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ENVIRONMENTAL AND HEALTH IMPACTS OF WASTE THROUGH A ONE HEALTH LENS IN THE FREE STATE PROVINCE

Motaung MA[1], Makhoahle PM[2*]

[1]Central University of Technology Free State, South Africa
[2]Faculty of Health and Environment Sciences Center for Quality of Health and Living

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Corresponding Author: Makhoahle PM
(pmakhoahle@cut.ac.za)

ABSTRACT

In South Africa, the waste management sector is supported by progressive national policies; however, significant implementation challenges persist at provincial and municipal levels. This study assessed residents' perceptions of environmental, health, and social risks affecting livelihoods and developed a Digitised Community Awareness and Self-Monitoring Tool (DCASMT) using a One Health approach. Findings showed that most landfill sites in the Free State operate below Department of Forestry, Fisheries and the Environment (DFFE) standards, with widespread open burning, leachate seepage, and vector proliferation. Inadequate fencing and monitoring allowed children and domestic animals to scavenge at half of the sites. Waste pickers faced increased occupational risks due to insufficient personal protective equipment and a lack of health monitoring. Ecological impacts, including livestock illness and increased rodent and mosquito infestations, highlighted risks to animal and environmental health. The study demonstrates how weak waste governance drives interconnected human, animal, and environmental health risks and proposes the DCASMT as a participatory tool for real-time monitoring, community reporting, and intersectoral coordination.

KEYWORDS: solid waste, landfills, pollution, marginalised communities, public health, environmental health, animal health, One Health, DCASMT concept

1 INTRODUCTION

In South Africa, the waste management sector is characterised by the presence of progressive national policy frameworks. Yet, it continues to face consistent implementation difficulties at both provincial and municipal levels (Department of Environment Forestry and Fisheries[DEFF], 2020). Section 24 of the Constitution of the Republic of South Africa (Act 106 of 1996), found in the Bill of Rights, guarantees the right to an environment that is not harmful to health or well-being, and mandates environmental protection for present and future generations. This protection is to be achieved through reasonable legislative and other measures that prevent pollution, promote conservation, and ensure sustainable development (RSA, 1996). The NEMA: Waste Act (Act 59 of 2008) provides a legal basis for an integrated policy framework for the environment, yet its effectiveness varies across provinces due to differences in institutional capacity, resource allocation, and enforcement (Department of Environmental Affairs [DEA], 2012; Polasi et al., 2020). The unequal distribution of waste management services in South Africa, particularly in the Free State, raises concerns about restoration, environmental justice, and social justice, particularly for low-income and historically marginalised communities (Rodseth et al., 2020; Kalina et al., 2024), including those working on and living in the vicinity of landfills.

In recent years, the integration of emerging technologies, particularly artificial intelligence (AI), has significantly enhanced countries' capacity to forecast municipal solid waste (MSW) generation and inform more effective planning and budget allocation strategies (Fan et al., 2025). Even in contexts where direct measurement tools and consistent records of waste generation are lacking, estimates are typically derived from demographic trends and economic activity at the municipal level. Industrial waste, in contrast, is frequently approximated based on production data, especially in cases where waste-related figures are sensitive, confidential, or inaccessible due to permit restrictions (DEA, 2012; Sadan and de Kock (2021) highlight that South Africa's waste data remains largely unreliable due to inconsistent reporting by municipalities and waste operators through the South African Waste Information System (SAWIS). Nonetheless, during a parliamentary portfolio committee briefing held on 15 February 2022, the DFFE estimated that South Africa generates approximately 107.7 million tonnes of waste annually. Alarmingly, about 92.7% of hazardous waste and 65% of general waste are still disposed of in landfills (Parliamentary Monitoring Group, 2022).

The Free State has 73 landfill sites, whose capacities are already stretched and are operated like dumpsites (Roberts 2013; AfriForum, 2021; The Green Guardian, 2023). Even though MSW services are mostly underpriced, residents and businesses fail to pay and have a direct impact on a municipality's budget and ability to render services or improve infrastructure (Polasi et al., 2021). According to the latest landfill audit of 153 landfills by AfriForum, it was identified that only 27 (14.3%) sites met 80% or above of the minimum requirement audit, and the worst-performing provinces were the Free State and Northern Cape. The report further revealed that none of the landfill sites in the Free State passed the audit for compliance with the minimum requirement (AfriForum, 2021; Burger, 2024). Due to the lack of a hazardous landfill site in the Free State, e-waste and healthcare risk waste are disposed of at general waste landfill sites (MMM, 2016). There is a paucity in the scientific literature investigating the impacts on health and the environment of municipal landfill sites in the Free State and on sustainable solutions relevant and appropriate for all South African communities, including the marginalised groups hence the study seeks to assess the perception of residents on the environmental, health, and social risk factors affecting their livelihood and develop a digitised community awareness and self-monitoring tool aimed at minimising environmental exposure and health implications for affected populations using the One Health approach. The available studies focus on respiratory health in those living near illegal dumpsites (Maluleka et al., 2025) and water quality, soil quality, and food security (Ololade et al.,2019; Mokhadi et al., 2020), and waste pickers' socio-economic context (Schenck et al., 2016). Most studies were based on the Mangaung Metropolitan Municipality.

