

Review

A Review of Indigenous Knowledge Systems and Their Application in Sustainable Solid Waste Management

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Abstract: Indigenous communities have always used their knowledge systems to improve their quality of life. For example, rural communities' resort to indigenous cultural practices to manage their own waste when local administration lacks coordinated ways to manage waste. In the context of indigenous knowledge systems, the idea of waste is non-existent. As indigenous knowledge is believed to provide a holistic framework for an approach that effectively promotes sustainability. As such, the current study conducted a systematic review to evaluate the extent to which indigenous solid waste management practices contribute to sustainable waste disposal methods. Using the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines, a literature search was carried out in the field of indigenous solid waste management practices. The results indicate a significant imbalance in the amount of conclusive evidence that has been produced to date that suggests the sustainability of indigenous solid waste management practices. It is for this reason that the current study has discovered a substantial literature gap in sustainable solid waste management associated with indigenous knowledge systems. This is an unprecedented trend, especially for a knowledge system that is supposed to promote sustainability practices. However, to improve the likelihood of incorporating indigenous solid waste disposal methods into modern practices, it is imperative to understand the foundational elements that contribute to the advancement of sustainability, lest the sustainability aspect associated with this knowledge system in the discipline of solid waste management remain a mere rhetoric.

Keywords: indigenous solid waste management; indigenous knowledge systems; sustainability; indigenous communities; traditional knowledge; indigenous waste disposal methods



Citation: Madonsela, B.S.; Semanya, K.; Shale, K. A Review of Indigenous Knowledge Systems and Their Application in Sustainable Solid Waste Management. *World* **2024**, *5*, 219–239. <https://doi.org/10.3390/world5020012>

Academic Editor: Manfred Max Bergman

Received: 18 March 2024

Revised: 8 April 2024

Accepted: 10 April 2024

Published: 12 April 2024



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1. Background

Indigenous knowledge systems have historically played an integral part in the survival of rural communities and have been essential for their existence. In the pursuit of global sustainability, it has become increasingly evident that indigenous knowledge systems possess invaluable insights that can contribute significantly to addressing environmental issues [1,2]. An area of utmost importance is solid waste management, where the intricate relationships between humans and the environment have historically been influenced by indigenous knowledge. In this regard, Siragusa and Arzyutov [3] point out that indigenous communities possess exceptional ecological knowledge and have consistently shown proficiency in the sustainable management of waste. Nevertheless, Crawford et al. [4] emphasise that whereas urban areas often have widespread access to various waste recovery and recycling options, within indigenous communities such services are frequently scarce or non-existent. As a result, indigenous communities struggle more often than not to exploit services such as material recovery and recycling due to the need for the

long-distance transportation of resources. It is fundamentally important to highlight these alternatives since they constitute a fundamental component of the sustainable waste management hierarchy. However, the absence of prospects for these alternatives as alluded is a cause of concern, particularly since the volume and types of waste materials that must be processed in rural areas are increasing due to the evolution of consumption patterns [5]. This is mainly due to the development of the economy and the improved living standards and lifestyles of indigenous peoples that have caused an exponential growth in solid waste [6]. For this reason, Salim et al. [7] is concerned that there is a growth of solid waste within indigenous communities amid the lack of a centralised and larger essential service infrastructure that supports sustainable solid waste management. Without a doubt, this requires further research that examines not only the waste disposal methods employed by indigenous communities but also the aspects of sustainability. Numerous scholars bemoan that solid waste management research is highly concentrated in urban areas [8–12], whilst rural areas are neglected although their consumption patterns have changed. Therefore, the scrutiny of indigenous waste management practices and the sustainability practices associated with them is of utmost importance due to the ensuing years of changing consumption patterns. In particular, favourable sustainability outcomes of these practices can be used to guide local government regulatory laws, such as bylaws, to recognise and incorporate the waste disposal methods of indigenous communities into integrated development plans. Consequently, to augment the likelihood of incorporating indigenous waste disposal methods into modern practices, it is imperative to comprehend the foundational elements that contribute to their sustainability. Hence, it is essential for the indigenous knowledge systems that are purported to be committed to the advancement of the sustainable development agenda to actively monitor the degree to which their intended outcome of sustainability is being achieved, lest the sustainability aspect associated with indigenous knowledge systems in the discipline of solid waste management remain a mere rhetoric. Therefore, considering this context, the aim of the current study is to assess the degree to which indigenous waste management practices prioritise the evaluation of sustainable waste disposal methods of indigenous communities. The goal is to contribute to the existing literature that supports the incorporation of indigenous knowledge systems into contemporary environmental practices, thus advancing a more sustainable and integrated future for humanity.

2. Literature Search

2.1. Search Strategy

The current study comprises an exploratory literature review aimed at holistically summarising themes of indigenous waste management practices. Subsequently, papers were selected to inform the review by extensively searching the range of multiple scientific reputable databases. In these databases, key thematic search terms such as “indigenous knowledge”, “sustainability”, AND “indigenous solid waste management” and “indigenous knowledge systems AND solid waste” were used to narrow down the search within the relevant scope of indigenous waste disposal methods. This systematic search was designated to capture a broad range of academic papers and any other associated technical reports within the indigenous waste management practices sector, thus avoiding comprehensively including all studies that may not be directly related to the topic at hand. As such, the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) reporting was fundamental to achieve this systematic search. Thus, in the current study, PRISMA, as depicted in Figure 1, facilitated the identification and inclusion of the pertinent literature. In this study, a comprehensive analysis was conducted on a total of 336 papers to fulfil the objectives of this research.

