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Solid Waste Characterization and Management in the Municipality of Datu Saudi Ampatuan, Maguindanao, Mindanao, Philippines

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Abstract: Identifying solid waste characterization and management is an important measure to determine the sustainability of the waste management practice. The researchers adopted a descriptive quantitative research study to gather data in the Municipality of Datu Saudi Ampatuan. A process called 'Pre-WACS' (Waste Analysis and Characterization Study) is a three-step methodology aimed at characterizing solid waste. Along with this, the observation of waste generators is perceived as crucial in this study. Identifying the sources of each waste type is essential in predicting the possible types of waste a municipality may produce, enabling waste management processes to be adequately prepared beforehand, and allowing for a more efficient waste management workflow. In the study, it was found that the municipality generated daily ~5.6 tons of solid waste. Residential waste sources contributed the highest amount of solid waste amounting to 1.6 tons, while the agro-industries waste sources contributed the least amounting to only 1.1 tons. Additionally, more than half of the solid waste was biodegradable and eligible for fertilizer production. In order to minimize the production of solid waste, it was recommended to increase recycling methods and use more sustainable ways to manage the waste generated by the municipality.

Keywords: Solid waste management, solid waste characterization, waste reduction, sustainable consumption, biodegradable waste

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1. Introduction

Various types of unwanted and discarded products including trash, garbage, and debris generated by households, agriculture sector, businesses, institutions, municipal services, and other sources are generally called solid waste or municipal solid waste (Abu-Qdais and Kurbatova, 2022, Mani and Singh, 2016; Srivastava et al., 2015). Municipal waste can consist of compostable organic matter (food and yarn waste) (Miezah et al., 2015; Wang et al., 2021), recyclable materials (wood, paper, cardboard, metals, glass, packaging materials, etc.), toxic materials (pesticides and other chemicals, medical waste, etc.), e-waste and contaminated waste (e.g., sanitary napkins, etc.) (Akram et al., 2019; Rousta et al., 2015; Ugwu et al., 2020; Ugwu et al., 2021).

Escalating global population, economic development, urbanization, and rising living standards have resulted in more production, consumption and ultimately increased waste generation. Increased generation of waste leads to contamination of air, soil and water, posing serious consequences for human

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health and the environment (Gu et al., 2021; Ren et al., 2022; Wiedmann et al., 2020). Sustainable development is closely linked with efficient waste management (Sharma et al., 2020). Sustainable recycling and efficient utilization of solid wastes are required to protect human health and achieve Sustainable Development Goals (SDGs) (Hannan et al., 2020; Pujara et al., 2019).

A sustainable waste management program aimed at reducing the amount of waste generation, increasing the reuse and recycling of waste (3R Principles) (Das et al., 2019; Tsai et al., 2020), and proper disposal of waste, that cannot be recycled or composted. Sustainable waste management programs are designed for environment-friendly waste management and long-term sustainability. Furthermore, such programs involve a range of strategies and initiatives to educate the public to reduce, reuse and recycle waste. By implementing a sustainable waste management program, we can help to protect the environment and support long-term sustainability (Abubakar et al., 2022; Das et al., 2019; Parajuly et al., 2020).

Although the COVID-19 pandemic has induced social isolation that caused alarming socioeconomic repercussions and indirect environmental impacts, there are still several positive impacts—air and surface water quality improvement, cleaner beaches, and reduction of noise pollution (Liang et al., 2021). Despite the COVID-19 pandemic, the world has still generated around 2.24 billion tons of waste which translates to about 0.79 kg of solid waste per person per day. Residents of developing countries are more negatively impacted by unsustainable waste management than citizens of developed countries. Over 90% of rubbish is frequently dumped in uncontrolled landfills or burned outdoors in low-income countries. These actions have detrimental effects on the environment, public safety, and health. Ineffective waste management produces methane, which contributes to climate change, acts as a breeding ground for disease-carrying organisms, and encourages urban violence (Solid Waste Management, 2022).

Despite the implementation of the Ecological Solid Waste Management Act of 2000 (Republic Act, RA 9003), the management of solid waste in the Philippines continues to become a problem (Riman et al., 2022; de Paz et al., 2020). In the Philippines, the average amount of solid waste produced per capita per day in 2015 reached 0.5 kg. From this data, the estimated daily production of 35,000 MT of 50,000 MT solid waste is collected by the concerned staff of the municipality or city. This has led to a realization that a new solid waste management plan needs to be in place, carefully planned, implemented, and enforced to ensure sustainability (Sapuay, 2016).