1.1. Integrated conceptual framework

The One Health principle is grounded in the recognition that the health of humans, animals, plants and the environment is interdependent and collectively influences the overall balance of the biosphere (De Oliveira & Gebreyes, 2022). While the One Health approach originates from the control of zoonotic diseases and antimicrobial resistance (AMR) mandates, it has ventured beyond the scope and extended to other meaningful environmental and pollution-related health threats, including waste exposure (Mumford et al., 2023). It has been widely adopted and recognised to handle complex issues by

the four collaborative partners, namely World Health Organisation (WHO), Food and Agriculture Association (FAO), World Organization for Animal Health (OIE) and United Nations Environment Program (UNEP), which collaborate in addressing health threats and ensure sustainability across sectors (WHO, 2019; De Oliveira & Gebreyes, 2022; Mumford et al., 2023; Pepin et al., 2024). Landfills are complex environmental systems that pose interlinked risks to human, animal and ecosystem health (Njoku et al., 2019). Within the context of waste landfill impacts, the One Health approach emphasises that waste exposure can simultaneously affect human, animal, and environmental health (Gebrekidan et al., 2024). In sub-Saharan Africa, zoonotic infections account for approximately 26% of the years of healthy life lost to infectious diseases. This burden is projected to increase as growing human populations encroach on wildlife habitats and ecosystem services deteriorate due to the conversion of forests into agricultural and grazing land (Henley et al., 2021). In relation to this study, the health impact, including the acquisition of zoonotic diseases, worsens with proximity to waste.

Although the One Health approach is often presented as inclusive, in practice it tends to prioritise dominant scientific perspectives related to health, thereby marginalising local communities and overlooking critical disciplines such as the social, psychological and economic sciences. There is growing recognition that the marginalisation of individuals and groups based on race, gender, socioeconomic status, education and occupation profoundly influences their health and wellbeing. Addressing these inequities requires the proactive and sustained inclusion of marginalised communities and their perspectives (Tomita & Slotow, 2020; Mabunda, 2023; Mumford et al., 2023). In addition to the well-established triad of human, animal and environmental health, the One Health conceptual framework should also encompass technical, technological and infrastructural factors, as well as socioeconomic and governance dimensions, to create a more contextually inclusive and responsive structure. Within this framework, One Health-based surveillance and response systems integrate human, animal and environmental health data through near real-time collection, analysis, and feedback to enhance the precision and long-term sustainability of public-health decision-making (Li et al., 2025).

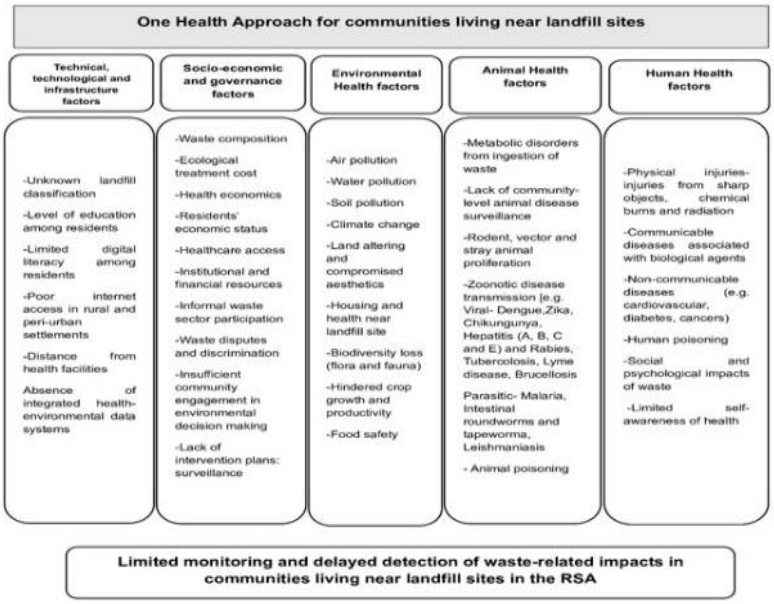

Figure 1.1: Conceptual frame for people living near landfill sites using the One Health Approach

2. METHODOLOGY

2.1. Research approach and design

This study is purely non-experimental and descriptive in nature. Non-experimental quantitative design is suitable for describing the phenomena, exploring and explaining the relationships between variables (Taherdoost, 2022). Due to the frequent changes that happen at landfill sites influenced by municipal implementation, politics and sometimes disasters, several other authors who conducted their studies at landfill sites with residents and/or waste pickers, also opted for the cross-sectional method in their studies (Kistan et al., 2020; Nambuli, 2021; Oghuehi et al., 2022).

2.2. Description of the study areas and selection criteria

The Free State is South Africa's third-largest province by land area, covering approximately 129 480 km², with a population of about 2.8 million distributed across four district municipalities, namely, Xhariep, Lejweleputswa, Fezile Dabi, Thabo Mofutsanyana, and the Mangaung Metropolitan Municipality (CSIR, 2024), as shown in Figure 1. The province faces numerous developmental challenges, including widespread poverty, high HIV/AIDS prevalence, skills shortages, migration of skilled people, and environmental degradation (Lejweleputswa District Municipality, 2017; COGTA, 2020; CSIR, 2020). Economically, the Free State ranks eighth in GDP contribution nationally, with its share declining from 0% in 2015 to -0.2% in 2019. Although agriculture occupies over 90% of the land, its economic contribution has declined, with an average of minus 5.5% annually between 2015 and 2020. Nonetheless, the sector remains important, contributing 12.1% to South Africa's gross agricultural income (Department of Economic, Small Business Development, Tourism and Environmental Affairs – Free State [DESTEA-FS], 2022). The study was situated in three district municipalities, namely Lejweleputswa, Fezile Dabi, and Thabo Mofutsanyana, and the nine local municipalities included in the study form a 60% and 45% representation of the parts of the Free State that were included in the study, respectively. The selection of the landfill sites for this study was based on proximity to human settlements and environmental resources and operational status, and activity level.

Figure 3.1: The administrative districts and municipalities in the Free State Province

2.3. Sampling techniques and size

Given the exploratory and descriptive nature of the study, a non-probability convenience sampling method was utilised to select participants (Udofia et al., 2017) living in the vicinity of landfill sites who were above the age of 18. The number of participants approached and asked to participate in the study was 185, while the actual number of participants who were willing to participate was 121.

