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Environmental and public health impacts of improper municipal abattoir waste management in Debre Markos town, Amhara region, Ethiopia

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ABSTRACT

Improper management of abattoir waste poses significant environmental and public health risks, particularly in developing countries such as Ethiopia. This study assessed the environmental and health impacts of poor abattoir waste disposal practices on communities living near the Debre Markos municipal abattoir. A cross-sectional mixed-method design was used, involving 186 households selected through stratified disproportionate random sampling. Households were grouped by distance from the abattoir: Zone I (<500 m), Zone II (501–1000 m), and Zone III (>1000 m). Data were collected using questionnaires, key informant interviews, and field observations, and analyzed with descriptive and inferential statistics using SPSS version 26. Results showed that all abattoir waste is openly disposed of without treatment, creating serious environmental and health hazards. Reported impacts included air and noise pollution, offensive odors, and exposure to disease-causing pathogens. About 64% of households reported illnesses linked to waste exposure, including respiratory infections (asthma and common cold), eye infections, cholera, and typhoid. Statistical analysis revealed a significant association between awareness of environmental degradation and factors such as age, duration of residence, and distance from the abattoir ($p < 0.05$). Improper waste disposal has also created social and economic burdens for residents. The study recommends relocating the abattoir to a non-residential area and improving waste management through approaches such as anaerobic digestion. Utilizing by-products for animal feed and compost production is also suggested to reduce waste and promote sustainability.

Keywords: Abattoir Waste Management, Debre Markos, Environmental and Health Impacts, Mixed-Method Approach, Sustainable Waste Utilization

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1. Introduction

Slaughterhouse waste (SHW) poses a significant environmental and public health risk due to its high organic load, pathogenic microorganisms, and unpleasant odor. Proper and sustainable management of this waste remains a major challenge for modern abattoirs, which continue to seek cost-effective and environmentally friendly solutions Borowski and Kubacki (2015).

Globally, the dramatic increase in meat consumption has resulted in a corresponding rise in the generation of abattoir waste. According to the Food and Agriculture Organization (FAO), global per capita meat consumption has more than tripled over the past few decades(FAO, 2011), intensifying the strain on urban sanitation systems, especially in low- and middle-income countries. Rapid urbanization and the growing number of daily animal slaughters have made waste management in urban abattoirs increasingly complex (Ezeoha & Ugwuishiwu, 2011).

In many developing countries, industrial waste particularly from abattoirs is often dumped without proper treatment or regulation. This unsanitary disposal practice leads to severe contamination of soil and water resources, contributing to disease outbreaks and environmental degradation (Norsa'adah et al., 2020). Abattoirs, as major generators of organic waste, are particularly problematic in this regard (Fearon et al., 2014).

Poorly managed abattoir waste contributes to a range of environmental and societal issues, including the transmission of infectious diseases, air and water pollution, and degradation of local ecosystems (Akinro et al., 2009). Despite its potential for reuse through composting, biogas generation, or conversion into bio-fertilizers, abattoir waste is frequently left to decompose in open areas, creating foul odors and serving as breeding grounds for vectors such as flies and rodents (Kefalew & Lami, 2021).

While several studies have proposed the valorization of abattoir waste into renewable energy and soil amendments (e.g., anaerobic digestion for biogas or bio-fertilizer production), the reality in many Ethiopian towns remains starkly different. In practice, abattoir waste is routinely disposed of directly into the surrounding environment without any form of treatment (Audu et al., 2020; Azadbakht et al., 2023; Sindibu et al., 2018). This has led to serious health consequences for nearby residents, including respiratory illnesses, waterborne diseases, and general declines in quality of life.

Despite the magnitude of the issue, abattoir waste management continues to receive minimal attention within broader industrial waste discussions in developing nations. In Ethiopia, research has largely focused on quantifying abattoir waste or exploring its energy potential, with few studies examining its direct impact on nearby communities and ecosystems (Temesgen & Ketema, 2024; Tolera & Alemu, 2020; Yunus, 2019)

Debre Markos town municipality abattoir releases all waste products into the environment, which harms the surrounding community's health and environment. Because of this practice, communities living around the abattoir always complain due to the bad odor caused by improper abattoir waste management. However, abattoir waste impacts on the surrounding environment were not yet studied.

Therefore, this study aims to evaluate the environmental and health impacts of improper abattoir waste disposal on the residents living near the municipal abattoir in Debre Markos town, East Gojjam Zone, Amhara Region, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted at the municipal abattoir in Debre Markos, a town located in the southeastern part of the East Gojjam Zone, Amhara Region, Ethiopia. The abattoir occupies an area of approximately 1,000 square meters and serves as the only officially recognized slaughter facility in the town, providing cattle slaughtering services exclusively (DMTM, 2019).