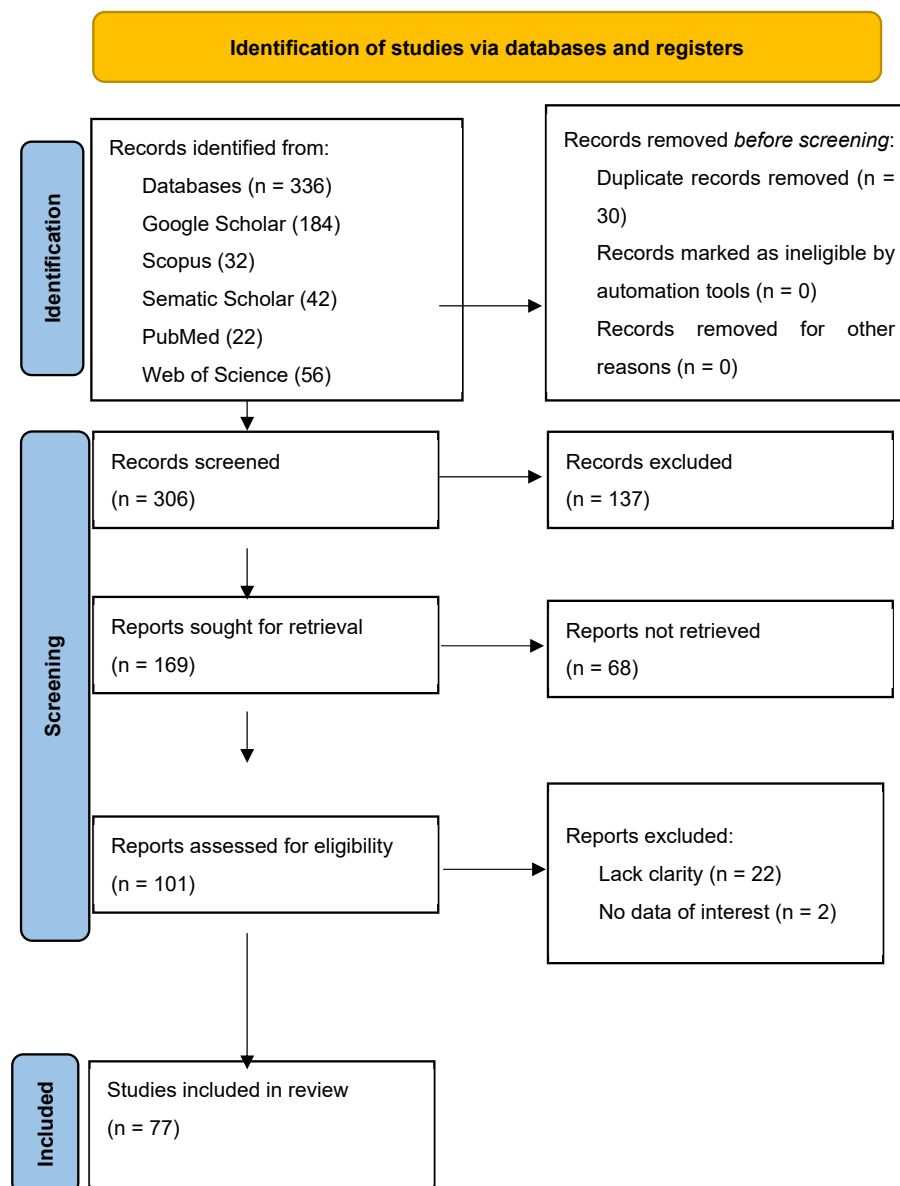


Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines for indigenous waste management practices.

2.2. Data Extraction and Selection of Studies

By utilising the global databases, the authors successfully identified records that could potentially be of relevance. As demonstrated in Figure 1, a dataset was identified, and the database search produced 336 records. The authors opted to employ five distinct reputable databases, namely Semantic Scholar (42), Scopus (32), Google Scholar (184), PubMed (22), and Web of Science (56). Subsequently, the data were stratified and examined using the reference manager programme EndNote 21 throughout data processing, as suggested by Grangxabe et al. [9]. EndNote 21 facilitated the elimination of duplicate papers, the categorization of articles through labelling, and the organisation of papers into subgroups. During the duplication process, thirty duplicates were excluded before screening as shown in Figure 1. Furthermore, after this bureaucratic process, which was intended to maintain the objectivity, transparency, and reliability of research, the Creswell [13] methodology framework of reading, analysing, evaluating, and summarising scholarly materials related to the review was implemented. To this end, an explanatory research approach was used to assess and explain the link between sustainability as well as the disposal methods of waste within indigenous communities. The method employed to analyse the metanalysis

3. Theoretical Framework of Indigenous Knowledge and Its Use in a Solid Waste Management System

From time immemorial Indigenous congenital knowledge has been used by indigenous communities to enhance their quality of life. That is, since the dawn of humanity, Indigenous communities have devised problem-solving techniques based on their knowledge systems [15]. Indigenous communities refer to collectives of individuals who are indigenous or aboriginal to a certain region or area. These societies have historically resided and continue to exist in certain geographical regions for long periods, to some extent even for thousands of years. They often possess unique cultural, linguistic, and social norms and customs that distinguish them from the prevailing cultures that may have established colonies or settled in the same region [16,17].

Indigenous communities consider indigenous knowledge systems the bedrock of their communities and solutions to the problems regarding conservation, restoration, and the sustainable use of nature, which benefits society at large [18,19]. This is achieved through the incorporation of locally developed skills, understanding, and philosophies by local communities with a long history and experiences of interacting with their natural surroundings [20]. It is for this reason that, more often than not, indigenous knowledge systems are intertwined with conserving and nourishing nature [21–23]. This is not startling, especially since indigenous knowledge holds cultural and environmental significance within rural communities.

In the indigenous community, all human endeavours are rooted within the indigenous knowledge system for the sole betterment of the society and to sustain humanity. For this reason, Kosoe [24] believes that “the practice of indigenous knowledge transcends all human activities, including solid waste management, and is preserved for future generations, building on them for the betterment of society”. Thus, there is a belief amongst indigenous communities that traditional waste management practices, for example, are against the indiscriminate disposal of waste [25]. Therefore, they make a positive contribution to sustainable waste management practices that effectively mitigate adverse health impacts as well the environmental impacts. This is achieved with minimal effort, if any, suggests Wahab [26], as indigenous waste management models promote cost-effective, efficient, and ecologically sound sanitation in the environment. It is therefore important to highlight that the cost-effectiveness of this model emanates from the fact that the foundational pillars of indigenous knowledge rest on cultural values [27]. Therefore, its application has no monetary value.