2.4. Questionnaires and Checklists

Structured questionnaires were used to assess the knowledge and perceptions of residents. Due to the diversity of ethnic groups at the dumpsite, the questionnaires were distributed to the participants in their preferred language, which was either Sesotho, English, or Afrikaans. Section A included demographic data and socioeconomic data (age, gender, nationality, education, family size, household income, employment opportunities, involvement in waste-picking). Section B inquired about their environment and livelihood (access to water and ablution amenities, energy sources, sanitation conditions, rental value, and crime in the areas). Section C gathered information on the health aspects of the participants (injuries sustained, health history and symptoms, healthcare visitation frequency, hospitalisation, smoking lifestyle, and response to disasters in their areas). The questionnaire was a combination of closed-ended and open-ended questions with nominal, ordinal and Likert-scale options (Ampofo, 2020). To ensure the content validity, the questionnaires were peer-reviewed by the study promoters and qualified field experts, and adjustments were made based on their responses to improve clarity and suitability. The questionnaires were pre-tested among residents in five towns in the Free State to validate the content and identify any ambiguities. Feedback from the pre-testing was used to make necessary adjustments and improve reliability.

A structured checklist was used to evaluate the environmental conditions in the vicinity of disposal sites through observations. Characteristics of the landfill and the conditions of its proximate environment (human settlements and natural resources) were evaluated using a structured checklist. The checklist was adapted from the one developed by AfriForum and the Minimum Requirements for Waste Disposal by Landfill guidelines and modified to suit the objective (Department of Water Affairs and Forestry (DWAF), 1998; De Klerk, 2021). Checklists were used during or after the observations, depending on feasibility and acceptability, as people tend to change behaviour and practices when they know that they are observed (Hawthorne effect) (Busetto et al., 2020), irrespective of whether the situation portrayed negative or positive outcomes. When permitted to do so, pictures

of the environmental conditions were taken, excluding human subjects.

2.5. Analysis

Numerical and nominal data collected through the questionnaire and checklist were coded and captured using the Mentimeter application. A biostatistician performed the analyses using IBM SPSS Version 29. Descriptive statistics summarised categorical and numerical data.

2.6. Ethical considerations

Ethical clearance was attained from the Health Sciences Research Ethics Committee at the University of the Free State (reference number: UFS-HSD2023/1726/0110), and approval was subsequently granted. Permission to conduct the study in the Free State was also obtained through the National Health Databases application system of the Free State Department of Health, with the approval reference number of FS2023/12/006.

3. RESULTS

3.1. Description of landfill site conditions under study

Table 1: Description of landfill sites' conditions and management in alignment with the DWAF minimum requirements of a landfill site

Minimum Requirements	Frequency and percentage of cases		
	Yes	Partially	No
1. Signs erected in the appropriate official languages indicating distance and route leading to the landfill site	6 (33.3%)		12 (66.7)
2. The route leading to the site allows two-way traffic	7 (38.9%)		11 (61.1%)
3. Information boards at the gate indicating what type of waste can be disposed of and site operating hours	6 (33.3%)		12 (66.7%)
4. There is 24-hour security personnel for control	2 (11.1%)		
The landfill site has a fence	4 (22.2%)	5 (27.8%)	9 (50%)
5. (a) Fence is 1.8 m high (where fencing is available, *n*=9)	4 (22.2%)	5 (27.8%)	
6. (b) Type of fence used (where fencing is available, *n*=9) (i) Barbed wire fence	1 (5.6%)		
(ii) Precast concrete panel		4 (22.2%)	
(iii) Galvanised steel (clear view) fence	2 (11.1%)		
(iv) Diamond link wire mesh with razor wire topping	1 (11.1%)	1 (11.1%)	
7. Vehicles are inspected upon arrival to confirm the type of waste entering the site		5 (27.8%)	13 (72.2%)
8. There are offices and ablution facilities	3 (16.7%)	2 (11.1%)	13 (72.2%)
9. There is clean water access on site	5 (27.8%)		13 (72.2%)
10. There is electricity	4 (22.2%)		
11.There is a weighbridge on site		2 (11.1%)	
12. Landfill gas monitoring equipment is installed			18 (100%)
13. There is a retention dam for leachate control	1 (5.6%)		17 (94.4%)
14. There is an emergency assembly and emergency control equipment on site (e.g. fire hydrants)			
15. Staff members wear personal protective equipment (gloves, masks, overalls, eye shields)		6 (33.3%)	12 (66.7%)
16. There is a clear waste operating management plan	2 (11.1%)		16 (88.9%)
17. The emergency evacuation plans are available onsite	2 (11.1%)	1 (5.6%)	15 (83.3%
18. Waste burning does not occur onsite			18 (100%)
19. Litter is contained inside the landfill			18 (100%)
20.Leachate is not trickling/flooding	9 (50%)		9 (50%)
21. The active landfill area has minimal birds, insects, and rodents			18 (100%)
22. Noise is controlled		5 (27.8%)	13 (72.2%)
23. Dust is controlled	1 (5.6%)		17 (94.4%)
24. Odours are controlled			18 (100%)
25.Medical waste is prohibited on-site	4 (22.2)		14 (77.8%)
26. Animal waste (carcass, stomach contents, bones, and blood) is prohibited on-site	2 (11.1%)		16 (88.9%)
27. Waste tyres are prohibited on-site			18 (100%)
28. E-waste is prohibited on-site			18 (100%)
29. There are waste pickers at the landfill	18 (100%)		
30. Recycling facilities are available on-site	3 (16.7%)		15 (83.3%)
31. Children are not present on-site	8 (44.4%)		10 (55.6%)
32. Domestic animals do not scavenge onsite			18 (100%)
33. No people are living on-site	7 (38.9%)		11 (61.1%)

Table 1 above presents the characteristic features of the landfill sites under study. The assessment revealed that half of the landfill sites lacked fencing and, where available at five sites (27.8%), they were

dilapidated fences resulting from vandalism and forced entry, or unsuitable for containing waste litter, as shown in Figure 3.1. Only four sites (22.2%) were fully fenced and properly maintained. Where fencing existed, it was typically 1.8 metres high, with cement palettes being the most preferred material, followed by galvanised steel and diamond wire mesh with razor-wire topping.