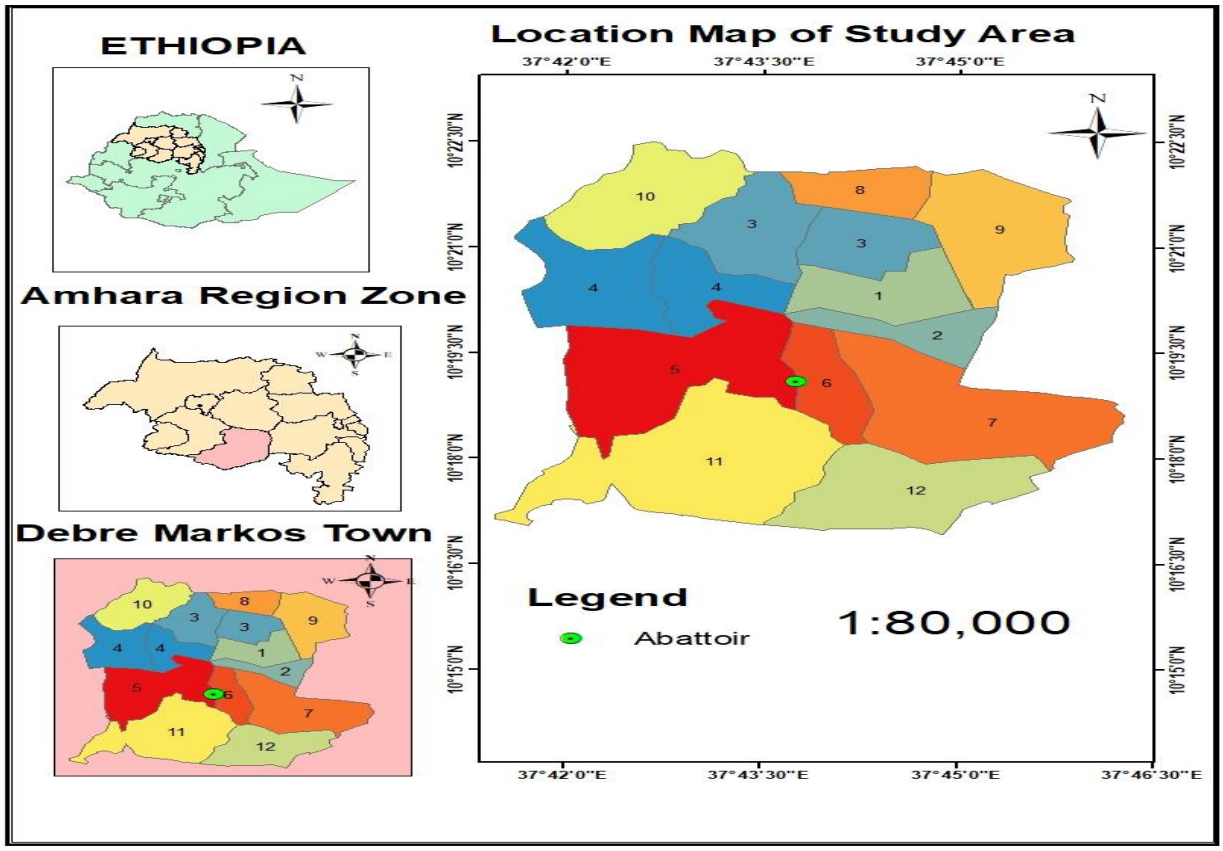

Figure 1: Location map of the study area

Geographically, Debre Markos is situated between latitudes 10°17′00″ to 10°21′30″ N and longitudes 37°42′00″ to 37°45′30″ E. It lies at an elevation ranging from 2,300 to 2,500 meters above sea level (Figure 1).

Due to its proximity to residential neighborhoods and lack of advanced waste treatment infrastructure, the municipal abattoir has raised ongoing concerns regarding its impact on the surrounding environment and public health.

2.2. Household Survey

2.2.1. Research Approach

The study was conducted during the spring season (October, 2022), a period characterized by high local wind speeds. This seasonal condition exacerbates the dispersion of pollutants from the abattoir, resulting in frequent complaints from nearby residents to the municipal authorities regarding negative impacts on their health and environment.

A mixed-methods approach was employed, integrating both quantitative and qualitative research methods to comprehensively assess the environmental and public health implications of abattoir waste disposal. The qualitative component included key informant interviews and field observations, while the quantitative aspect involved a structured household questionnaire. This methodological triangulation ensured a deeper understanding of the issues from multiple perspectives.

2.2.2. Sampling Design

A cross-sectional survey design was adopted to evaluate the impacts of abattoir waste on the surrounding community. Respondents were selected based on their residential proximity to the abattoir, categorized into three zones: Zone I: Within 0–500 meters, Zone II: Between 501–1000 meters and Zone III: Beyond 1001 meters. This stratification was based on the revised guidelines of the Ethiopian Ministry of Urban Development and Construction, which recommend a minimum 500-meter buffer between abattoirs and residential settlements (Hassen, 2020).

2.2.3. Data Sources and Types

Both primary and secondary data sources were utilized. Primary data were collected through structured questionnaires, key informant interviews, and systematic field observations. Secondary data were obtained from published and unpublished materials, including scientific journals, previous research reports, and records from the municipal administration.

2.2.4. Data Collection Tools

2.2.4.1. Questionnaire

The structured questionnaire, informed by previous studies, included both closed- and open-ended questions. It covered three key domains: socio-demographic characteristics, environmental impact assessments, and public health outcomes. Participants were also asked to rate perceived environmental impacts on a scale of 1 to 3—where 1 = low, 2 = moderate, and 3 = high—following the ranking framework proposed by (Dada et al., 2021).

2.2.4.2. Key Informant Interviews

Focal individuals from relevant offices, including abattoir doctor, two kebele health extension workers, abattoir worker association with 12 members were interviewed about the public health and environmental problems associated with improper abattoir waste disposal.

2.2.4.3. Observation

A total of 12 direct observation sessions were conducted (three per season throughout the year) using a standardized checklist. These observations focused on the abattoir's environmental sanitation, including waste handling, collection, transportation, and final disposal practices.

2.3. Population

2.3.1. Target Population

The target population consisted of household heads residing near the municipal abattoir, who were believed to be directly affected by the abattoir's operations.

2.3.2. Sampling Frame

The sampling frame comprised all households located within a 1.5-kilometer radius of the abattoir. A preliminary field survey identified a total of 345 households within this area.

2.3.3. Sampling Unit

The sampling unit was individual households. Given that the environmental and health impacts of abattoir waste are expected to be more pronounced among households in closer proximity, the study used spatial stratification to reflect impact gradients. The area was mapped into three 500-meter intervals using a handheld GPS device. Household distribution in each zone was recorded and used to guide stratified sampling, ensuring representation across varying exposure levels (Dada et al., 2021).

2.3.4. Sample Size Determination and Sampling Techniques

2.3.4.1. Sample Size Determination

Using the condensed formula for proportions provided by Yamane's formula, the number of sample houses was chosen (Yamane, 1967). Then, a random number of sample houses in equal numbers were chosen (n/3) from each stratum.

$$n = N/1+N\,(e)^2$$

Where: n = the sample size

N = the total population size in the three strata

e = the acceptable sampling error (the level of precision)

Thus, based on the above formula N= 345 and e = at 95% is equal to 0.05, the sample size n was determined to be $345/1+345(0.05)^2 = 186$.

