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COMPARISON OF CHRONIC HEAVY METAL CONTAMINATION LEVEL IN THE BODY BETWEEN CHEMICAL PESTICIDE SPRAYERS AND GENERAL PUBLIC AROUND AGRICULTURAL AREAS

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Abstract

Introduction: *The increasing use of chemical pesticides in agriculture raises concerns about heavy metal exposure. This study compares chronic heavy metal contamination levels (Pb, Cd, Cr^{6+}) in the urine of pesticide sprayers and the general public in agricultural areas.* ***Methods:*** *A cross-sectional study with 100 respondents, equally divided between sprayers and the general public, was conducted. Data were gathered through interviews, observations, and laboratory tests. Heavy metal levels in urine were analyzed using Atomic Absorption Spectroscopy (AAS). Factors like age, work duration, spraying frequency, and Personal Protective Equipment (PPE) use were examined through Mann-Whitney and linear regression tests.* ***Results and Discussion:*** *Pesticide sprayers had significantly higher mean levels of Pb (0.084 mg/kg), Cd (0.010 mg/kg), and Cr^{6+} (0.010 mg/kg) than the general public. Key contributors to this accumulation included age, working hours, and the number of pesticide mixtures used. Inadequate PPE use and long exposure times were common, leading to health complaints such as nausea, vomiting, and headaches, indicating the harmful effects of pesticide exposure.* ***Conclusion:*** *Pesticide sprayers are at greater risk of heavy metal accumulation due to prolonged exposure and poor safety measures. Improving PPE use and reducing exposure are critical to minimizing health risks from heavy metal contamination. Awareness campaigns are necessary to protect agricultural workers.*

INTRODUCTION

The use of chemical pesticides has become a common practice worldwide over the past few decades. Globally, more than 3.5 million tons of pesticides were used in 2022, representing a 4 percent increase compared to usage in 2021 (1). This usage also marked a 13 percent increase over the past decade and a doubling compared to data from 1990. The trend in chemical pesticide usage has risen significantly, especially in developing countries that focus on increasing crop yields (2-4). The tendency of the agricultural sector to use chemical pesticides is driven by their effectiveness in controlling pests quickly (5-7). Rapid and efficient pest control is crucial for the success of agriculture (8). The hazardous chemicals in pesticides, such as heavy metals, raise concerns due to their environmental impact (9-11). Certain types of pesticides, particularly those containing organophosphates and carbamates, are rich in heavy metals like lead, mercury, and cadmium (12-13). These heavy metals pose environmental risks and significantly negatively affect human health.

The entry of heavy metals from pesticides into the human metabolic system can occur through two main pathways: direct and indirect exposure (9). Direct exposure occurs when individuals, particularly agricultural workers, inhale or come into direct contact

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with pesticides during application, allowing heavy metals to enter the body through the respiratory system. Indirect exposure can happen through contamination caused by pesticide application, affecting soil and water, which then enter the food chain. Plants grown in contaminated soil (14), fish living in polluted waters (15), or contaminated water consumed or used for sanitation can introduce heavy metals into the human body (16), leading to adverse health effects. Heavy metals can cause acute and chronic toxic effects within the human body. These metals accumulate in body tissues and are difficult to eliminate, leading to long-term health issues (17).

Pesticide poisoning occurs not only among farmers, pesticide applicants, or those in direct contact with them but also among the general population living near agricultural areas. Studies have reported increased pesticide poisoning cases among non-agricultural residents, particularly in rural areas. In Jiangsu Province, China, of the pesticide poisoning cases reported between 2007-2016, 76.6% were from non-occupational causes (18). Pesticides have also been linked to stunting in children aged 2-5 years (19). This is due to children's playing habits in agricultural areas, storing pesticides in homes, and mothers' involvement in spraying pesticides, washing spraying equipment, and pesticide mixing. Pesticides also pose a carcinogenic risk to the community, where residents consume chili peppers contaminated with arsenic from agricultural processes, including pesticide use (20). Pesticides also can cause skin diseases among onion farmers (21).