Figure 3.1: Precast concrete panel fencing vandalised in the Viljoenskroon landfill site

Basic staff facilities such as shelters, ablution blocks, and clean water were present at five sites, of which three (16.7%) were in good condition, and two (11.1%) were vandalised and left unusable. Vehicle registration and minor inspection at entry were recorded at five (27.8%) landfills, capturing information such as vehicle origin, time of entry, and registration details, though the contents of waste loads were not inspected.

Organised waste-picker associations are present and active at a few landfill sites, providing a degree of regulation and conflict resolution, including adherence to safety rules such as avoiding waste off-loader vehicles, minimising noise, and refraining from waste-burning practices. At sites with active staff supervision, vehicle speeds were limited to 20 km/h, reducing dust and noise, but at the majority of sites, this requirement was not complied with. However, only two sites (11.1%) had operational plans and emergency evacuation procedures available onsite, while 15 sites (83.3%) lacked such documentation.

Only three sites (16.7%) had formal recycling facilities with designated buildings, compactors and dedicated staff. These facilities either acted as intermediaries between waste pickers and buyers or directly purchased recyclable materials. Children and infants were observed at eight (44.4%) landfills, as shown in Figue 3.2 to 3.3, either participating in waste picking or accompanying parents, particularly where no security personnel were present to prohibit entry. These sites were overseen by contracted personnel or Extended Community Worker Programme (ECWP) employees appointed by local municipalities. While staff were equipped with personal protective equipment (PPE), compliance with safety practices was inconsistent. Waste pickers who formed part of the recognised association, such as the Waste Picker Association, had partial personal protective equipment, including overalls and reflectors, while waste pickers operating individually did not have any form of PPE.

Figure 3.2: School-age children were identified in the Bothaville landfill site

Figure 3.3: School-age children were identified in the Virginia landfill site

Infrastructure was generally poor: most sites had no weighbridges, and the two sites (11.1%) that did had non-functional equipment. Only three landfills had working machinery, such as bulldozers or excavators, typically to push waste to the sides to make way for incoming waste vehicles. One site operated a water tanker to suppress dust and odours by wetting the soil. No sites applied lime or had landfill gas collection or monitoring systems in place.

Medical waste, including discarded medicines, syringes, sanitary products, diapers, bandages and swabs, was observed in the majority of sites, mixed

with general waste, as shown in Figures 3.4 to 3.7. Workers and guards also recorded incidents involving deceased foetuses and fatalities among waste pickers, which were typically reported as natural deaths by authorities. Chemical waste, including aerosols, vehicle oils, and paint containers from households and workshops, as well as various industrial waste, was observed being disposed of in several landfill sites, as shown in Figures 3.8 to 3.9.

Figure 3.4: Discarded pills observed in the Theunissen landfill site identified in the Theunissen landfill site

Figure 3.5: Discarded pills observed in the Winburg landfill site

Figure 3.6: Injection needles and syringes

Figure 3.7: A Discarded Inhaler Was Observed In The Winburg Landfill Site

management of disposed waste, and limited monitoring at the entrances of most landfill sites, domestic animals, including cattle, pigs, goats and dogs, as well as wildlife, particularly birds and burrowing small mammals, were frequently observed scavenging for food and edible organic waste, and even inhabiting the landfill sites, as illustrated in Figures 3.10 to 3.12.

Figure 3.8: Industrial Waste And Residues Observed In The Harrismith Landfill Site

Figure 3.9: Aerosols are paint containers disposed of in bulk in the Vredefort landfill site

Figure 3.10: A Flock Of Birds (Seagulls) Were Noticed Gathering Fleshly Disposed Waste In The Sasolburg Landfill Site

Figure 3.11: Cattle were observed feeding on waste in the Pereng, Phuthaditjhaba landfill site

Figure 3.12: Pigs feeding on abattoir (bones and hides) waste were observed in Theunissen

Figure 3.13: A whole sheep carcass was decomposed openly in the Vredefort landfill site Tyres were observed at all landfills, and some were submerged in leachate, while others were burned, as shown in Figures 4.14 and 4.15. Although some efforts towards the Recycling and Economic Development Initiative of South Africa (REDISA) tyre collection were underway in other landfill sites, implementation remained limited. Leachate pools and leachate-filled trenches were present on approximately half of the sites, likely exacerbated by seasonal rainfall, as shown in Figure 3.11. Electronic waste (e-waste) was also received at all sites, often stripped for valuable metals by waste pickers on arrival before final disposal.

Annexure 3.14: Waste tyres and burnt tyre debris were identified in the Bothaville landfill site

Annexure 3.15: Tyre waste piles identified in the Harrismith landfill site

Open burning of waste was observed at all landfills, with visible signs of ongoing combustion. As a measure to reduce waste volumes, or 'clean' e-waste, which is a term used to describe the burning of plastic or fibre components to extract valuable metals like copper, waste was burned and had residues at all sites during site visitations. There are also unclear speculations about whether the burning may persist in relation to unmonitored landfill gas, as all sites were non-engineered and lacked gas monitoring equipment or simply due to human intervention.

Figure 3.14 above show some of the landfill sites that were burnt.