Based on the above formula, the sample respondents were estimated to be 186. After this, the researcher stratified those respondents into three strata as it is mentioned in the research design by using the following disproportionate stratified formula N =n/k (Lettor, 2015).

Where: - N= Sample size for each stratum.

n = sample size for the study

k = the number of strata

N = 186/3 = 62.

Based on this standard, the required samples were selected randomly from each stratum. Specifically, 62 respondents were randomly selected from within the 500-meter radius of the abattoir, another 62 respondents were selected from between 501-1000 meters, and the remaining 62 respondents were selected from beyond 1001 meters from the abattoir site.

2.3.4.2. Sampling Techniques

Disproportionate stratified random sampling was employed to select respondents. The study area was divided into three strata based on distance from the abattoir, as outlined in the research design. Households within each stratum were randomly selected using random number tables. The kebele where the abattoir is located was purposively selected based on proximity. Similarly, key informants were purposively selected for qualitative data collection due to their relevance and direct involvement in abattoir operations and health monitoring.

2.4. Method of Data Analysis

The data were coded, checked for consistency, missing values, and amended where necessary, then cleaned, entered, and analyzed using SPSS (Statistical Package for Social Sciences) version 26. Descriptive statistics, including percentages and frequencies, were used to analyze the effects of abattoir waste on the environment and public health. Inferential statistics, such as chi-square and one-way ANOVA, were employed to compare environmental and health impacts across three groups: households within 500m, 501-1000m, and ≥1001m from the abattoir. A P-value of 0.05 was considered statistically significant for the relationship.

For the qualitative data, interview responses were transcribed. Iterative thematic analysis was used to assess the data, and the authors provided a thematic summary and explanation for attribute comparison and analysis.

3. Results and Discussion

3.1. Abattoir Waste Management Practices

The municipal abattoir in Kebele 06, Debre Markos, constructed in 1978 G.C. on a 1,000 m² swampy site, now lies amidst expanding residential areas. Originally isolated, urban encroachment has led to heightened community concern regarding its impact on health and the environment. Field observations revealed that the abattoir lacks a protective fence, allowing access to scavenging animals. Solid waste—including paunch contents, legs, hooves, and horns—is openly stored for extended periods, emitting foul odors and attracting flies. Liquid waste (primarily blood, urine, and washing water) is temporarily held in a septic tank, but overflows once capacity is exceeded, releasing untreated effluent into surrounding areas (Appendix, photos).

Key informant interviews confirmed frequent community complaints submitted to the town administration, citing air pollution, respiratory ailments, and vector-borne diseases as major concerns. The poor design of the abattoir, lack of waste treatment infrastructure, and limited municipal budget were identified as root causes of the current waste mismanagement.

As Belachew et al. (2023), which is part of this study indicated, ,each slaughtered cattle requires approximately 88.13 liters, resulting in an estimated 2,643.9 liters of wastewater generated daily and approximately 565,794.6 liters annually. This wastewater, along with urine and blood, is temporarily stored in a septic tank. However, it once full, it overflows and is discharged untreated into nearby areas, leading to environmental contamination. None of this waste undergoes any form of treatment before release, contributing to widespread environmental contamination. The findings of this study are consistent with previous research by Ekpunobi et al. (2024), who emphasized that improper abattoir waste management can severely impact environmental quality and public health, particularly in urban areas. The overflow of untreated liquid waste and the open disposal of solid residues found in this study echo concerns raised by Krystosik et al. (2020), who documented similar practices leading to vector proliferation and community health issues.

On the other hand, unlike more advanced abattoir systems in some middle-income countries where biogas digesters or composting facilities are increasingly used (Azadbakht et al., 2023), the Debre Markos

facility remains rudimentary. This disconnect highlights the missed opportunity for converting organic waste into valuable by-products such as bio-fertilizer or animal feed, as recommended by (Fearon et al., 2014).

The current waste management practices at Debre Markos abattoir are far from meeting sanitary standards and pose significant environmental and public health risks. These findings reinforce the need for infrastructural improvement, policy enforcement, and sustainable waste utilization approaches to mitigate ongoing hazards.

3.2. Socio-Demographic Characteristics of Households Living Around the Abattoir

Association of Socio-Demographic Factors with Environmental and Health Problems are discussed below

3.2.1. Sex of Respondents

Among the surveyed households, 84.4 % of respondents were male, while only 15.6 % were female (Table 1). Statistical analysis revealed no significant association between respondents' gender and their awareness of the environmental and health impacts of abattoir waste ($p > 0.05$).

The finding of no significant gender difference in environmental awareness aligns with Mohai (2014), who reported similar results in their study, indicating that men and women may exhibit comparable levels of environmental concern in certain contexts.

However, qualitative data from key informant interviews in this study suggested that women tend to be more aware of the health and environmental impacts related to abattoir waste. This perception stems from the longer period of time they stay at home due to their responsibility for childcare, food preparation, and household cleaning exposing them more directly to environmental health hazards coming from abattoir. This observation is consistent with the findings of Park et al. (2012), who argued that women generally exhibit higher sensitivity and concern towards environmental and social well-being issues due to their caretaking responsibilities.

Conversely, other research presents contrasting evidence. For example, Larson et al. (2010) found that men often demonstrate greater environmental awareness and more favorable attitudes toward environmental protection. This discrepancy may be explained by sociocultural differences, variations in environmental education, or the specific context of each study population.

Overall, while quantitative analysis showed no significant gender differences in awareness in the Debre Markos community, qualitative insights and some prior studies suggest that gender roles may influence perceptions and attitudes towards environmental and health issues differently across settings.

3.2.2. Age of Respondents

The largest proportion of respondents (37.6 %) was aged between 31 and 40 years (Table 1). Statistical analysis revealed a significant association between age and awareness of environmental impacts, particularly concerning air pollution and pathogen exposure from abattoir waste ($p < 0.05$). Older respondents demonstrated higher levels of awareness compared to younger age groups.

This finding supports the perspective of Ogunbode and Arnold (2012), who reported that environmental awareness tends to increase with age, potentially due to accumulated life experience and longer exposure to local environmental issues. In the context of Debre Markos, older individuals are more likely to reside permanently in the village, often due to limited employment opportunities, which enables them to observe and understand the extent of environmental and health problems caused by the abattoir waste over time.