Heavy metal contamination issues resulting from chemical pesticide use require further attention. Studies on heavy metal contamination in the environment and humans, particularly in agricultural settings, are essential to prevent more severe impacts on the environment and human health.

METHODS

This study is observational analytic research with a cross-sectional design. Data were collected during the planting season, from July to September 2022. The study involved two groups: active pesticide sprayers and the general public, with a 1:1 ratio. The total number of respondents was 100. The pesticide sprayer group consisted of individuals who had been working for at least five years and considered it their primary occupation. The comparison group comprised members of the general public living in areas with similar sociodemographic characteristics who had no exposure to agricultural pesticides.

Data from the respondents were collected through interviews, observations, and laboratory tests. The levels of Pb, Cd, Cr^{6+}, and age were collected from both groups. Data on work duration, length of work hours, spraying frequency, use of personal protective equipment (PPE), body posture during spraying, habits after spraying activities, and the types of pesticides used during the study period were gathered from the pesticide sprayer group. The Pd, Cd, and Cr^{6+} levels were tested in the laboratory. Data on age, work duration, and spraying frequency were collected using questionnaires. Direct observation was conducted to gather data on PPE usage, body posture during spraying, habits after spraying activities, and the types of pesticides used.

The heavy metal testing methods based on Indonesian National Standard 06.6989.45:2005 for Lead (22), 06.6989.16:2004 for cadmium (23), and 6989.71:2009 for hexavalent chromium (Cr^{6+}) (24). Lead was tested by reacting it with Ammonium Pyrrolidine Dithiocarbonate (APDK) within a pH range of 0.1 to 6 (optimal pH 2.3 ± 0.2) to form a complex that was then extracted using the organic solvent Methyl Iso Butyl Ketone (MIBK) and measured for absorbance using Flame Atomic Absorption Spectroscopy (AAS) with an air-acetylene flame. Cadmium was tested by adding nitric acid to the sample to dissolve the metal analyte and remove interfering substances. After dissolution, cadmium was measured using AAS with acetylene gas (C_2H_2). Hexavalent chromium ions were reacted with diphenyl carbazide in an acidic environment to form a red-purple complex that absorbed light at a wavelength of 530 nm or 540 nm. The absorbance intensity measures at that wavelength were proportional to the sample's concentration of hexavalent chromium ions.

Data were analyzed using the IBM 23 SPSS statistical package. Respondent data with a ratio scale would first be tested for normality using Kolmogorov-Smirnov, such as Pb, Cd, and Cr^{6+}. Then, a Mann-Whitney analysis will be followed to determine the differences between the two groups of respondents. A linear regression analysis tested with dummy variables was performed to determine the factors influencing the variation of heavy metals in sprayer respondents. Respondents received detailed explanations of rights and obligations when participating in this study. Without pressure from the research team, respondents who agreed participated in giving their informed consent before urine specimen collection and interviews.

RESULTS

The study analyzed the differences in heavy metal concentrations (Pb, Cd, and Cr6+) in the urine of pesticide sprayers and the general public, the frequency distribution of risk factors, and subjective

health complaints among active pesticide sprayers. Determinant factors were identified through linear regression analysis. These results illustrate how pesticide exposure affects the accumulation of heavy metals in the body and its impact on the health of the sprayers.

Table 1. Differences in Heavy Metal Test Results in the Urine of Pesticide Sprayers and the General Public

Group	Pb (mg/kg)	Cd (mg/kg)	Cr^{6+} (mg/kg)
Exposed Respondent (n=50)			
Mean	0.084220	0.010414	0.010482
Maximum	0.227900	0.017800	0.019300
Minimum	0.016300	0.000100	0.001100
Non-Exposed Respondent (n=50)			
Mean	0.009324	0.003521	0.005362
Maximum	0.031000	0.008900	0.095000
Minimum	0.000500	0.000100	0.000100
p-value	**0.000***	**0.000***	**0.013***

This study found significant differences in heavy metal levels (Pb, Cd, and Cr^{6+}) between pesticide sprayers and the general public. Laboratory results showed that the average Pb concentration in the urine of pesticide sprayers was 0.084 mg/kg, much higher than the general public, which had an average of only 0.009 mg/kg. The same trend was observed for Cd and Cr^{6+} levels, with the pesticide sprayer group showing higher concentrations. Statistical tests revealed a significant difference, with p-values below 0.05, indicating that pesticide exposure directly influences the accumulation of heavy metals in the body.