These are common-sense ideas, and the cultural knowledge of indigenous communities reflects the everyday realities of their living arrangements. To this effect, Assua [28] accentuates that the cultural background of a community can significantly influence how they generate and manage solid waste. This is because cultural ideas, values, and perceptions of waste in relation to place and time shape decisions on resource use and waste management strategies. According to Madonsela and Machate [15], the theories of indigenous knowledge are intergenerational. That is an indication that in essence the indigenous waste management practices of the current generation could be passed down to the next generation. Rightfully so, as, with respect to this matter, the indigenous waste management practices of one generation can impact that of another generation. This directly addresses the issue of social norms which could be significant in explaining the waste management practices of various indigenous communities.

Within these rural communities, indigenous knowledge is a vast and invaluable system of information that is flexible and dynamic, based on talents, aptitudes, and methods of problem-solving that shift with time in response to changing environmental circumstances. However, communities that are devoid of waste collection services, such as rural communities, are left to manage waste by themselves. To achieve this, they intuitively rely on indigenous knowledge practices. Brondízio et al. [29] indicate that indigenous communities around the globe use various pathways to manage their solid waste. Indigenous waste management methods are believed to be instrumental in the

preservation of the natural environment, and in some instances, it goes as far as rehabilitating the natural environment from previous impairment [30], because the indigenous waste management epistemology is believed to focus on the concept of sustainability in contrast to conventional methods that are centred around the disposing of the waste [31].

Thus, in this context, the belief is that the epistemology of indigenous sustainability is about indigenous communities considering what they can offer the environment [2], given that in the concept of indigenous beliefs, there is no such thing as waste, and even dead or discarded material from one area of an ecosystem is constantly used to benefit other parts [32]. Interestingly, observations indicate that indigenous waste management practices incorporate some of the sustainable waste management hierarchy stages. This mostly includes rudimentary waste reduction, reuse, and recycle approaches. For example, the old use of ash and recycled material to make the soil fertile among indigenous groups in Liberia and Ghana in West Africa has been recorded [33]. Including the indigenous practices of recycling metal waste, paper, glass, and plastic as well as recycling organic solid waste into compost [30,34–37]. In other instances, Siragusa and Arzyutov [3] outlined indigenous practices that reused waste materials such as car tyres to decorate gardens and oil barrels, as well as plastic bottles, to collect rainwater for irrigation, just to mention a few. Bello et al. [38] concur with this proposition, highlighting that the majority of the waste in indigenous communities is managed in a manner that benefits the environment, i.e., decomposing organic waste material.

This, amongst other things, includes “the old use of ash and recycled material to make the soil fertile among indigenous groups” [33]. It is for this reason that indigenous solid waste management practices, no matter how small they may seem, always make a difference in reducing the amount of generated solid waste [39]. To this end, Kosoe et al. [24] emphasize that “the declarations emanating from the international community signify a call for the inclusion of indigenous peoples and their knowledge systems in addressing environmental and sustainability challenges, particularly solid waste management in developing countries”. Similarly, Roberts and Okereke [39] have in recent times advocated for an urgent inclusion of certain indigenous solid waste management practices in the government agenda of strategies focused on managing solid waste.

4. Solid Waste Generation Rate per Capita in the Indigenous Communities

In order to achieve sustainable solid waste management, it is necessary to understand the mechanism of solid waste generation. Especially within the indigenous communities where consumption patterns have been reported to have evolved. The waste generation rate per capita is fundamental in the analysis of waste management. It helps communities to plan and manage resources more effectively. However, it is generally complex to quantify waste generation rate per capita, even more so for indigenous communities that are characterized by a scanty database of indigenous waste management practices [40]. Research indicates that the waste generation rate per capita is associated with population and gross domestic product [41]. That is, the income level influences the waste generation rate per capita. A high source income is directly proportional to an increased generation rate per capita [42].

Within rural indigenous communities, incomes are usually low, if they exist at all. It is for this reason that the waste generation per capita rate of indigenous communities is usually low [43]. Vinti and Vaccari [44] corroborate that “this is mainly due to lower lifestyle, income, and resource consumption”. Poverty and lack of materials can make people more environmentally sustainable; indeed, they give decisive importance to product reuse. In this aspect, such communities have a more sustainable approach than others. They are more inclined to a circular economy and sustainable solid waste management hierarchy principles that consider waste reduction and material reuse to be essential. However, notwithstanding Vinti and Vaccari [44]’s assertion, it is important to highlight that consumption patterns in rural areas have changed. This is a grey area that future environmental studies of indigenous waste management should tackle.

Furthermore, it is important to highlight that in certain developing countries, it has been discovered that often the amount of waste produced per income group is as follows: individuals with a low income generate 0.41 kg per person per day, individuals with a middle income generate 0.74 kg per person per day, and individuals with a high income generate 1.29 kg per person per day [45]. As such, on a global scale, the annual creation of solid waste is roughly 1.3 billion tonnes. This is projected to rise by 2.2 billion tonnes per year by 2025. Essentially, this signifies a substantial rise in the rate of solid waste production per individual, increasing from 1.2 to 1.42 kilogrammes per person per day [46]. The problem here is that an increase in municipal solid waste per capita coupled with insufficient municipal solid waste management service is a cause for concern [47]. However, these anticipated projections are far lower than the waste generation rate per capita recorded in the indigenous communities, as seen in Table 1 below.

Table 1. Indigenous communities waste generation rate per capita.