On the other hand, some studies have found that younger individuals are generally more environmentally conscious, as suggested by Zhang et al. (2018). This difference could be attributed to variations in education, media exposure, or cultural factors that shape environmental attitudes differently across regions.

This study highlights that, in the Debre Markos community, age is an important factor influencing awareness of abattoir waste impacts, with older residents showing greater recognition of the associated environmental and health risks.

3.2.3. Educational Level of Respondents

The majority of respondents (37.1%) had completed secondary education, while 11.8 % reported having no formal education (Table 1). Statistical analysis showed no significant association between education level and awareness of the environmental and health impacts of abattoir waste ($p > 0.05$).

Generally, education is recognized as a key factor in promoting environmental awareness, with numerous studies indicating that higher education levels correlate with greater knowledge and proactive environmental behavior (Zsóka et al., 2013).Educated individuals often have better access to information and greater capacity to understand complex environmental issues.

However, the lack of a significant relationship in this study suggests that awareness of the problems caused by improper abattoir waste management may be widespread across all education levels in this community. This could be because the negative effects such as foul odors, flies, and visible pollution are directly experienced by everyone living near the abattoir naturally, making the issue evident regardless of formal education.

3.2.4. Marital Status of Respondents

Most respondents were married (76.9%), while smaller proportions were single (15.1%), divorced (8%) (Table 1). Statistical analysis showed no significant association between marital status and awareness of the environmental and health impacts of abattoir waste ($p > 0.05$).

Some studies suggest that married individuals may demonstrate greater engagement with environmental issues, potentially due to increased family responsibilities and concern for household well-being (Grønhøj & Ölander, 2007). Family commitments can motivate individuals to be more protective of their living environment.

However, in this study, marital status did not significantly influence awareness levels regarding the impacts of abattoir waste. This could imply that concerns about environmental health in the community are widespread and not strongly shaped by family status. The pervasive nature of the abattoir waste problem may make its effects obvious to all residents, regardless of marital status..

3.2.5. Family Size of Respondents

The majority of households (44.6%) had between 4 and 6 family members (Table 1). Analysis revealed no significant association between family size and awareness of the environmental and health impacts of abattoir waste ($p > 0.05$).

Some studies suggest that larger families, particularly those with children, may be more environmentally aware due to greater exposure to environmental risks and concerns for family health (Satterthwaite, 2014). Larger households might also have a heightened interest in maintaining a safe and healthy environment.

However, other research contradicts this view, reporting no clear relationship between family size and environmental attitudes or awareness (Getachew et al., 2021). The findings from this study support the latter, indicating that family size does not significantly influence awareness of abattoir waste issues in this community.

This suggests that in the context of Debre Markos, environmental concerns related to abattoir waste are commonly recognized across households of all sizes, possibly because the negative effects are immediately noticeable and affect the entire community regardless of family composition.

3.2.6. Living Duration of Respondents

The largest group of respondents (30.7%) had lived in the area for 16–20 years (Table 1). Statistical analysis revealed a significant association between living duration and awareness of environmental impacts related to abattoir waste, including air pollution, noise pollution, pathogen exposure, and aesthetic degradation ($p < 0.05$).

Residents who have lived near the abattoir for many years are more likely to recognize the cumulative negative impacts caused by poor waste management as it is supported by the study of Reames and Bravo (2019) who confirmed in the study that longer residency in an area often correlates with greater environmental awareness, as extended exposure allows individuals to directly observe and experience pollution and related health risks. This finding is also consistent with other previous study highlighting that prolonged community exposure to environmental hazards increases awareness and concern (Adams et al., 2011). This underscores the role of lived experience in shaping perceptions of environmental quality and health risks.

Table 1: Socio-demographic characteristics of the respondents (N=186)

Variables	Category	Frequency (%)	Chi-square P-value	Variables	Category	Frequency (%)	Chi-square P-value
Sex	Male	157 (84.4)	> 0.05	Family size	<5	40 (21.6)	> 0.05
	Female	29 (15.6)			4–6	83 (44.6)	
	Total	186 (100)			7–9	51 (27.4)	
Age	<20	13 (7.0)	< 0.05		>10	12 (6.4)	
	21–30	36 (19.4)			Total	186 (100)	
	31–40	70 (37.6)		Education level	Uneducated	22 (11.8)	> 0.05
	41–50	35 (18.8)			Primary school	34 (18.3)	
	51–60	24 (12.9)			Secondary school	69 (37.1)	
	Total	186 (100)			Diploma	38 (20.4)	
Marital status	Married	143 (76.9)	> 0.05		Bachelor degree and above	23 (12.4)	

Single	28 (15.1)		Total	186 (100)	
Divorced	15 (8.0)	Living duration	<5 years	17 (9.1)	< 0.05
Total	186 (100)		11–15	45 (24.2)	
			16–20	57 (30.7)	
			21–25	23 (12.4)	
			>25	9 (4.8)	
			Total	186 (100)	

Source: Own survey (2022)

This study revealed that both age and living duration significantly influenced residents' awareness of the environmental and health impacts of abattoir waste. In contrast, factors such as sex, educational level, marital status, and family size showed no significant association with awareness. These findings suggest that personal experience and long-term exposure play a more critical role in shaping understanding of abattoir waste issues than demographic characteristics. Therefore, targeted environmental education and policy interventions should focus on engaging different age groups and long-term residents to effectively raise public awareness and promote sustainable abattoir waste management practices.

3.3. Environmental and Health Problems Faced by Respondents Living Around the Abattoir

Table 2 presents the respondents' ratings of various environmental and health impacts associated with the abattoir, including health issues, air pollution, noise pollution, water pollution, pathogen exposure, and aesthetic degradation. All these impact variables showed statistically significant associations with the distance of respondents' residences from the abattoir ($p < 0.05$).

