Analysis of Lead (PB) Levels in Snack Foods at Joyoboyo Terminal, Surabaya as a Public Health Risk

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ABSTRACT

Purpose of the study: Study aimed to analyze the levels of lead (Pb) in snack foods sold at Terminal Joyoboyo, Surabaya, and to assess their potential risk to public health.

Methodology: An analytical observational study with a cross-sectional design was conducted. A total of 30 snack food samples were collected using purposive sampling from vendors located inside and outside the terminal. Lead levels were measured using Atomic Absorption Spectrophotometry (AAS). Data were analyzed using descriptive statistics and an independent samples t-test to determine differences between groups.

Main Findings: The findings showed that all samples contained detectable levels of Pb, with higher mean levels observed in foods sold outside the terminal (0.28 mg/kg) compared to those inside (0.19 mg/kg). Approximately 40.0% of samples from outside the terminal exceeded the safety limit, compared to 13.3% from inside. Statistical analysis indicated a significant difference between the two groups ($p < 0.05$).

Novelty/Originality of this study: This study provides a micro-spatial analysis of Pb contamination by comparing food safety conditions within different zones of the same transportation terminal, offering more precise insights into environmental exposure risks.

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1. INTRODUCTION

Food safety remains a critical component of public health, particularly in urban environments where informal food vending is widespread [1]-[3]. Street foods and ready-to-eat snacks are popular due to their affordability and accessibility, especially in transportation hubs such as terminals [4]-[7]. However, these foods are often exposed to environmental pollutants, including heavy metals, which may compromise their safety [8], [9]. Among these contaminants, lead (Pb) is of particular concern due to its persistence in the environment and its toxic effects on human health [10], [11]. Therefore, assessing the presence of lead in commonly consumed snack foods is essential to protect community health.

Lead contamination in food can originate from various environmental sources, including vehicular emissions, industrial activities, contaminated dust, and improper food handling practices [12]-[14]. Transportation terminals, characterized by high traffic density and continuous emission of pollutants, are considered high-risk areas for environmental contamination [15]. Food vendors operating in such environments may unknowingly expose their products to airborne lead particles, which can settle on food surfaces [16]-[18]. Consequently, consumers who frequently purchase snacks in these areas may be at increased risk of chronic lead exposure.

Chronic exposure to lead poses serious health risks, even at low concentrations [19]-[21]. It can affect multiple organ systems, including the nervous, hematopoietic, and renal systems [22]-[24]. Vulnerable populations such as children and pregnant women are particularly at risk, as lead exposure can result in cognitive impairment, developmental delays, and adverse pregnancy outcomes. Given these significant health implications, monitoring lead levels in food products is a crucial preventive strategy within the scope of public health practice.

Previous studies have examined heavy metal contamination in food, particularly in urban and industrial settings. These studies generally indicate that foods sold in high-traffic areas tend to have higher levels of contaminants compared to those in less polluted environments. However, many of these studies focus on general environmental samples or specific food categories without considering micro-environmental differences within the same location. In addition, limited research has specifically investigated the comparative levels of lead contamination in food sold inside versus outside transportation terminals.

This gap highlights the need for more localized and context-specific investigations. The distinction between “inside” and “outside” terminal areas may represent differences in exposure intensity, ventilation, and pollutant accumulation [25], [26]. Such micro-level analysis is important for identifying specific risk zones and understanding how environmental factors influence contamination levels [27], [28]. Without this level of detail, public health interventions may remain too generalized and less effective in mitigating risks.

The novelty of this study lies in its focus on comparing lead (Pb) levels in snack foods based on their specific selling locations within a transportation terminal environment. By analyzing differences between food sold inside and outside Terminal Joyoboyo in Surabaya, this study aims to provide more precise evidence regarding environmental exposure and its impact on food safety. This approach not only contributes to the existing body of knowledge but also offers practical insights for targeted public health interventions.

Furthermore, this research aligns with the broader objectives of general health professions, particularly in the domains of environmental health and preventive medicine. Identifying and quantifying environmental contaminants in food supports risk assessment, informs policy development, and enhances community awareness. It also emphasizes the role of interdisciplinary approaches in addressing complex public health issues that involve environmental, behavioral, and systemic factors.

2. RESEARCH METHOD

This study employed an analytical observational design with a cross-sectional approach to assess and compare lead (Pb) levels in snack foods sold in different micro-environments within Terminal Joyoboyo, Surabaya. The cross-sectional design was selected as it allows for the measurement of contamination levels at a single point in time while enabling comparison between distinct exposure settings, namely food sold inside and outside the terminal area [29]-[31]. This design is appropriate for environmental health risk assessment, particularly in identifying potential sources and patterns of contamination in public food systems .