Table 2. Frequency Distribution of Risk Factors among Active Pesticide Sprayers

Determinant Factors	f (n = 50)	%
Personal Protective Equipment		
Not complete	19	38
Complete meet standard	22	44
Complete does not meet the standard	9	18
Body Position		
Body position does not adjust to wind direction	38	76
Body position adjusts to wind direction when remembering	10	20
Body position always adjusts to wind direction	2	4
Length of Working (year)		
< 10 year	5	10
> 10 year	45	90
Age (year)		
31 – 40	21	42
41 – 50	21	42
51 – 60	8	16
Working hours (in a day)		
< 5 hour	18	36
> 5 hour	32	64
Spraying Frequency (in week)		
1-2 in a week	14	28
3-4 in a week	25	50
5-6 in a week	11	22
Amount of Pesticides Mixture		
1-3 (mix)	31	62
> 4 (mix)	19	38
Dosage		
Appropriate	9	18
Inappropriate	41	82
Type of Pesticides		
Organophosphate	32	64
Carbamate	1	2
Mix	17	34
Chemical Fertilizers		
Yes	43	86
No	7	14
Environmental Conditions		
Humidity		
< 60%	8	16
60 – 80%	42	84
pH		
Optimum	34	68
Not optimum	16	32
Temperature		
Optimum	36	72
Not optimum	14	28

Based on the frequency of risk factors among pesticide sprayers, most respondents did not use complete personal protective equipment (38%), and only a small percentage always adjusted their body position to the wind direction while spraying (4%). Moreover, most sprayers had been working for over ten years (90%) and sprayed for more than five hours daily (64%). These factors potentially increase the risk of pesticide exposure and heavy metal accumulation in the body.

Table 3. Frequency Distribution of Subjective Health Complaints among Active Pesticide Sprayers

Subjective Health Complaints	f (n = 50)	%
Headache		
Yes	26	52
No	24	48
Nausea		
Yes	40	80
No	10	20
Vomitting		
Yes	36	72
No	14	28

The subjective complaints reported by the sprayers demonstrate the health impacts of pesticide exposure. After spraying, 72% of respondents reported vomiting, 80% experienced nausea, and 52% suffered from headaches. These complaints highlight the direct effects of pesticide exposure on workers' health.

The results of the linear regression test showed that several risk factors were significantly correlated with heavy metals levels in the urine of pesticide sprayers. A positive relationship was found between age, working hours, and the amount of pesticide mixtures with Pb levels in urine. This indicates that older workers, those with longer working hours, and those using a higher concentration of pesticide mixture are at greater risk

of Pb accumulation in the body. All three factors show a positive relationship with Pb levels in urine. However, there was no significant relationship between other factors, such as the use of personal protective equipment, body position, length of working, spraying frequency, dosage, type of pesticide, and the use of chemical fertilizers, with Pb levels in urine. For Cd and Cr^{6+} levels in urine, there are no significant relationships with any of the determinant factors were found.

Table 4. A Linear Regression Test for Determinant Factors and Pb, Cd, Cr^{6+} Levels in the Urine of Active Pesticide Sprayers