Author(s)	Waste Generation per Capita [kg/(Inhab. × Day)]	Study Area (s)
Năstase [48]	0.81	Romania
Orhorhoro and Oghoghorie [46]	0.43	Nigeria
Dikole and Letshwenyo [49]	0.36	Botswana
Rajpal et al. [50]	0.18	India
Rodseth et al. [42]	0.32	South Africa
Yakah et al. [51]	0.47	Ghana
Rodrigo-Illarri et al. [52]	0.46	Colombia
Perizeau et al. [53]	0.23	Canada
Lozano Lazo et al. [54]	0.54	Bolivia
Diéguez-Santana et al. [55]	0.51	Ecuador
Blazquez and Paredes-Belmar [56]	1.48	Chile
Requena-Sanchez et al. [57]	0.42	Peru

5. An Overview of Solid Waste Management Practices within Indigenous Communities

From ancient times, prior to colonization, indigenous waste management practices have been instrumental in preventing, disposing, reducing, and reusing waste material within indigenous communities. Before the introduction of mainstream sciences facilitated through the colonial means, Wahab [26] postulates that indigenous waste management practices have always been at the centre of sanitation, holding together sustainable environmental health issues within rural communities. In indigenous communities, the practices associated with waste management are not exclusively designated to certain agencies. Given that funding for waste management in indigenous communities has been severely lacking [28,58]. Indigenous communities across the globe are cognizant of the impacts and risks of inadequate waste management practices within their surroundings. To mitigate the impacts associated with poor waste management, indigenous communities proactively take it upon themselves to prevent waste issues by using their indigenous knowledge [59]. Therefore, within indigenous communities, it becomes the responsibility of every individual to manage waste effectively [60].

Thus, in some instances, communal labour has been integrated within indigenous communities to tackle waste issues. However, since the advancement of human civilization, indigenous waste management practices have been overlooked and relegated to the background by the current generations [24], although indigenous communities have previously been acknowledged as having effective waste management practices [61]. Despite this observation, in recent times experts “in their quest to create sustainable waste management approaches, have not recognized the role informal indigenous groups and community-based organizations could play in addressing the problem of waste management” [37].

Subsequently, in some indigenous communities this has bred a negligent attitude towards waste management, prompting individuals to abandon their indigenous waste management practices. According to Fruitema [35] “this has led to far too many failed

attempts at addressing pollution concerns and waste-management”. Consequently, waste management has been treated as the sole responsibility of the service providers. In line with this view, Asomani-Boateng [37] substantiates that within indigenous communities, the establishment of a solid waste management department “led the people to think that waste was not their problem, and they did not have the responsibility to manage it anymore. Making a certain group work as cleaners changed the habit of the people and it also broke the trend of people managing their waste themselves”. Thus, it is clear from the above that overlooking indigenous waste management practices gives rise to more waste-related problems.

6. Documented Indigenous Knowledge Systems of Solid Waste Management Practices

Overall, a total of twenty-one detailed research studies that documented indigenous waste management practices were included in the current review. These research studies represent the spatial coverage of indigenous waste management practices documented across the globe. A detailed summary of the main indigenous waste management practices associated with these studies is presented in Table 2 below.

Furthermore, Table 2 provides information about the study aims and the geographical areas of the research, as well as the disposition of the studies toward the assessment of the sustainability of indigenous waste management practices. The content of Table 2 is evidence that the knowledge systems of indigenous people are indeed geographically confined. That is, each community possesses an indigenous knowledge system that is in line with its geographical location, although some of these practices are similar despite their geographical locations. For instance, the indigenous waste management practice of composting biodegradable waste is shown to be a common method amongst indigenous communities regardless of geographical location. Whilst in contrast to the composting method, not all indigenous communities seem to exercise waste trading in expectation of monetary gain. As such, overall, Table 2 indicates that there are discrepancies in indigenous waste management practices. Moreover, another interesting observation is the number of waste management practices employed by indigenous communities. Similarly, there seems to be variability in the number of indigenous disposal methods employed in each geographical setting. This is not surprising. However, indigenous knowledge is contextualized as a knowledge system that is unique within every indigenous community, thus it is neither singular nor universal, but rather a voluminous, diverse, and highly localised source of wisdom. In addition, Figure 3 below captures the crux of indigenous solid waste management practices.

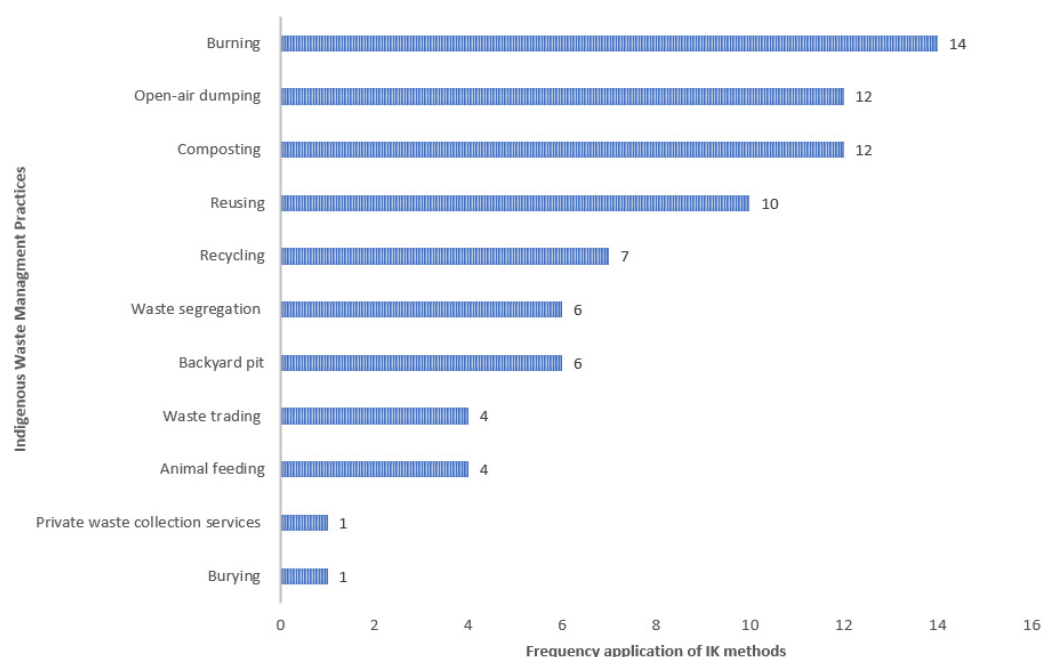


Figure 3. Indigenous waste management practices shown in order of frequency.