3.2. Perceived and lived experience of residents living proximate to landfills

Table 2: Impacts of landfills on the immediate environment, health, and livelihood

Level of agreement	Frequency	Valid Percentage (%)
Odours from the site are unbearable.		
Strongly disagree	5	4,1
Disagree	1	0,8
Neutral	15	12,4
Agree	6	5
Strongly agree	94	77,7
Total	121	100
Smoke fog from waste burning affects our daily chores.		
Strongly disagree	15	12,4
Disagree	12	9,9
Neutral	8	6,6
Agree	13	10,7
Strongly agree	73	60,3
Total	121	100
Local water sources are contaminated.		
Strongly disagree	35	28,9
Disagree	14	11,6
Neutral	27	22,3
Agree	9	7,4
Strongly agree	36	29,8
Total	121	100
Compromised environmental aesthetics (e.g. eyesore waste heaps, leachate, and smoke)		
Strongly disagree	23	19
Disagree	4	3,3
Neutral	7	5,8
Agree	11	9,1
Strongly agree	76	62,8
Total	121	100
There is an increase in road accidents due to the smoke fog.		
Strongly disagree	68	56,2
Disagree	18	14,9
Neutral	9	7,4
Agree	8	6,6
Strongly agree	18	14,9
Total	121	100
Loss of property or goods (e.g. housing, car) from uncontrolled fires		
Strongly disagree	58	47,9
Disagree	10	8,3
Neutral	7	5,8
Agree	7	5,8
Strongly agree	39	32,2
Total	121	100
Residents opt to sell their properties or move to other areas because of the unbearable living conditions.		
Strongly disagree	86	71,1
Disagree	17	14
Neutral	9	7,4
Agree	2	1,7
Strongly agree	7	5,8
Total	121	100
Rented tenants are not staying longer in their rentals, and the renting business is compromised.		
Strongly disagree	87	71,9
Disagree	19	15,7
Neutral	8	6,6
Agree	2	1,7
Strongly agree	5	4,1
Total	121	100
Lack/ loss of business (our businesses are not busy and flourishing)		
Strongly disagree	92	76
Disagree	15	12,4
Neutral	6	5
Agree	2	1,7
Strongly agree	6	5

Total	121	100
Flooding during storms (drains blocked with waste)		
Strongly disagree	49	40,5
Disagree	6	5
Neutral	14	11,6
Agree	12	9,9
Strongly agree	40	33,1
Total	121	100
Poor crop production		
Strongly disagree	67	55,4
Disagree	18	14,9
Neutral	12	9,9
Agree	8	6,6
Strongly agree	16	13,2
Total	121	100
High cases of chemical poisoning in children		
Strongly disagree	25	20,7
Disagree	6	5
Neutral	6	5
Agree	13	10,7
Strongly agree	71	58,7
Total	121	100
High (sudden) mortality rate in animals		
Strongly disagree	15	12,4
Disagree	1	0,8
Neutral	7	5,8
Agree	7	5,8
Strongly agree	91	75,2
Total	121	100
High vector infestation (e.g. mosquitoes, flies, cockroaches)		
Strongly disagree	8	6,6
Disagree	1	0,8
Neutral	1	0,8
Agree	3	2,5
Strongly agree	108	89,3
Total	121	100
High rodent infestation (e.g. rats, snakes)		
Strongly disagree	9	7,4
Disagree	1	0,8
Neutral	1	0,8
Agree	5	4,1
Strongly agree	105	86,8
Total	121	100
High cases of gender-based violence (e.g. rape, beatings)		
Strongly disagree	31	25,6
Disagree	7	5,8
Neutral	10	8,3
Agree	8	6,6
Strongly agree	65	53,7
Total	121	100
The area is noisy		
Strongly disagree	28	23,1
Disagree	20	16,5
Neutral	11	9,1
Agree	10	8,3
Strongly agree	52	43
Total	121	100
High crime rate (burglary, street robbery)		
Strongly disagree	22	18,2
Disagree	4	3,3
Neutral	6	5
Agree	11	9,1
Strongly agree	78	64,5
Total	121	100

The results in Table 11 indicate that most respondents strongly agreed that odours from the sites are unbearable (77.7%) and that smoke or fog from waste burning affected their daily activities

(60.3%). Additionally, 62.8% strongly agreed that environmental aesthetics have been compromised (e.g. unsightly waste heaps, leachate, and smoke), while 29.8% strongly agree that local water sources are contaminated.

Conversely, 56.2% of respondents strongly disagreed that smoke or fog has led to an increase in road accidents, and 47.9% strongly disagreed that uncontrolled fires have caused a loss of property or goods (e.g. housing, vehicles). The majority (71.1%) strongly disagreed that residents sell their properties or relocate due to unbearable living conditions. Similarly, they disagreed that there was a lack or loss of business. Regarding environmental hazards, only 40.5% and 55.4% of respondents strongly disagreed that they experienced flooding during storms and poor crop production, respectively.

In terms of health and safety, 58.7% of respondents strongly agreed that children experience high rates of chemical poisoning. Likewise, 75.2% strongly agreed that there had been sudden deaths among animals, as shown in Figure 3.16. A further 86.8% strongly agreed that rodent infestations (e.g. rats and snakes) were prevalent.

Figure 3.16: A sheep from a local community herd was found dead on the Paul Roux landfill site

4. DISCUSSION

4.1. Waste-related environmental and public health risks through a One Health lens

4.1.1 Environmental factors

Field observations revealed that the type of waste loads was not inspected upon arrival at landfill sites, leading to the indiscriminate disposal of various hazardous and non-hazardous waste streams. Medical waste, including discarded medicines, syringes, inhalers, sanitary products, diapers, bandages and swabs, was observed at most sites, often mixed with general waste. Similarly, chemical waste such as aerosols, vehicle oils and paint containers from households, workshops and small-scale industries were commonly disposed of together with domestic refuse. These findings highlight a lack of waste segregation at source and weak enforcement of regulatory controls.

