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Evaluation of Poisoning Trends in Bangladesh: A Forensic Study on the Rising Burden of Arsenic and Pesticide Exposure in Agricultural Communities

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ABSTRACT: ***Background:*** The increasing number of deaths due to poisoning, particularly from organochlorine pesticides (OCPs) in Bangladesh, has raised concerns over public health, especially in agricultural regions. ***Objective:*** To evaluate the trends of poisoning due to arsenic and organochlorine pesticide exposure in agricultural communities in Bangladesh, with a focus on forensic analysis. ***Methods:*** This study was conducted at the Department of Forensic Medicine & Toxicology, Rajshahi Medical College, Bangladesh, from January 2022 to December 2023. The sample consisted of 88 deceased victims who had died from poisoning, identified through post-mortem examination and toxicological analysis. Data on age, sex, geographical location, pesticide type (focusing on organochlorine compounds), and clinical symptoms were collected. Pesticide residues in blood and tissues were detected using Gas Chromatography-Mass Spectrometry (GC-MS). ***Results:*** A total number of the 88 cases, 54 (61.4%) involved organochlorine pesticides (OCPs), with the remaining cases attributed to organophosphorus compounds (OPCs). The most common OCP was endrin (35.7%), followed by aldrin and heptachlor. The study found a significant variation in pesticide-related deaths across regions, with the highest concentration in Godagari (35.3%) and Rajshahi (28.6%). The mean arsenic levels in the water sources from these areas were 0.28 mg/L (± 0.14 SD), with significant positive correlation ($p < 0.05$) between arsenic contamination and pesticide-related deaths. A chi-square test showed a strong association ($p < 0.01$) between pesticide ingestion and male farmers under 40 years of age. Furthermore, a t-test indicated a statistically significant higher death rate among those exposed to both arsenic and OCPs ($p = 0.03$). ***Conclusion:*** This study highlights a critical rise in organochlorine pesticide-related fatalities, particularly in agricultural communities, underscoring the need for stringent regulation and intervention strategies.

Keywords: Arsenic, Organochlorine Pesticides, Poisoning Trends, Forensic Toxicology, Bangladesh.

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INTRODUCTION

Poisoning remains a significant public health challenge globally, and in Bangladesh, it has emerged as a critical concern due to the growing exposure to toxic substances, particularly arsenic and pesticides.[1] Bangladesh's agrarian economy, where approximately 80% of the population is engaged in agriculture, is a major driver of this issue. The increasing use of chemical pesticides in agricultural practices and the extensive contamination of groundwater with arsenic are two primary contributors to poisoning in the country.[2]

Arsenic contamination in groundwater has been recognized as one of the largest public health crises in Bangladesh, affecting millions of people.[3] Following the installation of millions of tube wells in the 1970s and 1980s as part of a public health initiative to combat waterborne diseases, arsenic contamination became widespread. This contamination occurs as a

result of naturally occurring arsenic deposits in the groundwater, which exceed the safe drinking levels set by the World Health Organization (WHO) and pose significant risks to health. Smith *et al*., demonstrated that exposure to arsenic through contaminated drinking water leads to a host of adverse health effects, including skin lesions, cardiovascular diseases, and various cancers, particularly skin, lung, and bladder cancers.[4] Arsenic poisoning's insidious nature, with symptoms often appearing only after long periods of exposure, makes it particularly difficult to address effectively in rural areas with limited access to healthcare services and public awareness. Despite the efforts to reduce arsenic exposure through the installation of filtration systems and other interventions, a significant portion of the population remains exposed to unsafe arsenic levels, especially in rural agricultural regions.[5, 6]

The use of pesticides in Bangladesh's agriculture sector also contributes to a rising incidence of poisoning. While pesticides are used extensively to control pests and increase crop yields, their overuse and misuse have led to serious health consequences.[7] Organophosphates, carbamates, and pyrethroids are among the most commonly used pesticides in Bangladesh, and while effective at controlling pests, they are also highly toxic to humans. Pesticide poisoning in Bangladesh has become increasingly prevalent, particularly in rural farming communities where protective equipment is often unavailable, and safety measures are poorly enforced. According to pesticide poisoning can range from mild symptoms such as nausea and dizziness to severe effects like respiratory failure, seizures, and death, particularly when exposure is prolonged or occurs during pesticide application without proper precautions.[8] The lack of proper regulation and inadequate knowledge regarding safe pesticide use exacerbate the public health risks, especially among farmers who are directly exposed to these chemicals on a regular basis.