The operations of abattoirs generate large quantities of organic waste, leading to complex and multidimensional health and environmental risks for nearby communities. These risks may manifest directly, such as through exposure to airborne pollutants and pathogens, or indirectly, through contamination of surface and groundwater sources and overall degradation of air quality as it is investigated by Dada et al. (2021)**.**This is also similar with the findings of Bello and Oyedemi (2009) who declared that residents living in close proximity to abattoirs are particularly vulnerable to reduced air and water quality, especially in the absence of effective waste disposal and treatment systems

Table 2: Cross-tabulation of environmental and health impacts by distance of house from abattoir site

Variable	Impact level	Distance of house from the abattoir site				Chi-square
		<500m	501 – 1000m	>1001m	Total	P value

Health	Low	0	22(35.48)	24(38.71)	46 (24.73)	0.01
impact	Moderate	18(29.03)	26(41.94)	38(61.29)	82(44.09)	
	High	44(70.97)	14(22.58)	0	58(31.18)	
Air	Low	0	0	0	0	0.00
pollution	Moderate	0	10(16.13)	40(64.52)	50(26.88)	
impact	High	62(100)	52(83.87)	22(35.48)	136	
Noise	Low	7(11.29)	48(77.42)	36(58.06)	91(48.92)	0.00
pollution	Moderate	38(61.29)	13(20.97)	26(41.94)	77(41.40)	
impact	High	17(27.42)	1(1.61)	0	18(9.68)	
Water	Low	25(40.32)	58(93.55)	32(51.61)	115(61.83)	0.04
pollution	Moderate	34(54.84)	4(6.45)	30(48.39)	68(36.56)	
impact	High	3(4.84)	0	0	3(1.61)	
Pathogen	Low	5(8.06)	41(66.13)	62(100)	108(58.07)	0.00
impact	Moderate	45(72.58)	21(33.87)	0	66(33.87)	
	high	12(19.36)	0	0	12(6.45)	
Aesthetic	Low	2(3.22)	27(43.55)	28(45.16)	57(30.64)	0.03
value impact	Moderate	34(54.84)	32(51.61)	31(50.00)	97(52.15)	
	High	26(41.94)	3(4.84)	3(4.84)	32(51.61)	

Notes: P-values < 0.05 indicate statistically significant differences across groups

3.3.1. Environmental Impacts

3.3.1.1. Air Pollution Impact

In this study, air pollution refers primarily to the emission of unpleasant odors from the abattoir. Respondents assessed the severity of the odor based on a scale explained by the researchers, following criteria adapted from Dada et al. (2021)**.** The results show that all households within a 500-meter radius reported experiencing a high level of odor impact (100%). Among those living between 501 and 1000 meters, 83.87% reported a high impact, while 16.13% reported moderate impact. For residents beyond 1001 meters, 64.52% indicated moderate odor impact and 35.48% reported a high impact (Table 2).

These findings clearly demonstrate that air pollution, as measured by odor intensity, is most severe in close proximity to the abattoir and decreases with increasing distance from the site. This pattern is consistent with prior studies; for example, Olawuni et al. (2017) reported that residents living within 200 meters of abattoirs experienced the highest levels of foul odors. Similarly, Abdullahi et al. (2015)

documented significant air quality contamination in communities near abattoir operations. Singh et al. (2014) further highlighted the impact of abattoir odors on residents' quality of life, noting that strong smells often forced individuals to stay indoors.

3.3.1.2. Noise Pollution Impact

In this study, noise pollution refers to unwanted sound disturbances primarily caused by scavenging animals such as hyenas at night and vultures, eagles, and dogs during the day, which gather around the abattoir to feed on waste. Residents were informed on how to assess noise levels categorized as low, moderate, or high based on guidelines adapted from Dada et al. (2021) before responding.

Among households within 500 meters of the abattoir, 27.42% reported experiencing high noise impact, 61.29% moderate impact, and 11.29% low impact. For those living between 501 and 1000 meters, most respondents (77.42%) reported low noise impact, 20.97% moderate, and only 1.61% high impact. Residents beyond 1001 meters primarily reported low (58.06%) and moderate (41.94%) noise impact, with no reports of high noise disturbance (Table 2).

These findings confirm that noise pollution levels significantly decrease as the distance from the abattoir increases. This pattern is consistent with Ochieng (2023), who attributed noise pollution near abattoirs to scavenging animals and reported similar disturbances in communities living nearby.

The results emphasize that noise generated by scavenging wildlife around abattoir sites is a notable environmental concern for nearby residents, particularly those living within close proximity to the facility.

3.3.1.3. Water Pollution Impact

The study found that water pollution impact varied significantly with distance from the abattoir. Among respondents living within 500 meters, 54.84% reported moderate water pollution impact, 40.32% low impact, and 4.84% high impact. For households between 501 and 1000 meters, most (93.55%) reported low impact, with only 6.45% indicating moderate impact. Those beyond 1001 meters reported low (51.61%) and moderate (48.39%) water pollution effects (Table 2).

Residents within the 500-meter radius reported serious contamination of groundwater sources such as wells, and surface waters including the Wuseta River, particularly during rainy seasons due to runoff. This contamination was identifiable by changes in water color and foul odors. Key informants said that

both people and animals use these water sources for drinking and washing, resulting in significant health and environmental problems. Although rainfall may appear to dilute contaminants, key informants emphasized that abattoir waste decomposes rapidly and disperses extensively, spreading pollution across both surface and groundwater.

These findings are consistent with prior research indicating severe water pollution near abattoirs. Elemile et al. (2019) reported contamination of shallow wells and streams that extended to groundwater sources. Adio et al. (2014) also documented both surface and underground water pollution around abattoir sites. Ojekunle and Lateef (2017)found that 58% of households experienced well water contamination due to abattoir waste. This study reinforces that poor abattoir waste management leads to significant environmental and public health risks through water contamination, particularly within close proximity to the abattoir.

3.3.1.4. Aesthetic Value Impact

Aesthetic degradation refers to the loss of attractiveness and overall visual appeal of a living environment, which can also lead to economic decline in affected areas. In this study, households within a 500-meter radius of the abattoir reported significant aesthetic problems primarily due to the emission of unpleasant odors from abattoir waste. Among the households living within 500 meters, 41.94% indicated a high impact, 54.84% moderate, and only 3.22% low impact. For those living 501-1000 meters away, 51.61% reported moderate impact, 43.55% low impact, and 4.84% high impact. Similarly, households beyond 1001 meters reported 50% moderate impact, 45.16% low impact, and 4.84% high impact (Table 2).