Table 2. Research studies that have undertaken indigenous waste management practices.

Author(s)	Study Area (s)	Study Aim	Objective of the Study to Assess the Sustainability Aspect of Indigenous Waste Management Practices	Indigenous-Generated Waste Management Practices	Population/Community Size
Rabonda [62]	South Africa (Sikhunyani Village)	To document indigenous knowledge systems as a possible alternative to current MSW management systems and assess the sustainability of their waste management methods.	The sustainability component of indigenous waste management practices is evaluated.	• Animal feeding—food waste; • Composting—food and garden waste. • Burning—plastic material and garden waste; • Open-air dumping—diapers and electronic waste; • Recycling of glass; • Reusing of cans; • Backyard pits.	• A total of 1545 households.
Izugbara and Umoh [30]	Nigeria (Ngwa)	To document traditional waste management practices among the Ngwa of Nigeria in the search for sustainable solutions to the crisis of waste management in Nigeria	The sustainability component of indigenous waste management practices is not evaluated.	• Waste segregation: separation of biodegradables from other waste; • Burying: pieces of steel from broken hoes and knives, clay pots, animal bones. • Composting: food and agricultural waste; • Burning: rags and fibre sacks; • Reusing of bottles; • Recycling bottles into fine sand to be used in smoothing the walls of building; • Recycling of old iron blades, bars, and scraps into hunting daggers, bullets, spears, and arrows, garden diggers, iron-tipped pegs, hooks, traps, kitchen, and carving knives.	• Population size is over a million.
Ajibade [32]	Nigeria	To examine the indigenous knowledge systems of waste management in Nigeria.	The sustainability component of indigenous waste management practices is not evaluated.	• Recycling of food and yard waste into animal feed; • Composting of organic waste from food, animal faeces, and dead plants; • Recycling of wood ashes into soap; • Recycling of animal bones and horns into plates, flutes, and decorating materials; • Recycling of agricultural waste, such as palm leaves, into brooms and weaving baskets; • Recycling of metal waste into knives, cutlass, jewellery and axes.	• Population/community size not defined.

Table 2. Cont.

Author(s)	Study Area (s)	Study Aim	Objective of the Study to Assess the Sustainability Aspect of Indigenous Waste Management Practices	Indigenous-Generated Waste Management Practices	Population/Community Size
Assuah and Sinclair [28]	Canada	To examine solid waste management on First Nations communities in western Canada to provide information and insight into programs, practices, policies, and activities.	The sustainability component of indigenous waste management practices is not defined.	- Reusing of clothes, shoes, and bags; - Sorting of glass, plastic bottles, cans, paper, and cardboards; - Composting of organic materials; - Recycling of metal materials; - Waste trading of recyclable materials for monetary compensation; - Open-air pits used for waste burial.	A population size of 554,185.
Oyegunl and Thompson [63]	Canada (Garden Hill and Wasagamack)	To address concerns about solid waste and establish alternative waste management programs.	The sustainability component of indigenous waste management practices is not defined.	- Backyard pits used for burial packaging products as well as modern plastic, paper, and steel cans; - Combustion of modern plastic and wood waste; - Waste sorting of valuable recyclables such as plastic bottles and containers.	A population size of 3994.
Zagozewski et al. [58]	Canada (Saskatchewan)	To gain an understanding of past and present waste disposal practices and to identify any human and environmental health concerns related to these practices.	The sustainability component of indigenous waste management practices is defined.	- Waste sorting of paint products from household waste; - Open-air dumping plastics, household products, and paper; - Combustion of waste.	A population size of 250,000
Senekane et al. [25]	Lesotho (Maseru)	To understand the different indigenous systems and practices of waste management and to perform a critical analysis of these systems and practices as evidence to inform waste management policy development in Lesotho.	The sustainability component of indigenous waste management practices is not defined.	- Garden waste used as animal feed; - Plastics reused as carrier bags; - Recycling of waste tyres into chairs; - Reusing of plastic waste material into plastic mats, handbags, and hats; - Waste trading of recyclable materials such as scrap metals, glass, and cardboard; - Burning of non-biodegradable waste; - Backyard pits used for waste dumping; - Dumping of non-biodegradable waste; - Communal waste management.	A population size of 6917.

Table 2. Cont.

Author(s)	Study Area (s)	Study Aim	Objective of the Study to Assesses the Sustainability Aspect of Indigenous Waste Management Practices	Indigenous-Generated Waste Management Practices	Population/Community Size
Peñafiel-Arcos et al. [64]	Ecuador (Río Blanco)	To design a comprehensive management system for domestic solid waste.	The sustainability component of indigenous waste management practices is not defined.	• Combustion of waste material; • Recycling of plastic and paper; • Composting of biodegradable waste.	• A population size of 115.
Taghipour et al. [65]	Iran	To determine the quantity and quality of rural household solid waste and also current management condition in rural communities in the northwest of Iran.	The sustainability component of indigenous waste management practices is not defined.	• Waste sorting of recyclable metals; • Dumping of waste.	• A population size of 24,956.
Taboada-González et al. [66]	Mexico (San Quintin and Vicente Guerrero)	To examine the perception of the community on municipal solid waste management.	The sustainability component of indigenous waste management practices is not defined.	• Informal waste collection in exchange for gratuity; • Combustion of waste in backyards; • Dumping of waste in ravines; • Waste trading of recyclable materials for monitory compensation.	• A population size of 30,432.
Rajpal et al. [50]	India (Uttarakhand)	To investigate the MSW management scenario in rural areas across the river Ganga and propose a possible sustainable waste management solution.	The sustainability component of indigenous waste management practices not defined.	• Open-air dumping of waste; • Composting; • Waste sorting.	• A population size of 1,890,422.
Asgari et al. [67]	Iran (Tehran and Alborz)	To devise an appropriate plan for effective solid waste management in this area.	The sustainability component of indigenous waste management practices is not defined.	• Combustion of organic waste; • Reusing of chopped straw with mud as construction materials.	• A population size of 198,674.
Bernard and Günther [68]	Brazil (Amazon State)	To characterize rural domestic solid waste in terms of quantity and quality with the intention to provide information for appropriate solid waste management policies.	The sustainability component of indigenous waste management practices is not defined.	• Reusing of organic matter to feed animals; • Composting of biodegradable waste; • Combustion of inorganic waste (paper and plastic); • Dumping in open-air sites; • Dumping of batteries and other items in backyard pits; • Recycling of organic matter into feedlots.	• A population size of 2269.