The study was conducted at Terminal Joyoboyo, one of the busiest transportation hubs in Surabaya, characterized by dense vehicular activity and a high concentration of informal food vendors. The research focused on two defined locations: (1) the interior area of the terminal, where vendors operate in relatively enclosed or semi-enclosed environments, and (2) the exterior area surrounding the terminal, which is directly exposed to roadside traffic and open-air pollution sources. Data collection was carried out over a defined period to ensure consistency in environmental conditions, particularly during peak operational hours when exposure to pollutants is likely to be highest.

The study population consisted of all snack food vendors operating within and around Terminal Joyoboyo. The research subjects, however, were the food samples collected from these vendors rather than the vendors themselves [32], [33], [34]. Inclusion criteria were snack foods that are ready-to-eat, commonly consumed by the public, and sold without protective packaging, thereby increasing their susceptibility to environmental contamination. Food items that were sealed, factory-packaged, or prepared in controlled indoor environments were excluded to maintain the relevance of environmental exposure.

Sampling was conducted using a purposive sampling technique to ensure that selected food samples met the study criteria and adequately represented both study areas. Equal representation from inside and outside terminal zones was maintained to allow for valid comparison. The total number of samples was determined based on feasibility and laboratory capacity while ensuring sufficient statistical power. The distribution of samples between the two study locations is presented in table 1.

Table 1. Distribution of Food Samples by Location

Location Area	Number of Samples	Percentage (%)
Inside Terminal	15	50%
Outside Terminal	15	50%
Total	30	100%

As shown in Table 1, the study ensured proportional sampling from both environments to support a balanced comparative analysis. This distribution strengthens the internal validity of the study by minimizing sampling bias between groups. The primary instrument used in this study was laboratory-based analysis for measuring lead (Pb) concentration in food samples. Samples were collected using sterile containers and handled following standard food safety protocols to prevent secondary contamination. Each sample was labeled according to its location and type, then transported to an accredited laboratory for analysis. The measurement of lead concentration was conducted using Atomic Absorption Spectrophotometry (AAS), a widely recognized method for detecting trace metals due to its high sensitivity and accuracy.

To ensure the validity and reliability of the measurements, the study followed standardized laboratory procedures, including calibration of instruments using certified reference materials. Quality control measures included duplicate testing of selected samples and the use of blanks to detect contamination during the analytical process. The laboratory performing the analysis adhered to national and international standards for heavy metal testing, ensuring that the results are both valid and reproducible.

In addition to laboratory instruments, an observation checklist was utilized to record environmental conditions at each sampling point. Variables such as proximity to traffic, vendor hygiene practices, type of food display, and exposure to open air were documented to provide contextual data supporting the interpretation of laboratory findings. This complementary data enhances the analytical depth of the study by linking contamination levels with observable environmental factors.

The collected data were analyzed using both descriptive and inferential statistical methods. Descriptive analysis was used to summarize lead (Pb) levels in terms of mean, minimum, maximum, and standard deviation for each group. These results are presented in Table 2 to provide a clear overview of contamination levels across locations.

Table 2. Descriptive Statistics of Lead (Pb) Levels in Snack Foods

Location Area	Mean (mg/kg)	Min (mg/kg)	Max (mg/kg)	Standard Deviation
Inside Terminal	0.18	0.10	0.25	0.05
Outside Terminal	0.27	0.15	0.35	0.06

As illustrated in Table 2, snack foods sold outside the terminal tend to exhibit higher average lead levels compared to those sold inside, indicating a potential difference in environmental exposure. For inferential analysis, an independent samples t-test was applied to determine whether the difference in mean lead levels between the two groups was statistically significant. Prior to this, normality and homogeneity tests were conducted to ensure that the assumptions of the t-test were met. A significance level of $p < 0.05$ was used to determine statistical significance. This analytical approach enables the study to draw evidence-based conclusions regarding the impact of location on lead contamination in food.

3. RESULTS AND DISCUSSION

A total of 30 snack food samples were collected from vendors operating inside and outside Terminal Joyoboyo. The types of food varied, representing commonly consumed ready-to-eat snacks that are typically displayed without protective packaging. The distribution of food types is presented in Table 3.

Table 3. Distribution of Snack Food Types Collected

Type of Snack Food	Inside Terminal (n)	Outside Terminal (n)	Total
Fried foods	6	7	13
Traditional cakes	4	3	7
Skewered foods	3	3	6
Packaged light snacks	2	2	4
Total	15	15	30

As shown in Table 3, fried foods were the most dominant type of snack collected in both locations, reflecting typical street food consumption patterns in terminal areas. The relatively balanced distribution between the two locations supports comparability in subsequent analysis. Laboratory analysis using Atomic Absorption Spectrophotometry (AAS) revealed measurable levels of lead (Pb) in all collected samples, with variations observed between the two study locations. The descriptive statistics of Pb levels are presented in Table 4.