Key informants highlighted that beyond health and environmental effects, the abattoir waste also causes economic challenges. Rental prices for dormitories and property values have reportedly dropped by half compared to other parts of Debre Markos town. Additionally, households are unable to operate poultry farms due to predatory birds like eagles and vultures attracted to the abattoir site.

Field observations revealed that stray dogs often carry abattoir remains, such as heads, legs, skins, and intestines, around the neighborhood, further contributing to the area's unpleasantness. The combined impact of air, water, and soil pollution from improper waste management results in a significant decline in the area’s aesthetic value. Consequently, the abattoir site is perceived as unattractive and uncomfortable, falling short of United Nations recommendations for abattoir locations suitable for residential proximity (Officha et al., 2018).

These findings are consistent with Ochieng (2023), who documented aesthetic degradation due to poor abattoir waste disposal practices. The presence of waste materials and scavenging animals contributes to a degraded environment, reducing both quality of life and economic value in nearby communities.

3.3.2. Health/Pathogen Impact

Households living within a 500-meter radius of the abattoir reported substantial health impacts, with 70.97% indicating high impact and 29.03% moderate impact. Those residing 501-1000 meters from the site experienced a mix of impacts: 35.48% low, 41.94% moderate, and 22.58% high. Meanwhile, residents beyond 1001 meters mostly reported low (38.71%) to moderate (61.29%) health effects (Table 2).

The study identified pathogens broadly as disease-causing organisms, including flies, insects, and rats that are prevalent in the area and pose significant health hazards to the community. Within the 500-meter radius, households reported the presence of disease vectors at varying levels: 19.36% high impact, 72.58% moderate, and 8.06% low. In contrast, those between 501-1000 meters reported predominantly low (66.13%) and moderate (33.87%) vector impacts, while beyond 1001 meters, only low impact was reported (Table 2).

These findings align with previous research by Singh et al. (2014), which similarly demonstrated an inverse relationship between health risks and distance from abattoirs. Olawuni et al. (2017) also emphasized the role of abattoir waste in attracting vectors such as flies and rodents, thereby increasing pathogen-related health problems in nearby communities to abattoir.

Analysis of Variance across Different Groups Related to Environmental and Health Impact

The study found statistically significant differences in the environmental and health impact ratings among the three distance-based groups, with all variables showing p-values less than 0.001 (Table 3). This indicates that the distance from the abattoir strongly influences the severity of perceived impacts.

These results are consistent with the findings of Bello and Oyedemi (2009)**,** who emphasized that proximity to an abattoir, along with factors such as wind direction, physical barriers, and the amount of time residents spend at home, significantly affect the level of health risks experienced by households.

Table 3: Analysis of variance (ANOVA) across groups related to environmental impact

Variables		Sum of Squares	Df	Mean Square	F	Sig.
Health impact	Between Groups	40.774	2	20.387	59.740	<0.001
	Within Groups	62.452	183	.341		
	Total	103.226	185			
Air pollution impact	Between Groups	13.978	2	6.989	56.643	<0.001
	Within Groups	22.581	183	.123		
	Total	36.559	185			
Noise pollution impact	Between Groups	29.495	2	14.747	53.068	<0.001
	Within Groups	50.855	183	.278		
	Total	80.349	185			
Water pollution impact	Between Groups	11.140	2	5.570	25.858	<0.001
	Within Groups	39.419	183	.215		
	Total	50.559	185			
Pathogen impact	Between Groups	40.355	2	20.177	122.686	<0.001
	Within Groups	30.097	183	.164		
	Total	70.452	185			
Aesthetic value impact	Between Groups	25.301	2	12.651	38.368	<0.001
	Within Groups	60.339	183	.330		
	Total	85.640	185			

Note: Df represents Degrees of Freedom; F(**F-value)** is the test statistic for ANOVA and **Sig.** stands for **"Significance"** level, which refers to the **p-value** obtained from the **ANOVA (Analysis of Variance)** test.

Variation in the Severity of Environmental and Health Impacts

The severity of health impacts, as well as air, noise, and water pollution, pathogen presence, and aesthetic degradation, was significantly higher among households living within a 500-meter radius of the abattoir compared to those residing 501–1000 meters and beyond 1001 meters (Table 4). For instance, health-related issues were markedly more serious for residents closest to the abattoir, highlighting a clear gradient of impact severity based on proximity.

Table 4: Multiple compilation of descriptive statistics across groups of the population

Dependent Variable	distance of the house from the abattoir	distance of the house from the abattoir	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Health impact	<500 m	501-100 m	.839*	.105	.000	.63	1.05
		>1001 m	1.097*	.105	.000	.89	1.30

	501-1000 m	<500 m	-.839*	.105	.000	-1.05	-.63
		>1001 m	.258*	.105	.015	.05	.47
	>1001 m	<500 m	-1.097*	.105	.000	-1.30	-.89
		501-100 m	-.258*	.105	.015	-.47	-.05
Air pollution impact	<500 m	501-100 m	.161*	.063	.011	.04	.29
		>1001 m	.645*	.063	.000	.52	.77
	501-1000 m	<500 m	-.161*	.063	.011	-.29	-.04
		>1001 m	.484*	.063	.000	.36	.61
	>1001 m	<500 m	-.645*	.063	.000	-.77	-.52
		501-100 m	-.484*	.063	.000	-.61	-.36
Noise pollution impact	<500 m	501-100 m	.919*	.095	.000	.73	1.11
		>1001 m	.742*	.095	.000	.56	.93
	501-1000 m	<500 m	-.919*	.095	.000	-1.11	-.73
		>1001 m	-.177	.095	.063	-.36	.01
	>1001 m	<500 m	-.742*	.095	.000	-.93	-.56
		501-100 m	.177	.095	.063	-.01	.36
Water pollution	<500 m	501-100 m	.581*	.083	.000	.42	.75
		>1001 m	.161	.083	.055	.00	.33
	501-1000 m	<500 m	-.581*	.083	.000	-.75	-.42
		>1001 m	-.419*	.083	.000	-.58	-.25
	>1001 m	<500 m	-.161	.083	.055	-.33	.00
		501-100 m	.419*	.083	.000	.25	.58
Pathogen impact	<500 m	501-100 m	.774*	.073	.000	.63	.92
		>1001 m	1.113*	.073	.000	.97	1.26
	501-1000 m	<500 m	-.774*	.073	.000	-.92	-.63
		>1001 m	.339*	.073	.000	.20	.48
	>1001 m	<500 m	-1.113*	.073	.000	-1.26	-.97
		501-100 m	-.339*	.073	.000	-.48	-.20
Aesthetic value impact	<500 m	501-100 m	.774*	.103	.000	.57	.98
		>1001 m	.790*	.103	.000	.59	.99
	501-1000 m	<500 m	-.774*	.103	.000	-.98	-.57
		>1001 m	.016	.103	.876	-.19	.22
	>1001 m	<500 m	-.790*	.103	.000	-.99	-.59
		501-100 m	-.016	.103	.876	-.22	.19