Table 2. Cont.

Author(s)	Study Area (s)	Study Aim	Objective of the Study to Assess the Sustainability Aspect of Indigenous Waste Management Practices	Indigenous-Generated Waste Management Practices	Population/Community Size
Kerdsuwan [69]	Thailand (Maiked)	This study focuses on sustainable development and eco-friendly waste disposal technology for local communities.	The sustainability component of indigenous waste management practices is not defined.	• Open-air dumping; • Burning of waste in the backyard.	• A total of 3720 households.
Mihai and Ingrao [40]	Romaria (Rural areas)	To highlight the crucial role of home composting in the recovery process of this fraction.	The sustainability component of indigenous waste management practices is not defined.	• Composting of organic waste.	• Population/community size not defined.
Vahidi et al. [70]	Iran (Chaharmahal, Bakhtiari and Yazd provinces)	To presents an overview of the current rural solid waste management programs in the central regions of Iran.	The sustainability component of indigenous waste management practices is not defined.	• Dumping of waste; • Burning of plastic, cardboard, and wood waste; • Disposal of rubber, metals, and textile waste in backyard pits.	• A population size of 1,270,000.
RetPatwa et al. [71]	India	To collect and compare solid waste generation, characterization, factors affecting solid waste treatment, and treatment technologies for organic and inorganic waste in rural India.	The sustainability component of indigenous waste management practices is not defined.	• Composting of organic waste; • Open-air dumping.	• A population size of 82,562.
Tran et al. [72]	Vietnam (Nam Dinh province)	To assess the current status of rural domestic solid waste management.	The sustainability component of indigenous waste management practices is not defined.	• Burial of organic, papers and plastic waste in backyard pits; • Burning of papers, leaves, and plastic waste.	• A population size of 10,462.
Creaser et al. [73]	Cambodia (Koh Dambang)	To present perspectives of solid waste in Cambodian communities.	The sustainability component of indigenous waste management practices is not defined.	• Burning of waste; • Dumping of waste; • Reusing of bottles for fuel storage; • Waste trading of recyclable bottle for monetary value.	• A population size of 200.

Table 2. Cont.

Author(s)	Study Area (s)	Study Aim	Objective of the Study to Assesses the Sustainability Aspect of Indigenous Waste Management Practices	Indigenous-Generated Waste Management Practices	Population/Community Size
Viljoen et al. [74]	South Africa (Northern Cape)	To assess the waste management practices and challenges of households in the municipality of a rural and remote town in the Northern Cape.	The sustainability component of indigenous waste management practices is not defined.	• Composting of food waste; • Reusing of papers; • Burning of old clothes; • Burning and burial; • Dumping of glass, clothes, and waste batteries.	• A population size of 9680.
Panta [75]	Papua New Guinea	To investigate the relevance of indigenous knowledge through indigenous solid waste management practices as a tool for in contributing to the improvement and sustainability of municipal solid waste management system.	The sustainability component of indigenous waste management practices is defined.	• Composting of biodegradable waste; • Reuse of plastic waste; • Burning of leaves, grass, and plastic waste.	• A population size of 500.

7. The Trends of Indigenous Solid Waste Management Practices

Figure 3 depicts the waste management practices from a global perspective that are frequently employed by indigenous communities in their quest to manage the scourge of solid waste given the absent or limited waste management services provided by local authorities. It can be seen that indigenous methods are characterized by numerous practices. A total number of eleven practices were recorded from studies across the globe, as shown in Table 2 above. Furthermore, the available data from several studies (as seen in Table 2) that were used to generate Figure 3 below indicate that while there are numerous waste management practices that are associated with indigenous communities, there are disposal methods that are frequent and consistent. As such, the combustion of waste, open-air dumping, composting, and reusing of waste material characterize the main practices that constitute solid waste management of indigenous communities.

As such, according to the observations in Figure 3, it is clear that burning practices are the main disposal method of waste used by indigenous communities. The practice of burning waste material is followed by open-air dumping, composting, and reusing as the most frequently used solid waste management methods that are prevalent within the indigenous communities. In terms of the current framework or hierarchy of indigenous waste management practices, the present study reveals that the primary means of managing waste are hazardous, thus presenting environmental health risks. This is further compounded by the recent addition of hazardous materials to the waste streams of indigenous communities, including plastic, which, when burned, emits polycyclic aromatic hydrocarbons. Thus, the combustion of solid waste emits several toxic substances that might potentially endanger both the general public and the surrounding environment within the neighbourhood of the burning site. The indigenous waste management practice of burning waste, despite appearing to be a priority, presents a significant challenge that complicates the achievement of the sustainable development goal (namely SDG 3) pertaining to good health and well-being. This equally goes for open-air dumping, which follows burning, as shown in Figure 3. As a result, this represents a setback for a knowledge system that is extensively linked to sustainability practices. However, not all indigenous waste management practices are inherently linked to methods that compromise sustainable development. For instance, composting, reusing, and recycling are fundamental practices of waste management that are generally associated with sustainability.