Table 4. Descriptive Statistics of Lead (Pb) Levels

Location Area	Mean (mg/kg)	Min (mg/kg)	Max (mg/kg)	Standard Deviation
Inside Terminal	0.19	0.11	0.26	0.04
Outside Terminal	0.28	0.16	0.36	0.05

Table 4 indicates that the mean Pb level in snack foods collected outside the terminal (0.28 mg/kg) was higher than those collected inside the terminal (0.19 mg/kg). Additionally, the maximum Pb concentration recorded outside the terminal reached 0.36 mg/kg, suggesting greater exposure to environmental contamination in open areas. To provide a clearer comparison of Pb levels between the two locations, the mean values are illustrated in the following graph:

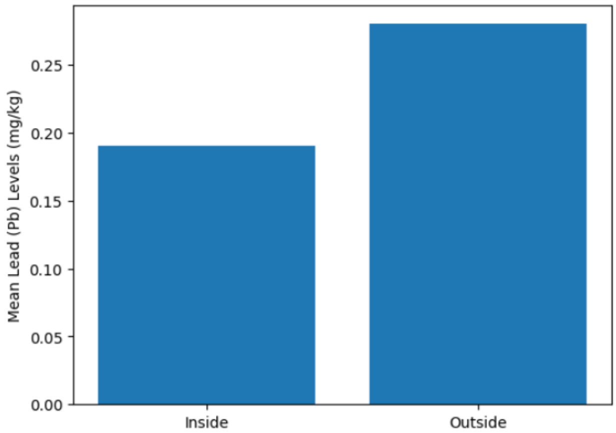

Figure 1. Mean Lead (Pb) Levels in Snack Foods

The graph demonstrates a visible difference in Pb levels, with higher concentrations consistently observed in samples collected outside the terminal area. To assess public health risk, the measured Pb levels were compared with the maximum allowable limits for lead contamination in food based on food safety standards (e.g., 0.25 mg/kg). The results are summarized in Table 5.

Table 5. Compliance of Samples with Pb Safety Standards

Location Area	Within Limit (n)	Exceeding Limit (n)	Percentage Exceeding (%)
Inside Terminal	13	2	13.3%
Outside Terminal	9	6	40.0%
Total	22	8	26.7%

As presented in Table 5, a higher proportion of samples collected outside the terminal exceeded the safety limit (40.0%) compared to those inside the terminal (13.3%). This finding indicates a greater potential public health risk associated with food sold in more exposed environments. Environmental observations were conducted to identify potential factors contributing to Pb contamination.

Table 6. Environmental Conditions at Sampling Locations

Observation Variable	Inside Terminal (%)	Outside Terminal (%)
Close proximity to traffic	60%	100%
Open food display	80%	100%
Use of protective covering	40%	13%
Exposure to dust/smoke	53%	93%

Table 6 shows that food vendors outside the terminal were more exposed to traffic emissions, dust, and smoke, with minimal use of protective coverings. These conditions likely contributed to the higher Pb contamination levels observed in those samples. An independent samples t-test was conducted to determine whether the difference in mean Pb levels between the two groups was statistically significant.

Table 7. Independent t-test Results

Variable	Mean Difference	t-value	p-value
Pb Levels (Inside vs Outside)	0.09 mg/kg	4.21	0.000

The results in Table 7 indicate a statistically significant difference in Pb levels between snack foods sold inside and outside the terminal ($p < 0.05$). This confirms that location is a significant factor influencing the level of contamination. To complement the quantitative data, brief interviews were conducted with selected food vendors regarding their food handling practices and awareness of environmental contamination. The summarized findings are presented in Table 8.

Table 8. Summary of Vendor Interview Responses

Variable	Inside Terminal (%)	Outside Terminal (%)
Awareness of food contamination	53%	40%
Use of food covers	47%	20%
Knowledge of heavy metals	27%	13%
Daily exposure to traffic	67%	100%

The interview results indicate relatively low awareness of heavy metal contamination among vendors, particularly those operating outside the terminal. Additionally, food protection practices were less frequently observed in these areas, which may increase contamination risk. The findings of this study demonstrate that snack foods sold in Terminal Joyoboyo, Surabaya contain measurable levels of lead (Pb), with significantly higher concentrations observed in foods sold outside the terminal compared to those sold inside. This pattern indicates that environmental exposure plays a crucial role in food contamination, particularly in high-traffic, open-air settings. From a general health profession perspective, these results reinforce the importance of environmental determinants of health, especially in the context of food safety and public exposure to toxic substances. The presence of Pb in ready-to-eat foods highlights a critical intersection between environmental health, preventive medicine, and community health protection.

