was seen and suggesting that the issue of non-compliance with PPE is prevalent, especially within economically disadvantaged agricultural communities.[12,14]

However, although PPE usage was anticipated to offer some protection, logistic regression analysis did not reveal significant associations, potentially due to the small sample size or inconsistent use patterns.

Interestingly, despite the extensive use of pesticides, only 20% of participants had detectable residues in their urine. This might be linked to factors such as the short half-lives of many pesticides in the human body, variations in the timing of exposure compared to sample collection, or the adoption of protective behaviors, even if applied inconsistently. Comparable low detection rates have been found in studies from other regions in India, as reported by Ghosh et al and Curl et al.[9,15]

In terms of health symptoms, 12% experienced eye irritation, and 7% reported skin problems during pesticide application findings that are consistent with those of de-Assis et al who associated acute pesticide exposure with dermal irritations and other health issues.[16] Chronic health problems, including diabetes and hypertension, were prevalent among participants, but no statistically significant links to pesticide residues were established. Notably, none of the samples revealed organophosphates like quinalphos or chlorpyrifos, which may indicate a change in pesticide usage trends, seasonal fluctuations, or a gradual phase-out as suggested by recent government initiatives aimed at decreasing the use of hazardous pesticides.

This study was limited by its cross-sectional design, which prevents establishing a temporal or causal relationship between pesticide exposure and health outcomes. Urine samples reflect only recent exposure and may underestimate long-term or intermittent pesticide contact due to the short biological half-lives of many compounds. The relatively small sample size and focus on three PHC areas may limit statistical power to detect weaker associations. Seasonal variations in pesticide use were not fully accounted for, as data collection occurred over a short time frame.

The findings are most applicable to smallholder and semi-commercial farming communities in the Mysuru district with similar cropping patterns, pesticide usage, and socio-demographic characteristics. Caution should be exercised in extrapolating results to large-scale commercial farms, regions with different climatic conditions, or agricultural communities with distinct pesticide regulation and enforcement practices. However, the observed trends in unsafe pesticide handling and low PPE use may be relevant to comparable rural agricultural settings in India and other low- and middle-income countries.

The study indicates that agricultural laborers are frequently exposed to various pesticides, often without adequate safety precautions, placing them at potential health risk. Despite the low detection rate of urinary pesticide residues, the widespread use of chemicals and limited PPE use highlight ongoing exposure concerns. These findings emphasize the urgent need for stricter enforcement of pesticide regulations, enhanced occupational health monitoring, and accessible educational programs for farmers.

Strengthening training initiatives on safe pesticide handling, PPE use, and personal hygiene, along with integrating occupational health education and routine screening into primary health services, is crucial. Local regulatory authorities should ensure compliance with safety standards, promote the availability of certified PPE, and oversee safe pesticide storage and disposal. Collaborative efforts between agricultural and health departments can improve surveillance and reduce pesticide-related health risks in farming communities.

CONCLUSION

The study identified pesticide residues in 21% of agricultural laborers, primarily carbendazim and tricyclazole. While these chemicals are used frequently, the low detection rates may be due to their short half-lives and inconsistent safety protocols.

Many participants exhibited inadequate use of PPE and a lack of awareness. Although no significant health connections were discovered, trends indicate higher exposure related to age and chemical usage. Recommendations include enhanced training, health surveillance, and stricter regulatory measures.

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