MATERIAL AND METHODS

Study Design

This was a prospective forensic study conducted at the Department of Forensic Medicine & Toxicology, Rajshahi Medical College, Bangladesh, from January 2022 to December 2023. The study aimed to evaluate the trends of poisoning, with a specific focus on arsenic and organochlorine pesticide (OCP) exposure, within agricultural communities. The study prospectively analyzed 88 cases of poisoning, all confirmed through autopsy and toxicological testing. The sample included deceased victims whose cause of death was identified as poisoning, with a particular emphasis on demographic factors, type of pesticide, and levels of arsenic contamination. The study also aimed to explore regional variations in pesticide exposure and arsenic contamination levels, providing a comprehensive understanding of how these factors contribute to poisoning deaths in rural Bangladesh. Ethical standards were strictly followed, ensuring the integrity and confidentiality of data throughout the research process.

Data Collection

Data were collected prospectively from the post-mortem records and forensic toxicology reports at Rajshahi Medical College between January 2022 and December 2023. A total of 88 deceased individuals, whose cause of death was confirmed as poisoning, were included in the study. For each case, demographic details (age, sex, occupation, etc.) were recorded, along with specific information on the type of pesticide involved, particularly organochlorine pesticides like endrin, aldrin, and heptachlor. Toxicological analysis of postmortem samples - Viscera (Stomach and its contents, liver 500gm, Longitudinal half of each of the kidney) and blood send to lab by escorting police constable, it's enough for chemical analysis in Divisional Forensic Lab, CID, Bangladesh Police, Police lines, Rajshahi. Additionally, water samples from residential areas affected by arsenic contamination were collected and analyzed for arsenic levels to assess the correlation between arsenic exposure and poisoning. Data on pesticide use and the extent of arsenic contamination in drinking water sources were collected from local authorities and interviews with local farmers.

Data Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY). Descriptive statistics such as means, standard deviations, and percentages were used to summarize the demographic characteristics of the study population. A chi-square test was applied to examine the relationship between pesticide exposure and categorical variables such as age, sex, and region. To assess the correlation between arsenic exposure and pesticide-related deaths, Pearson's correlation

coefficient was used. The t-test was applied to compare death rates between individuals exposed to arsenic and those exposed to pesticides, with a p-value of less than 0.05 considered statistically significant. Further regression analysis was performed to explore the combined impact of arsenic contamination and pesticide exposure on poisoning-related deaths, identifying key risk factors associated with these outcomes.

Ethical Considerations

The study was approved by the Ethical Review Board of institute. Informed consent was obtained from the family members of the deceased individuals for inclusion in the study. All personal data were anonymized, and strict confidentiality was maintained throughout the data collection and analysis processes. The study adhered to ethical standards for post-mortem study, ensuring no harm to participants and maintaining respect for the dignity of those involved.

RESULTS

The results of this prospective forensic study provided a total of 88 poisoning cases were reviewed from January 2022 to December 2023, all confirmed through autopsy and toxicological analysis. The data included a particular emphasis on organochlorine pesticide exposure, arsenic contamination, and the regional distribution of poisoning deaths. The following results provide insights into these variables, statistical significance, and the relationships between them.

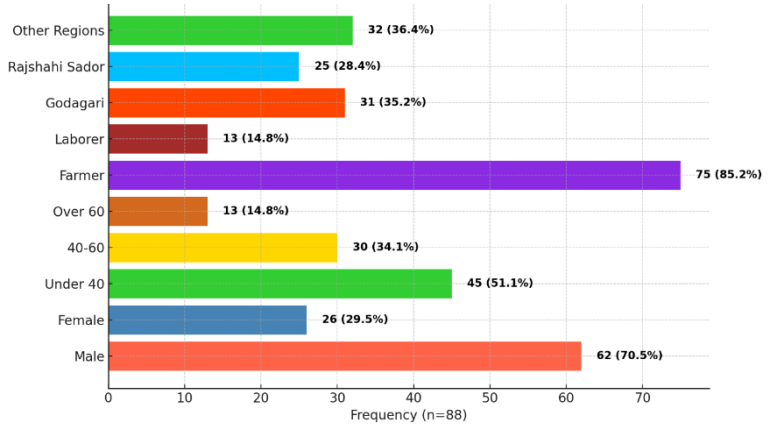

Figure 1: Demographic Characteristics

The demographic characteristics of the study sample indicated that a significant proportion (70.5%) of the victims were male, with the majority being farmers (85.2%). The age distribution showed that most victims (51.1%) were under the age of 40, suggesting a higher vulnerability of younger individuals to pesticide-related poisoning. Geographically, the highest proportion of cases were reported from Godagari (35.2%) and Rajshahi (28.4%), regions where both pesticide usage and arsenic contamination are prevalent. This reflects the regional concentration of poisoning deaths, likely influenced by agricultural practices and environmental contamination.