In the Free State, the majority of landfill sites are neither engineered nor designed to accommodate hazardous waste (Afriforum, 2021). Even at the few sites equipped with synthetic liners, prolonged exposure to toxic substances can cause structural degradation, compromising containment integrity and increasing risks of soil and groundwater contamination (Alabi et al., 2023). Leachate pools and trenches were visible on approximately half of the observed sites, exacerbated by seasonal rainfall, and most residents believe their water sources are contaminated. Prior studies confirm that uncontrolled leachate discharge contributes significantly to water source contamination (Danthurebandara et al., 2013; Deffnika et al., 2021). At some sites, tyres and plastics were partially submerged in stagnant leachate pools, which could provide breeding habitats for disease vectors.

The unsafe co-disposal of healthcare and household hazardous waste reflects systemic governance and infrastructural weaknesses. Health-care risk waste (HCRW) is particularly concerning, as it is ranked second only to radioactive waste in terms of toxicity (WHO, 2008). Studies show that there is no accurate national estimate of the HCRW generated in South African households, largely due to ambiguous classification within the National Environmental Management: Waste Act (NEM: WA) and the absence of a clear national strategy for its management (RSA, 2008; Zithathile & Atangana, 2018a). This regulatory gap has resulted in unsafe disposal practices. For example, Magagula et al. (2022) found that unused medicines are often mixed with general household waste, while Berrian et al. (2016) report that 80% of caregivers in Mpumalanga disposed of used diapers by burning, burying, or dumping them in open spaces and rivers. Similarly, Made et al. (2021) observe that poor planning and mismanagement of hazardous waste such as batteries, medical waste and chemicals increase disease risks among waste pickers.

As a measure to reduce waste volumes or "clean" e-waste, open burning was observed at all sites. This practice, commonly used to extract valuable metals such as copper, involves burning plastic or fibre components, producing toxic residues and air pollutants. Similar trends were reported in Ghana, where 34% of waste pickers reported burning e-waste, 25% burning wires, and 10% removing wire

coatings as part of their routine activities, typically four days per week (Takyi et al., 2021). The burning of waste contributes to poor air quality, odour nuisance and greenhouse gas emissions. In the present study, 77.7% of respondents strongly agreed that odours from landfill sites were unbearable, and 60.3% indicated that smoke or fog from waste burning disrupted their daily activities. The unpleasant odours are primarily associated with hydrogen sulphide (H_2S), volatile organic compounds, and other sulphur-containing gases produced during waste decomposition (Danthurebandara et al., 2013; Njoku et al., 2019). The problem is compounded by the disposal of abattoir waste, as the Free State is South Africa's leading cattle-producing province, accounting for 11% of the national herd (Stats SA, 2020). These processes collectively contribute to greenhouse gas emissions and climate change. According to the Intergovernmental Panel on Climate Change (IPCC), the waste sector contributed approximately 5% of global greenhouse gas emissions in 2014, primarily from solid-waste disposal and wastewater treatment. South Africa ranked among the top 20 global carbon dioxide emitters in 2019 (European Union [EU], 2024).

The physical security and management of landfill sites were also found to be inadequate. Only five sites (27.8%) had fencing, most of which was vandalised or unsuitable for containing litter. Damaged or missing fences allow unauthorised access, including by criminals, and have reportedly facilitated illicit activities such as the disposal of human remains and aborted foetuses. These findings underscore the broader social risks associated with unmanaged landfill sites. Indeed, 64.5% of respondents strongly agreed that the surrounding community experiences high crime rates, echoing findings from Nigeria, where proximity to landfill sites was associated with increased crime and community dissatisfaction (Akinrogundeg et al., 2019).

Interestingly, despite these challenges, a majority of respondents (71.1%) strongly disagreed that residents sell their properties or relocate due to poor environmental conditions, while 76% disagreed that living near landfill sites leads to loss of business or rental income. These perceptions contrast with studies from the South Africa Lesotho and Ghana, where property values and rental demand declined near landfill sites (Du Preez et al., 2016; Ofori, 2021; Mokoka, 2022). This divergence may reflect a form of risk normalisation among low-income residents, who may prioritise affordability and proximity to income-generating opportunities, such as recycling, reported by 62% of participants, over environmental or health risks. The environmental health burden associated with these sites extends beyond visible pollution. A study by Bouwman et al. (2020) detected traces of pharmaceuticals and microplastics, including antiretroviral residues, in South African water resources. Although the concentrations were below harmful limits, prolonged exposure could contribute to the growing problem of antimicrobial resistance. Together, these findings reveal that inadequate waste governance, unsafe disposal practices, and environmental degradation interact to reinforce a cycle of health vulnerability and social inequity among communities living near landfill sites.

4.1.2 Animal factors

Domestic animals and wildlife, particularly birds and small burrowing species, were frequently observed scavenging for food and edible organic waste on landfill sites, including waste contaminated with human excreta from disposable nappies. Cattle herds were also seen grazing on litter-contaminated pastures in the vicinity of landfill sites in several towns. Approximately 75.2% of respondents strongly agreed that sudden deaths have occurred among animals grazing on or near these sites. Similarly, a study conducted in the Eastern Cape reported that 53.8% of residents had witnessed animals consuming litter, while 69% associated various animal health problems, such as pain, poor body condition, abdominal distension, abnormal respiration, and signs of dehydration or anorexia, and, in worst cases, sudden death with waste ingestion (Nongcula et al., 2020). Further investigations revealed that plastics, wire, nails, rope, bones, stones, cloth, hair and polybezoars were among the most common foreign materials recovered from slaughtered animals exposed to waste (Nongcula et al., 2020). The ingestion of such materials is highly detrimental, as animals can develop a range of environmental and infectious diseases, including clostridial infections such as blackleg, botulism, malignant oedema, red-water disease, enterotoxemia (types C and D), and tetanus conditions often associated with exposure to contaminated waste (TB Hub, 2020; Dejene, 2023; MSD Animal Health, 2022). Moreover, human faeces are well-recognised carriers of infectious and zoonotic pathogens. Faecal contamination not only poses immediate health risks to both animals and humans but also contributes to long-term environmental threats, notably the emergence and spread of antimicrobial resistance (AMR) (Deffnika et al., 2021; Kordecki et al., 2023).