Determinant Factors	Pb (mg/kg)		Cd (mg/kg)		Cr^{6+} (mg/kg)	
	B	*Sig*	*B*	*Sig*	*B*	*Sig*
Personal Protective Equipment	-0.012	0.296	-6.333	0.996	0.000	0.278
Body Position	0.003	0.784	-0.001	0.745	0.001	0.948
Length of Working	-0.009	0.714	0.001	0.719	-0.001	0.675
Age	*0.022*	*0.032**	-0.001	0.276	0.000	0.679
Working hours	*0.010*	*0.046**	0.000	0.811	0.000	0.775
Spraying Frequency	-0.006	0.643	0.002	0.274	0.001	0.913
Amount of Pesticides Mixture	*0.054*	*0.004**	0.002	0.447	-0.002	0.609
Dosage	-0.013	0.485	-0.004	0.122	-5.912	0.482
Type of Pesticides	0.003	0.828	0.001	0.483	-0.001	0.773
Chemical Fertilizers	-0.003	0.891	-0.003	0.232	0.000	0.863

DISCUSSION

The higher levels of heavy metal accumulation in the sprayers group suggest that direct pesticide exposure significantly contributes to heavy metal accumulation. This finding aligns with previous research, highlighting the risk of heavy metals, such as lead, cadmium, and chromium, for individuals regularly exposed to pesticides due to their work environment (25). Most pesticide sprayers in this study did not use PPE as its standard (82%), and many had been working for over 10 years (90%). This aligns with previous studies that showed that prolonged exposure and lack of proper PPE use increase the likelihood of heavy metal accumulation in workers' bodies (26). While the general public may also be exposed to heavy metals through the food and drink, they consume, the risk factors for workers significantly impact the level of heavy metal accumulation in the body.

Most pesticide sprayers reported subjective health complaints such as nausea, vomiting, and headaches. These symptoms are similar to findings from other studies that identified symptoms of pesticide poisoning (27-28). Heavy metals such as lead (Pb), cadmium (Cd), and hexavalent chromium (Cr^{6+}) can cause nausea, vomiting, and headaches through several toxic mechanisms. These metals generate oxidative stress and trigger neuroinflammation, leading to neuronal damage and neurotransmitter imbalances, which result in headaches (29-30). Lead, for instance, disrupts calcium homeostasis in neurons, impairing normal signaling (31), while cadmium causes headaches by generating reactive oxygen species (ROS), which disrupt cellular biochemistry, damage DNA, and affect the nervous system, potentially leading to neurological disorders (32). The gastrointestinal (GI) issues caused by heavy metals stem primarily from their ability to disrupt biological processes when ingested. Heavy metals, upon entering the body through contaminated food or water, accumulate in the GI tract where they can interact with and damage cellular structures, leading to inflammation and irritation (33-34). This is often exacerbated by the fact that concentrations of heavy metals in the GI tissue may be much higher compared to other body parts due to ingestion. The toxic effects of metals include oxidative stress, interference with enzyme functions, and DNA damage, which can result in various gastrointestinal pathologies such as ulcers, diarrhea, and inflammation. These pathologies caused symptoms like nausea and vomiting.

Our study found that the relationship between age and Pb levels are not in line with other studies that state that the age of workers does not affect the accumulation of pesticide residues in the body (35). However, the study showed findings that there was a strong correlation between the accumulation of pesticide residues and exposure time. Other studies showed no significant difference in blood lead levels based on age but significant differences in cadmium levels (36). Several studies have shown that most of the effects caused by organophosphates are chronic so that it should be related to the accumulation of heavy metals (37-38). Organophosphate pesticides can also cause endocrine disruption by increasing thyroid hormone levels (39-40).

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AUTHORS' CONTRIBUTION

ASP: Conceptualization, Methodology, Software. RN, KCD, RIW: Data curation, Writing- Original draft preparation. MAM: Visualization, Investigation, Software, Validation. ZAZ: Reviewing and Editing.

CONCLUSION

This study found that pesticide sprayers are significantly more exposed to heavy metals like Pb, Cd, and Cr^{6+} compared to the general public. The

elevated levels of these metals in their urine are strongly correlated with factors such as age, working hours, and the number of pesticide mixtures used. Moreover, the improper use of personal protective equipment (PPE) and extended years of exposure contribute to health risks, as evidenced by symptoms like headaches, nausea, and vomiting among sprayers. These findings underscore the importance of proper safety practices to minimize heavy metal accumulation and its adverse health effects.

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