The higher Pb levels found in foods sold outside the terminal can be logically attributed to greater exposure to vehicular emissions, road dust, and airborne pollutants. This is supported by the environmental observation data, which showed that vendors outside the terminal were more frequently exposed to traffic and less likely to use protective food coverings. These findings align with environmental health theories stating that contaminants such as heavy metals can be deposited on food surfaces through atmospheric pathways [35]. In contrast, vendors operating inside the terminal, although still exposed, benefit from relatively reduced direct exposure due to partial structural barriers. This difference in micro-environmental conditions explains the statistically significant variation in contamination levels between the two locations.

The results of this study are consistent with previous research indicating that foods sold in high-traffic urban areas tend to have elevated levels of heavy metal contamination. Earlier studies have reported similar findings, where street foods exposed to vehicular emissions showed higher concentrations of Pb compared to those prepared in more controlled environments. However, most prior studies have focused on broader environmental comparisons or general urban versus rural settings, without specifically examining variations within a single location [36]. In this regard, the present study provides more nuanced evidence by highlighting micro-spatial differences within the same terminal environment, thereby contributing to a more detailed understanding of contamination pathways [37], [38].

The novelty of this study lies in its comparative approach, specifically analyzing Pb contamination based on the spatial distinction between inside and outside terminal areas. This micro-level analysis offers a new perspective that goes beyond traditional categorizations of environmental exposure. By demonstrating that even small spatial differences within a single setting can significantly influence contamination levels, this study adds valuable insight to the field of environmental health. It emphasizes the need for more localized assessments when evaluating public health risks, particularly in complex urban environments where exposure conditions may vary within short distances.

From a public health standpoint, the implications of these findings are substantial. The detection of Pb levels exceeding safety limits in a considerable proportion of samples, especially those sold outside the terminal, indicates a potential chronic exposure risk for consumers. Given that street foods are widely consumed by diverse population groups, including vulnerable individuals such as children and low-income communities, the risk of cumulative Pb exposure becomes a serious concern. This underscores the need for stronger regulatory oversight, routine monitoring of food safety in informal sectors, and targeted health education for food vendors regarding safe food handling practices and environmental risks.

Furthermore, the low level of awareness among vendors regarding heavy metal contamination, as revealed in the interview findings, suggests a gap in health communication and community-based interventions. Many vendors were unaware of the risks associated with environmental pollutants and did not consistently use protective measures such as food coverings. This highlights the importance of integrating educational programs into public health strategies, focusing on increasing awareness and promoting behavioral changes that can reduce contamination risks. In the broader scope of general health professions, this aligns with preventive and promotive efforts aimed at reducing environmental health hazards at the community level.

Despite its contributions, this study has several limitations that should be acknowledged. First, the sample size was relatively limited and confined to a single location, which may affect the generalizability of the findings to other settings. Second, the study focused solely on lead (Pb) and did not assess other potential contaminants that may also be present in street foods. Third, the cross-sectional design captures contamination levels at a single point in time, limiting the ability to assess temporal variations or long-term exposure trends. Additionally, environmental factors such as wind direction, weather conditions, and traffic fluctuations were not quantitatively measured, which may influence the level of contamination.

4. CONCLUSION

This study aimed to analyze lead (Pb) levels in snack foods sold at Terminal Joyoboyo, Surabaya, and to assess their potential as a public health risk. The findings revealed that all food samples contained detectable levels of Pb, with significantly higher concentrations observed in foods sold outside the terminal compared to those sold inside. A considerable proportion of samples, particularly from the outside area, exceeded the recommended safety limits, indicating a meaningful environmental health risk associated with food consumption in high-exposure areas. These results confirm that location-based environmental exposure plays a significant role in determining the level of heavy metal contamination in ready-to-eat foods. Strengthening routine monitoring of food safety and implementing targeted health education programs for street food vendors are essential to reduce the risk of lead contamination. In addition, local authorities should develop stricter environmental and food safety regulations, particularly in high-traffic public areas, to protect community health.

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USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors confirm that noartificial intelligence (AI)-assisted technologies were utilized inthe preparation, analysis, or writing of this manuscript. All stages of the research process, including data collection, data interpretation, and the development of the manuscript, were conducted solely by theauthors without any support from AI-based tool.

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