Abattoir waste, including bones, hides, carcasses and blood, was detected at 16 landfill sites (88.9%),

originating primarily from local abattoirs and households. The presence of such waste provides food sources for rodents and other vectors, thereby facilitating their proliferation and increasing the risk of disease transmission. In several instances, whole animal carcasses, including those of sheep and chickens, were observed being openly disposed of at landfill sites. When animals die before reaching slaughterhouses, their carcasses are frequently discarded alongside general municipal waste, a practice that poses considerable environmental, biosecurity and public-health concerns (Clark, 2022). According to the Meat Safety Act (RSA, 2000), condemned materials must be disposed of through approved methods such as safe incineration, denaturing, or burial. These processes should include disinfection and the immediate covering of material at a depth of at least 60 cm below the ground surface and must occur at secure sites situated at least 100 m from water sources or public areas, with disposal authorised by the provincial executive officer and local government. In addition, such waste may be processed at sterilisation facilities under the National Environmental Management: Waste Act (RSA, 2008) and Schedule 3 of the Act, non-infectious animal carcasses, including those euthanised by veterinarians to prevent further suffering, are categorised as general or healthcare waste. Conversely, carcasses that are infectious or treated with veterinary pharmaceuticals are classified as hazardous waste and must be managed at authorised hazardous-waste facilities, as they are prohibited from disposal at ordinary landfill sites (RSA, 2008; EarthPet, 2021). Furthermore, the National Norms and Standards for the Disposal of Waste to Landfill designate non-infectious animal waste as moderate-risk waste (Type 2), which requires disposal at a Class B landfill facility and all infectious wastes to be treated at a hazardous-landfill site; yet there are no records of whether the animal waste was infectious or non-infectious due to the minor or little monitoring at sites.

Improper handling and disposal of abattoir and animal waste represent a significant environmental health hazard. These practices contribute to soil and water contamination, attract disease vectors, and increase the risk of zoonotic transmission between animals and humans. When combined with the widespread presence of decomposing organic matter and faecal contamination on landfill sites, such conditions create an ideal environment for the proliferation of pathogens and the development of antimicrobial resistance, thereby intensifying the public health burden in nearby communities. Consistent with these risks, 86.8% of respondents strongly agreed that rodent infestations, particularly rats and snakes, are prevalent near landfill sites, while3% strongly agreed that disease vectors are common in these areas. The majority of respondents (86%) identified house flies as a persistent household nuisance, followed by 82.6% who reported a proliferation of mosquitoes, especially during the warmer months, and 80.2% who expressed similar concerns about rats and mice. Other nuisance and vector species frequently mentioned included ants, cockroaches, snakes, stray dogs and cats, bugs, and lice. It should be noted that the data were collected during a relatively short period spanning the warm peak season from December to March (summer to early autumn). As such, the findings may not fully capture seasonal variations in vector and rodent activity. Environmental factors such as temperature, humidity and wind direction fluctuate across seasons and may influence the breeding and nesting behaviour of these species. Spring and summer are typically recognised as peak breeding periods for rodents and vectors due to the abundance of vegetation, natural food sources (such as seeds and insects), and rainwater that provide suitable nesting and breeding conditions. These observations highlight the importance of conducting longitudinal studies to assess seasonal differences in the ecological and health impacts of landfill sites throughout the year (Wu et al., 2016; Krystosik et al., 2020).

4.1.3 Human factors

School-age children and infants were observed in 44.4% (8) of landfills, either participating in waste picking or accompanying parents, particularly where no security personnel were present to prohibit entry. Similar findings were identified in the northern region of Ghana, where 80% of the total sum of waste pickers were children, with only 20% attending school (Global Plastic Action Partnership, 2025). These effects lessened as the distance from the landfill increased. This shows that child access to landfill sites may not only have implications for school attendance. In the case of South Africa this undermines the South African School Act of 1996 (SASA) that states that school attendance is compulsory for children from the first day of the year in which they turn seven, until the last school day of the year in which they turn fifteen, or until they complete Grade 9, whichever occurs first (Department of Education – Free State, 2025). According to the Children's Act of 38 of 2005 Regulations, all waste must be properly covered, kept out of reach of children, and handled using safe disposal methods (RSA, 2008).

Approximately 58.7% (71/121) of respondents strongly agreed that children experience high rates of chemical poisoning associated with proximity to landfill sites. This finding, while notable, is slightly lower than the 65.9% (254/385) reported in an explanatory mixed-method study conducted in Kampala, Uganda, which assessed caregivers' knowledge, attitudes, and chemical safety practices. The observed variation may be influenced by differences in sample size, study design, and contextual factors. Whereas the Ugandan study targeted a larger cohort and focused specifically on household chemical exposures, the present study examined environmental exposures emanating from landfill sites, which may account for the comparatively lower level of agreement among respondents (Akello et al., 2025). According to Siddiqua et al. (2022), children living close to landfills showed reduced immune function, with lower levels of lysozyme and immunoglobulin A (SIgA) due to exposure to gases such as CH_4, H_2S and NH_3. 53.7% of respondents strongly agreed that there are high cases of gender-based violence, such as rape and beatings, which puts the safety of children in more jeopardy. In the year 2019/2020, there were 42,289 rape cases, which translates to 115 rapes per day, as well as 7,749 sexual assaults reported (The Conversation, 2022).