8. Disposition to Evaluate the Sustainability of Indigenous Waste Management Practices

Numerous factors have contributed to the increase in solid waste generation as well as its diversity within the indigenous communities. Interestingly, this has been caused by the unprecedented increase in population size as well as the economic development which has a direct bearing on the income changes that subsequently influence consumption patterns. It is for this reason that the waste type has notably changed or evolved in recent times within the indigenous communities. These factors contribute to waste generation in indigenous communities and pose a significant challenge to the sustainability of indigenous solid waste management practices. Therefore, given this and the fact that the evolution of solid waste that is characterized by hazardous waste types such as plastic and electronic waste, it is necessary to understand the role of indigenous solid waste management methods in sustainability practices. Thus, to understand this role, data from the studies with interest in indigenous waste management practices from various indigenous communities were synthesized, as shown in Table 2. The aims, as well as the objectives, of these studies were extensively evaluated to appraise and understand the inclination towards sustainability. However, despite the fact that indigenous waste management practices have always played a central role in maintaining sustainable environmental health in rural communities, the current review reveals that the majority of research studies have shown little interest in evaluating the sustainability of these indigenous methods, as depicted in Figure 4. Figure 4 underscores the propensity of scholars of indigenous waste management to quantify the sustainability of these approaches.

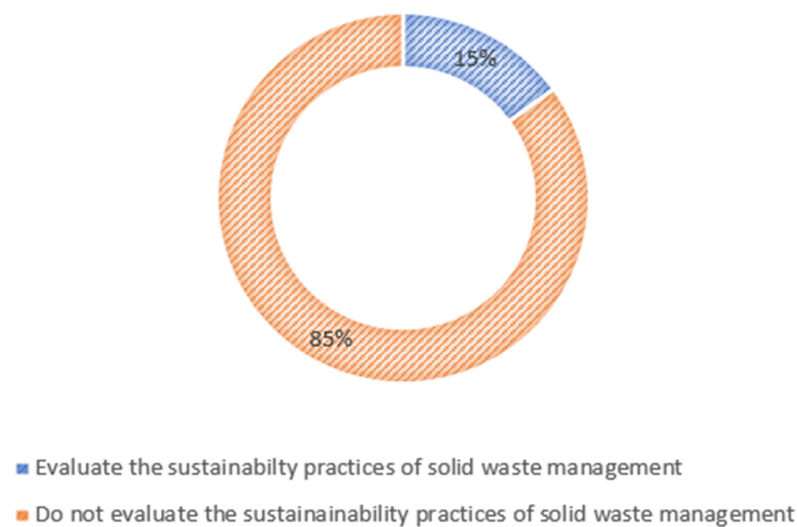


Figure 4. The proportion of studies that evaluate sustainability associated with indigenous solid waste management practices.

From across the globe, studies associated with indigenous waste management practices have been scrutinized and their sustainability discrepancies are visually illustrated, as demonstrated in Figure 4. Although indigenous knowledge systems are seen as crucial for achieving sustainable development objectives, Figure 4 indicates that most of the available research on indigenous waste management methods does not focus on measuring the sustainability practices of solid waste management. It is for this reason that statistically, only a small proportion (15%) of research has examined the sustainability of indigenous waste management practices used for solid waste. Evaluating these practices, the current study has discovered that researchers used an assessment criterion that incorporated a triple-bottom-line framework associated with environmental, social, and economic sustainability. That is, researchers evaluated indigenous waste management practices against the environmental, economic, and social impacts. However, one cannot help but notice the absence of quantitative indicators since the bulk of their sustainable indicators are of a qualitative nature. Moreover, in contrast to sustainability, a significant majority (85%) showed little interest in evaluating the sustainability of these indigenous waste management methods (Figure 4). Moreover, these inconsistencies are not surprising, since these results correlate with most of the primary goals of the conducted research studies, whose aim was not to assess the sustainability aspect of the disposal methods being used, as shown in Figure 5 below. This observation is reinforced by the overview aims of the research studies carried out within indigenous communities, focusing on the management of solid waste using indigenous knowledge.



Figure 5. Overview aims of global studies that have conducted indigenous waste management practices.

In line with previous discussions, Figure 5 presents the overview of the aims of research studies that have explored the waste management practices of indigenous communities across the globe and is derived from Table 2. From Figure 4, it is clear that the majority of the studies that endeavour to understand the waste disposal methods of indigenous communities do not underscore the sustainability aspects of these practices, despite the substantial association of indigenous knowledge concepts with the sustainability agenda. That is, in accordance with observations illustrated in Figure 4, the majority of researchers from then to recent times have shown a significant interest in either examining the indigenous knowledge systems of waste management (35%) or documenting these practices (30%), whilst the practices associated with the sustainability of the indigenous disposal methods of waste are relegated to the background (15%). The following data represent a breakdown of the study aims which focused on methods of waste disposal among indigenous communities, which are:

- A. To assess sustainability of waste management methods (3) (15%);
- B. To document indigenous waste management practices (6) (30%);
- C. To examine the indigenous knowledge systems of waste management (7) (35%);
- D. Miscellaneous (4) (20%).

The contents of Figure 5 indicate that there is a gap in the evaluation of sustainability practices associated with indigenous disposal practices. To this effect, numerous studies across the globe that have undertaken the study of indigenous waste disposal techniques show evidence of a high inclination to document and examine indigenous knowledge systems of waste without consideration for sustainability. It is for this reason that only an insufficient number (15%) have attempted to evaluate the sustainability of indigenous waste disposal methods, although these knowledge systems have been in use from time immemorial. These discoveries are puzzling for knowledge systems that are regarded as having long, good-standing relationships with the environment. Moreover, this finding provides evidence that while indigenous knowledge is recognised for its holistic approach, which considers the interconnectedness of environmental, social, and cultural aspects and emphasises a comprehensive and integrated understanding of sustainability, in waste management practices, this is still considered a theoretical concept. The lack of scholarly interest on a global scale regarding the sustainability of these knowledge systems prevents the in-depth accountability of their contributions to sustainable waste management objectives, which are fundamentally important to attaining the SDGs.