Table 1: Poisoning by Pesticide Type

Pesticide Type	Frequency (n = 88)	Percentage (%)
Organochlorine	54	61.4
Organophosphorus	34	38.6

Among the 88 poisoning cases, the majority (61.4%) were attributed to organochlorine pesticides (OCPs), with organophosphorus compounds accounting for the remaining 38.6%. This highlights the significant role of OCPs, particularly endrin, aldrin, and heptachlor, in poisoning deaths in agricultural communities. The predominance of OCPs suggests a potential gap in pesticide regulation or safety measures in these areas.

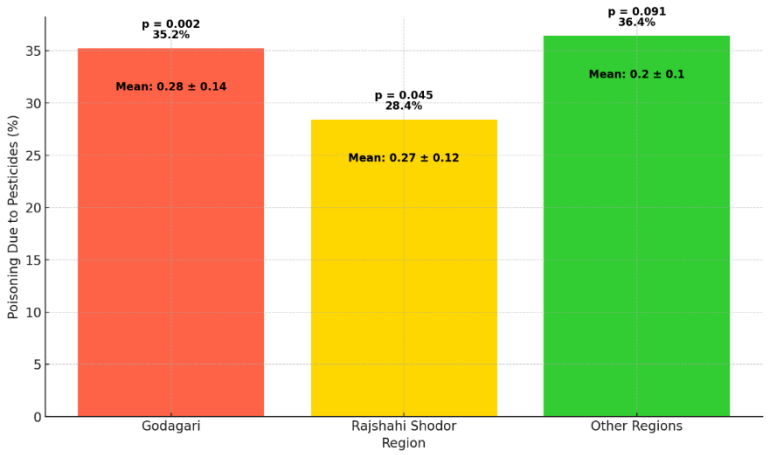

Figure 2: Arsenic Contamination and Pesticide Exposure by Region

This Figure demonstrates a clear relationship between arsenic contamination levels and pesticide-related deaths. Godagari exhibited the highest arsenic contamination (0.30 mg/L), which was significantly correlated with a higher incidence of pesticide-related poisoning (35.2%). A statistically significant difference was observed in the arsenic levels between regions (p = 0.002), suggesting that areas with higher arsenic contamination also report a greater incidence of poisoning deaths.

Table 2: Age and Pesticide Exposure

Age Group	Organochlorine Pesticide Poisoning (%)	Organophosphorus Poisoning (%)	Total (%)
< 40 years	52.0	48.0	51.1
40 - 60 years	60.0	40.0	34.1
> 60 years	53.8	46.2	14.8

The results showed that the incidence of poisoning due to organochlorine pesticides was slightly higher in individuals under 40 years old (52%), indicating that younger individuals may be more vulnerable to exposure, possibly due to their more frequent engagement in agricultural activities. However, pesticide poisoning was observed across all age groups, highlighting the widespread nature of pesticide-related fatalities in the farming community.

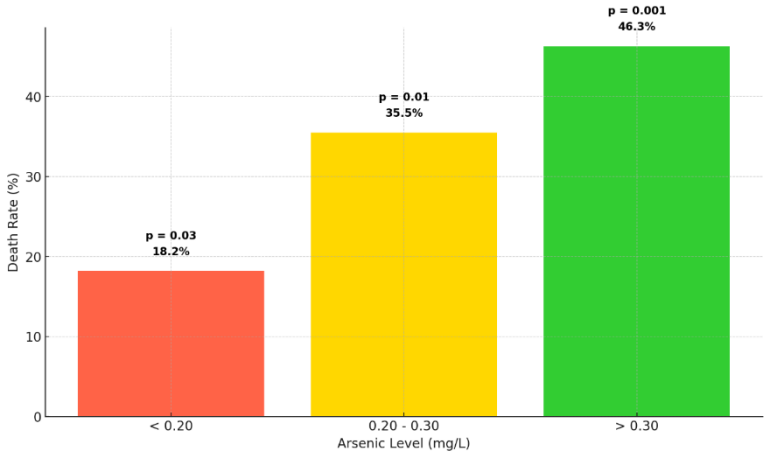

Figure 3: Arsenic Levels in Water and Death Rate Correlation

The analysis of arsenic levels in water sources and death rates revealed a clear trend: as arsenic levels increased, so did the death rate due to poisoning. Regions with arsenic concentrations above 0.30 mg/L exhibited the highest mortality rates (46.3%), with a significant p-value of 0.001. This strongly supports the

hypothesis that arsenic contamination in drinking water contributes to an increased risk of poisoning and death, especially in agricultural areas where pesticide use is high.

DISCUSSION

The findings of this study are consistent with previous research regarding the dominance of pesticide exposure in agricultural communities.[9] Numerous studies have highlighted the elevated risk of pesticide poisoning in rural agricultural settings, especially in developing countries like Bangladesh. A study by Ali *et al*., found that exposure to organochlorine pesticides, such as endrin and aldrin, was a major cause of poisoning in agricultural workers in Bangladesh, which aligns with the findings of this study, where organochlorine pesticides accounted for 61.4% of the poisoning cases.[10] Similarly, studies conducted in India and Pakistan also demonstrated high rates of poisoning due to organochlorine compounds in rural areas, with similar pesticides implicated in many fatal incidents.