Only waste pickers affiliated with recognised organisations, such as the Waste Picker Association, were found to possess partial personal protective equipment (PPE), which typically included basic items such as overalls and reflectors. This finding underscores the crucial role that structured and well-established waste picker associations play in promoting occupational safety and facilitating access to essential protective resources. In contrast, unorganised or independent waste pickers often operate without adequate safety gear, exposing themselves to significant occupational hazards. A study conducted in South Africa revealed that many waste pickers resort to collecting and reusing discarded, worn-out clothing from landfill sites as makeshift PPE, which provides minimal protection against cuts, puncture wounds, and exposure to infectious materials (Made et al., 2020). According to the Occupational Health and Safety Act (Act No. 85 of 1993), landfill operators bear the legal responsibility to ensure the safety and welfare of all individuals working within landfill environments, including waste reclaimers. The Act stipulates that operators must supply and enforce the use of appropriate protective clothing, such as industrial gloves, boots with reinforced soles, and high-visibility tunics, which also function as identification and registration markers. Similarly, the Department of Water Affairs and Forestry (DWAF, 1998) prescribes that all site personnel should be equipped with suitable protective gear, including gloves, boots and overalls, as well as smoke masks and goggles when working under hazardous or dusty conditions. Despite these regulatory provisions, evidence suggests that the enforcement of occupational health and safety measures at landfill sites remains weak and inconsistent nationwide. The inadequate provision of PPE and the lack of structured safety oversight not only compromise the health and dignity of waste pickers but also reflect broader institutional neglect within the informal waste sector. Strengthening waste picker associations, integrating them into formal waste management frameworks, and ensuring compliance with occupational safety regulations are therefore essential to advancing both human rights and environmental justice in South Africa's waste economy.

The majority of respondents (79.2%) reported that they either smoked or had family members who smoked, while 20.8% indicated that neither they nor their family members engaged in smoking. This high prevalence of smoking is particularly concerning in landfill environments, where individuals are already exposed to multiple biological and chemical hazards. Biological hazards, in particular, are derived from microorganisms that enter the host and proliferate within the body, leading to disease. These pathogens can easily be transmitted through contaminated hands, ingestion, and smoking practices (EU, 2020). Given that most waste pickers handle waste manually, often without adequate protective equipment, smoking during or after work may further increase the risk of infection and exposure to harmful microorganisms.

4.2. Proposition for a digitised community awareness and self-monitoring tool

The findings of this study reveal a need for an integrated and participatory approach to environmental and public health monitoring within local communities in the vicinity of landfills in the Free State. Challenges such as limited awareness of waste-related health risks, weak regulatory enforcement and disintegrated reporting mechanisms have collectively hindered effective prevention and early response strategies. To address these challenges, this study proposes the establishment of a Digitised Community Awareness and Self-Monitoring Tool (DCASMT). This is a mobile and web-based system designed to strengthen local municipalities through community participation, digital monitoring and data-driven decision-making.

4.2.1 Conceptual basis of DCASMT

The DCASMT function is in support of the One Health approach, which recognises the intrinsic interconnection between environmental, animal and human health systems (Destoumieux-Garzón et al., 2018; WHO, 2024b). The model aligns with existing South African legislative frameworks such as the Occupational Health and Safety Act (Act No. 85 of 1993), the Children's Act of 38 of 2005 Regulations, the National Environmental Management: Waste Act (Act No. 59 of 2008), and the Health Act (RSA, 1977), all of which emphasise the promotion and protection of public and environmental health. Within the context of landfill management, the proposed tool seeks to operationalise these principles by enhancing surveillance, improving public awareness, and fostering shared accountability for environmental health risks.

The DCASMT has two primary functions: firstly, awareness creation, aimed at improving community knowledge, attitudes, and behaviours related to waste exposure and hygiene; and secondly, self-monitoring, which enables residents to document and report environmental, and health indicators associated with landfill proximity. By combining participatory data collection with immediate feedback, the model bridges the gap between local lived experiences and municipal or provincial response mechanisms (Li et al., 2025).

It provides accessible multimedia resources such as videos, infographics, and voice-over tutorials in multiple local dialects to promote environmental health literacy. It will operate similarly to an application called MomConnect, which is a national-level mobile health information messaging programme from the National Department of Health that connects new mothers to health services and provides them with vital health information via SMS and WhatsApp messages (Pillay & Motsoaledi, 2018). The awareness and education hub will push notifications to disseminate urgent information on seasonal risks, such as vector proliferation during warmer months.

4.2.2. Anticipated outcomes of DCASMT

The DCASMT offers a transformative pathway towards improved environmental governance and public-health resilience. It enhances community awareness by providing accessible, localised education; strengthens participatory monitoring through real-time reporting; and promotes institutional responsiveness via integrated data analytics. By facilitating early detection of health and environmental risks, the model contributes to reducing disease burden and exposure in vulnerable landfill-adjacent populations.

Moreover, the model reinforces environmental justice by positioning communities not merely as passive beneficiaries, but as active partners in the protection of their own health and environment. The DCASMT therefore embodies the practical application of the One Health framework in South Africa's waste management context, linking digital innovation, public participation and evidence-based governance for sustainable environmental health outcomes.

5. CONCLUSION

The findings of this study reaffirm and extend the existing literature on the intersection between waste management, environmental degradation and public health outcomes within developing contexts. In the Free State province, landfill sites classified as 'general' are functionally receiving mixed and hazardous waste streams, including e-waste, medical waste, industrial residues and abattoir by-products. This misclassification underscores systemic weaknesses in institutional oversight, monitoring and enforcement of waste management regulations.

The study recommends the following:

-The South African government should develop and enforce a comprehensive national guideline or by-law for the collection, segregation and disposal of household medical, e-waste and chemical waste. The Departments of Health, Forestry, Fisheries and the Environment (DFFE), together with the local municipalities, should be reviewed regularly (e.g. every 5 years) to ensure accurate waste designation and compliance. Strategies in line with waste management hierarchy and sustainable development plans (SDGs) need to be adopted for management and divert waste from landfills, of which most are already past their standard operational period.

-The proposed DCASMT should be institutionalised to facilitate participatory and real-time monitoring of environmental hazards and associated health outcomes. Furthermore, establishing a unified database that integrates environmental monitoring data with public health records would enable evidence-based and proactive decision-making.

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