9. Discussion

In some jurisdictions of rural government authorities, over ninety-three percent of the communities lack access to refuse collection services [76]. However, there is a growing consensus which suggests that a solution to societal concerns or challenges should begin with an understanding of local dynamics [15]. Therefore, in the absence of organized means to control the scourge of waste by the local authority, rural communities resort to indigenous cultural practices to manage their own waste. Indigenous cultural practices directly feed into indigenous knowledge systems, which are generally associated with sustainability. To this effect, Mazzochi [77] retains that indigenous knowledge provides a concrete framework for an approach that effectively promotes sustainability. However, despite this viewpoint, there are a meagre number of studies that discuss the sustainable footprint of indigenous waste management practices.

In general, there is a significant imbalance in the amount of research that to date has focused on the sustainability of indigenous waste management systems. As such, a negligible number of studies have investigated the sustainability practices linked to indigenous waste disposal methods, as presented in Figure 5. This is an unprecedented trend, especially for a knowledge system that is purported to underpin sustainability. This reflexion is, however, in line with the concerns raised by McGregor [2] that despite the existence of protocols that advocate for the acknowledgement and use of indigenous ecological knowledge as a crucial component in the pursuit of sustainability, there has been little

assessment of the strategies employed to attain this sustainable future. Furthermore, there has been limited monitoring of the extent to which the intended objective of sustainability has been achieved.

Therefore, in order to guarantee recognition of the value of indigenous knowledge as a system capable of addressing global environmental issues, it is critical that researchers of indigenous waste knowledge systems focus on the evaluation of sustainability practices associated with the knowledge system. Accentuating the positive role of indigenous knowledge in the field of environmental studies, McGregor [2] posits that science and technology, in isolation, have been reported to be unable to resolve the current environmental challenges. Therefore, alternative techniques are necessary, particularly those with extensive and proven track records such as indigenous ecological knowledge that have drawn more attention in recent decades, especially in the field of sustainable development. In as much as this premise is true for agriculture, climate change, biodiversity, water quality management, fishing, farming, education, and conservation [78–81], it remains a fallacy for indigenous waste management practices not because the skills and technologies of indigenous communities employed for waste disposal are incapable of being sustainable but due to limited research that has left a substantial gap in this regard.

Essentially, this suggests that the primary objective of most research on waste disposal systems within indigenous communities, as shown in Table 2, should be to evaluate sustainability practices, especially if these practices are to be adopted as economically viable alternative means for managing waste in developing countries. The most predominant practices of documenting and examining the indigenous knowledge systems of waste management (Figure 5) should never be treated as the means to an end, but should be treated as the elementary phase that is necessary to document for posterity the knowledge system that for decades has been characterized by oral transmission and is thus at risk of extinction [82–84]. The emphasis here is that there is a need to go beyond and above documentation by incorporating the sustainability aspect of associated practices, given that the positive sustainability outcomes of these practices may be used to guide the regulatory legislations of local governments, such as bylaws, to recognize and incorporate the waste disposal methods of indigenous communities into integrated solid waste management plans. However, to enhance the likelihood of incorporating indigenous waste disposal methods into modern practices, it is imperative to comprehend the foundational elements that contribute to their sustainability.

10. Conclusions

The current study has discovered that evaluating sustainable indigenous waste disposal methods not only addresses environmental concerns but also contributes to economic and social well-being, thus fostering a more sustainable and resilient indigenous society for posterity; to date, research on indigenous waste management practices has not taken into account the concerted efforts needed to associate research outcomes with sustainability. That is, in general, there is a significant imbalance in the amount of research that to date has focused on the sustainability of indigenous waste management systems. To this end, the overwhelming majority of researchers have demonstrated considerable interest in either documenting or investigating the indigenous knowledge systems of waste management without consideration for sustainability. These discoveries are puzzling, particularly for a knowledge system that is regarded as having a long, good-standing relationship with the environment. However, the current study does not overlook and is not oblivious to the fact that indigenous knowledge has only been recently recognised and is only now increasingly attracting more attention in the field of environmental research. In context of the research gap of sustainability within studies of indigenous waste disposal methods, the current study advocates for a paradigm shift skewed towards research output associated with evaluating the extent to which the intended objective of sustainable solid waste management or associated aspects has been achieved. This is fundamental for the waste disposal methods of indigenous communities, especially if they are to be incorporated into

modern practices. This will subsequently minimize the current research gap surrounding studies on indigenous waste management methods that direct their focus on documenting or investigating these practices.

11. Future Studies

- There is a need for research studies that assess the sustainability of the indigenous waste management approaches given the dearth of studies that concentrate on the sustainability of the disposal practices used by indigenous communities.
- This premise is based on the current literature review, which has noted a substantial research gap that necessitates further investigation into the sustainability of solid waste management methods used by indigenous communities.
- The importance of conducting research on sustainable waste management cannot be overstated, as such investigations have the potential to contribute to the increasing understanding of the ecological, social, and economic consequences associated with indigenous waste disposal practices.
- Research on sustainable solid waste management can enhance public consciousness and inform indigenous communities about the benefits of sustainable waste disposal methods.
- Sustainable solid waste management presents environmental and social solutions that can enhance the well-being of both the environment and indigenous communities and thus reduce any potential exposure to environmental and social risks that may arise from improper waste practices.
- To effectively comprehend indigenous waste management, it is crucial for future studies to prioritise the monitoring of consumption patterns, particularly due to the changes in consumption patterns within rural communities in recent years.

Author Contributions: Conceptualisation, B.S.M.; methodology, B.S.M.; validation, K.S. (Khomotso Semanya) and K.S. (Karabo Shale); writing—original draft preparation, B.S.M.; writing—review and editing, K.S. (Khomotso Semanya) and K.S. (Karabo Shale); visualisation, B.S.M. All authors have read and agreed to the published version of the manuscript.

Funding: This work is part of a PhD project funded by the South African National Research Foundation (grant number 138164).

Institutional Review Board Statement: This paper does not contain any studies involving human participants or animals performed by any of the authors.

Data Availability Statement: The data presented in this study are available on request from the corresponding authors.

Acknowledgments: The authors thank the South African National Research Foundation for their financial support.

Conflicts of Interest: The authors declare that they have no known conflicts of interest or personal relationships that could be perceived as having influenced the work described in this paper.

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