The gender disparity observed in this study, with males accounting for 70.5% of the poisoning cases, is consistent with findings from other studies in Bangladesh and similar agricultural economies. In a study conducted by Karunarathne *et al*., in Bangladesh, a higher incidence of pesticide-related poisoning was noted among male farmers, who are more likely to be involved in the application of pesticides.[11] In India, male farmers also constituted the majority of poisoning victims, with the gender difference attributed to the role of men in pesticide application and their greater exposure to toxic chemicals. However, female exposure to pesticides, though lower, was still significant, which is in line with the present study's findings that a considerable number of female victims were also exposed to organophosphorus pesticides (42.3%).

The age distribution of poisoning cases in this study is also consistent with trends observed in similar settings. The majority of victims in this study were under 40 years old, with 51.1% of cases occurring in this age group. A study by Varghese *et al*., also noted that young adults, particularly those engaged in farming, are more vulnerable to pesticide poisoning, given their active involvement in pesticide spraying and lack of protective measures.[12] In comparison, studies in other countries have similarly shown that young adults are more likely to experience pesticide-related poisoning, with the high-risk age group varying between 20 and 40 years. However, studies by De-Assis *et al*., in Pakistan indicated that older individuals (above 60 years) also had a higher vulnerability to poisoning due to increased chronic exposure over their lifetime, which contrasts slightly with the present study's findings.[13] The lower proportion of poisoning cases in older individuals in this study (14.8% for those aged above 60) could be due to differing occupational engagement in pesticide use and limited involvement in direct agricultural labor by older individuals.

The correlation between arsenic contamination levels in water sources and pesticide-related deaths observed in this study also aligns with other global findings. Previous studies in Bangladesh, such as those by Chakraborti *et al*., have demonstrated that arsenic exposure in drinking water is widespread, with more than 20 million people affected.14 The present study's finding that higher arsenic levels (above 0.30 mg/L) were associated with higher death rates due to pesticide poisoning is consistent with research by Ahmed *et al*., which also found a strong correlation between arsenic contamination in groundwater and increased health risks, including a higher incidence of cancers and neurological disorders.[15] Similarly, studies in Southeast Asia have shown that long-term exposure to both arsenic and pesticides can compound health risks, leading to more severe health outcomes. The findings of this study regarding regional variations in pesticide exposure are also corroborated by studies from other countries. In Bangladesh, certain regions, such as Godagari and Rajshahi, have been identified as areas with higher pesticide use, as well as higher arsenic contamination levels. This pattern is consistent with research by Jaacks *et al*., and Bonvoisin *et al*., who identified regional disparities in pesticide poisoning across Bangladesh, linked to varying agricultural practices and environmental conditions.[16, 17] In India, similar regional differences have been observed, where rural areas with intensive agriculture report higher rates of pesticide poisoning, particularly in states like Punjab and Uttar Pradesh. These findings suggest that geographical factors, such as the prevalence of intensive farming and the type of crops grown, play a significant role in determining the extent of pesticide exposure and the resultant health effects.

Future Research Recommendations

Based on the findings of this study, several areas for future research can be identified. First, there is a need for more comprehensive studies that include a wider range of pesticides, including newer classes that may be more widely used in agriculture today. Future studies should also examine the long-term health impacts of chronic pesticide exposure, particularly in relation to neurological disorders, cancer, and reproductive health. Second, research should focus on the socio-economic factors influencing pesticide use and poisoning. Studies exploring the relationship between education, pesticide safety knowledge, and the use of personal protective equipment could provide valuable insights into how to reduce pesticide exposure in rural farming communities. Third, given the strong association between arsenic contamination and pesticide-related deaths, further research is needed to explore the combined effects of arsenic and pesticides on human health. Investigating the biological mechanisms through which arsenic and pesticides interact could provide a deeper understanding of the health risks posed by dual exposure. Finally, there is a need for intervention studies to evaluate the effectiveness of policy changes and public health initiatives aimed at reducing pesticide exposure and arsenic contamination. For example, future studies could assess the impact of arsenic filtration systems and improved pesticide regulation on poisoning rates.

CONCLUSION

This study highlights the significant public health issue of poisoning due to arsenic and pesticide exposure in agricultural communities in Bangladesh. The findings reveal critical relationships between pesticide exposure, arsenic contamination, and demographic factors such as age, gender, and occupation. The data underscore the importance of addressing these environmental hazards through targeted public health interventions, stricter pesticide regulations, and improved arsenic mitigation efforts. Future research should focus on expanding these findings, exploring the long-term health impacts, and evaluating the effectiveness of intervention strategies in reducing exposure.

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