*. The mean difference is significant at 0.05 level of confident interval.

3.3.2.1. Impact of Abattoir Waste on Household Health

In this study, 64% of households across the three distance strata reported that abattoir waste had caused health illnesses within their families, while 36% indicated no such health effects (Table 5). This highlights the significant health risks posed by abattoir operations, which generate large amounts of organic waste that can directly and indirectly affect residents' health through contamination of surface and groundwater sources and deterioration of air quality.

These findings are consistent with prior research. Ochieng (2023) also emphasize the complex health hazards and environmental pollution linked to abattoir waste. Similarly, Bello and Oyedemi (2009) reported that communities living near abattoirs often face poor air and water quality, especially where waste disposal systems are inadequate, reinforcing the connection between proximity to abattoirs and increased health risks.

Table 5: Health illness of households in the family

Health illness in the family	Frequency	Percent
Yes	119	64.0
No	67	36.0
Total	186	100.0

Source: own survey (2022)

3.3.2.2. Association between Family Health Illness and Distance from the Abattoir

The study found a clear association between the proximity of households to the abattoir and the occurrence of health illnesses in their families. Among households within a 500-meter radius, 79.03% (49 respondents) reported health illnesses attributed to abattoir waste, while 20.97% (13 respondents) reported no such illness. For those living between 501 and 1000 meters, 67.74% (42 respondents) reported health issues, and 32.26% (20 respondents) did not. In contrast, only 45.16% (28 respondents) of households beyond 1001 meters reported health illnesses, while 54.84% (34 respondents) reported none (Figure 2).

These findings indicate that health illnesses related to abattoir waste decrease as distance from the abattoir increases, with those living closest being the most affected. This aligns with Ochieng (2023), who reported that many diseases affecting households were strongly linked to exposure to abattoir waste.

3.3.2.3. Association of Types of Diseases and Distance from the Abattoir

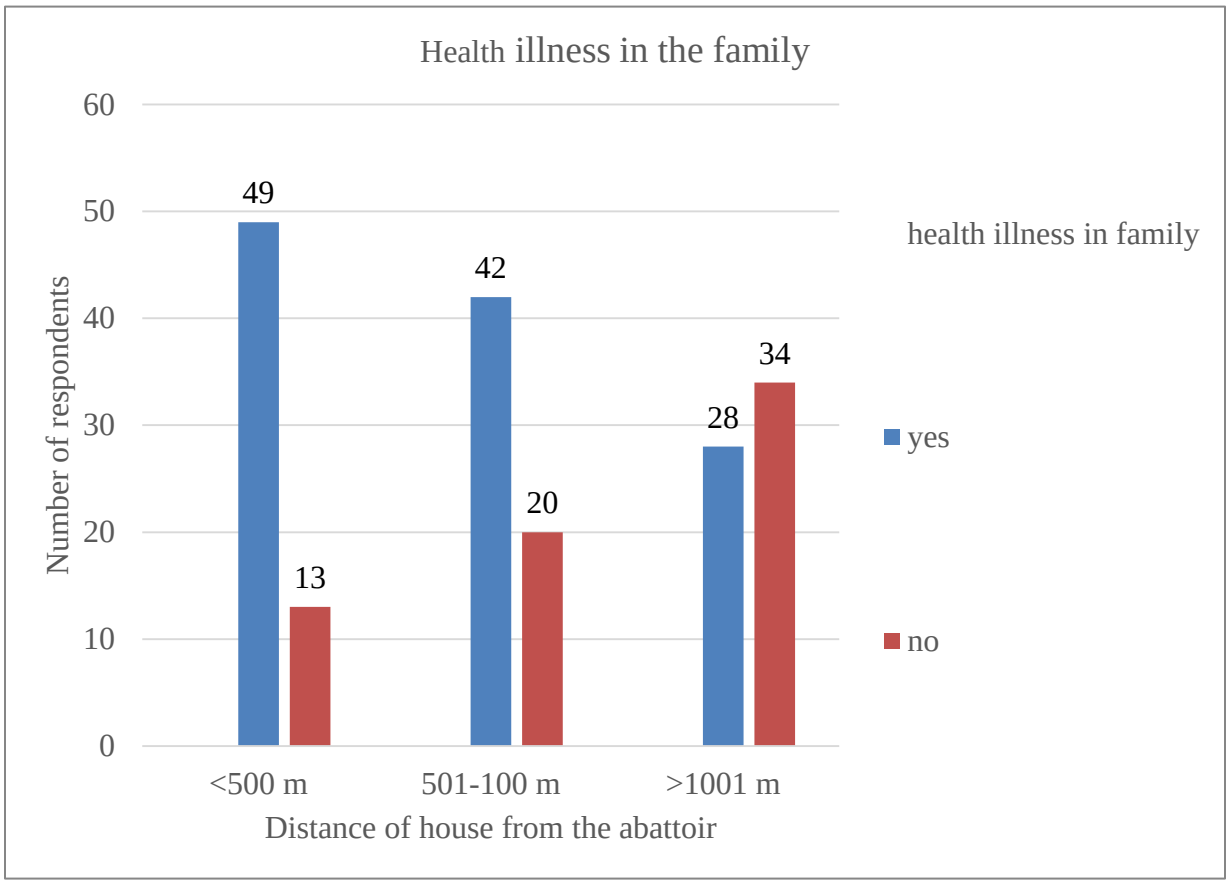

Figure 2: Health illness in the family and distance from the abattoir

The study revealed varying frequencies of diseases among households at different distances from the abattoir. Within a 500-meter radius, respiratory diseases and cholera were reported 30 and 10 times, respectively. For residents living between 501 and 1000 meters, these cases decreased to 27 (respiratory diseases) and 5 (cholera). Beyond 1001 meters, the frequencies further declined to 19 and 2, respectively (Figure 3). This trend clearly indicates that the prevalence of these diseases diminishes as the distance from the abattoir increases. Key informants identified respiratory diseases, cholera, eye infections, and typhoid as the major health concerns in the community, with respiratory diseases being the most frequent. These findings align with Abdullahi et al. (2015), who reported that respiratory illnesses such as common colds and asthma are among the most prevalent diseases linked to abattoir waste exposure.

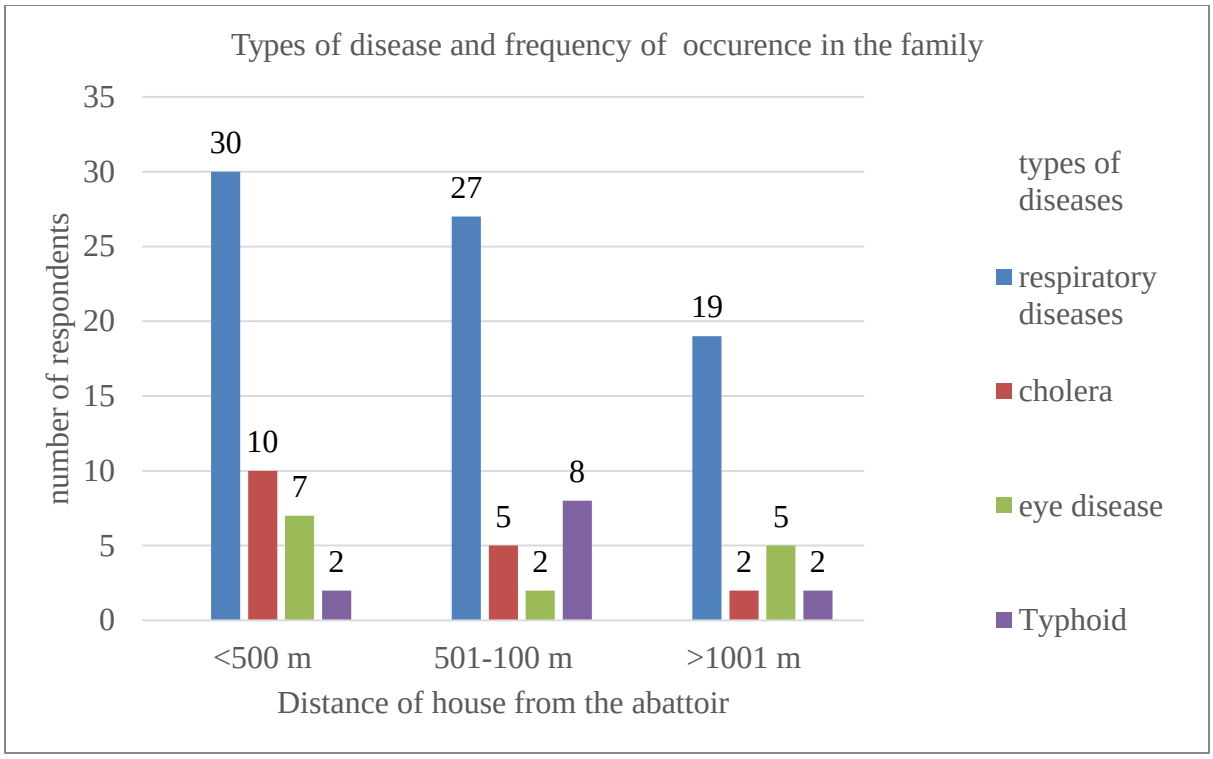

Figure 3: Disease frequency and distance from the abattoir

4. Conclusions

This study investigated the environmental and health problems caused by improper waste management at the Debre Markos municipality abattoir. The results highlight significant impacts on air quality, noise, water, aesthetics, and public health, especially among residents living close to the abattoir. A majority of households reported illnesses such as respiratory problems, typhoid, cholera, and eye diseases, with risks increasing the nearer they lived to the facility.

The current abattoir waste management system is inadequate, resulting in pollution and health hazards. To mitigate these risks, the following actions are recommended:

- Utilize abattoir waste efficiently, such as using condemned meat parts for animal feed, processing blood for poultry feed, composting rumen contents, and repurposing horns for crafts.
- Relocate the abattoir away from residential areas to minimize environmental and health impacts.
- Implement proper waste management practices and adopt sustainable solutions.
- Explore biogas technology to treat waste, producing energy and bio-fertilizer.
- Strengthen municipal regulation to control illegal slaughtering activities.

- Conduct further research on the influence of seasonal changes and wind direction on waste impact in the area.

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Declaration of Conflict of Interest

The authors declare no conflicts of interest

Authors' Contributions

Kiros Getachew and Netsanet Asmare contributed equally to the conceptualization, methodology development, data collection, and analysis. They facilitated the data collection process, entered the information into EXCEL and SPSS for analysis, wrote the manuscript, and handled feedback from reviewers, including editing the paper.

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Appendix (photos taken by researchers during data collection, 2022)

Photo 1: Slaughtering house of the abattoir

Photo 2: Liquid waste discharged from the slaughtering house

Photo 3: Bone waste from the abattoir site

Photo 4: Cattle restraining area until inspection

Photo 5: Heap of rumen contents waste in the abattoir site

Photo 6: Liquid waste disposal pipeline

Photo 7: Improperly disposed of legs of slaughtered cattle