Different local government units have taken the challenge of improving solid waste management ever since the implementation of RA 9003. Several studies, across the Philippines, highlighted the efforts for improvement of the solid waste management system. In Barangay Matictic, Norzagaray, Bulacan, new methodologies were used to find efficient and smart strategies for solid waste management. It involved several group discussions and interviews with external & internal stakeholders. It was proposed to increase funding for efficient solid waste management for traditional solutions e.g., putting up a sanitary landfill and recycling programs, and efforts to bring positive change in the behavior and attitude of households. However, the success of such programs is highly dependent on the reduction of waste generation prevented through effective resource allocation and strict waste segregation. These strategies can be enforced through incentive schemes or awareness campaigns (Debrah et al., 2021; Iqbal et al., 2022; Struk, 2017).

The Waste Analysis and Characterization Study (WACS) conducted in Barangay Matictic showed that a major waste segment (51% or 0.6 MT) is biodegradable and can be managed through vermicomposting (de Paz et al., 2020). Earthworms naturally turn organic garbage into compost through a process called vermicomposting. Compost created through this environmentally friendly procedure is traditionally and frequently used as a biofertilizer to enrich soil fertility and promote plant growth and development (Singh and Sinha, 2022).

Moreover, the municipality of Batad in Iloilo also had another method to deal with solid wastes. A five-day WACS showed that over half of its solid wastes (50.47%) are also biodegradable. Similar to the solution of Barangay Matictic, the municipality of Batad's biodegradable wastes are conveyed to its vermicomposting facility. This is a collaborative project of the Northern Iloilo Polytechnic State College, the Local Government Unit of Batad (LGU-Batad), the Provincial Environment and Natural Resources Office (PENRO), and the Commission on Higher Education (CHED) Central Office (Montero et al., 2019).

The Municipality of Datu Saudi Ampatuan is currently composed of eight barangays with a

population of 31,060 and an average annual growth rate of 2.60%, which is based on the recent census gathered in the year 2020. The simple growth of the population would equate to waste generation in the municipality. Municipal waste is generated from various sources associated with varying human activities. These wastes are diversified in nature and have different physical features depending on their origin; thus, creating a classification is quite challenging.

The Municipality of Datu Saudi Ampatuan faces the following solid waste management concerns and issues: improper waste disposal, lack of waste reduction, lack of segregation at source, lack of backyard composting, and lack of disposal facility; littering and throwing of waste materials in public areas, drainage canals, road right-of-ways, creeks, and rivers; burning of plastics and other wastes elsewhere; lack of manpower, equipment, support logistics, and facilities to effectively implement components in solid waste management in accordance with RA 9003; and lack of functional structure to oversee, lead, monitor, and evaluate solid waste management operation (Ecological Solid Waste Management, 2021 of Datu Saudi Ampatuan, 2019-2029).

In light of the aforementioned concerns of the Local Government Unit, the researchers subsequently sought to determine the solid waste characterization and management in the Municipality of Datu Saudi Ampatuan, Maguindanao, specifically as follows; 1) determine the sources of the waste produced by the municipality, 2) assess the percentage of waste composition in terms of biodegradable, recyclable, residual, and special wastes produced daily from various waste sources, 3) the participation of the local residents in the solid waste practices indicators, and 4) formulate solid waste management strategies for policies development of the municipality of Datu Saudi Ampatuan. .

2. Materials and Methods

The study is descriptive quantitative research based on the data gathered and validated by the local government of the municipality of Datu Saudi Ampatuan in the province of Maguindanao, Philippines. The solid waste characterization was conducted through a method called Pre-WACS (Waste Analysis and Characterization Study) activities, consisting of 3 stages. First, the preparation and training to ensure the availability of all inputs and resources for the project. Subsequently, the actual characterization gives comprehensive instructions for the effective segregation and measurement of the various waste categories from representative trash sources and accurate recording. The final stage consists of data consolidation and analysis.

In order to acquire the data for this study, an inventory of the sources was created by classifying them according to the following categories: households, public markets, food establishments, general stores, industries, institutions, service centers, recreation centers, and health-related sources. Furthermore, all individuals that are non-household and are located within the public market, stores and transport terminals were considered a part of these categories.

The eight barangays that are currently covered by the waste collection, namely: Kabinge, Salbu, Kitapok, Kitango, Elian, Dapiawan, Madia, and Gawang, were all considered for determining the sample area. Since the area is a small-scale municipality with small to medium LGU, the sample size recommended by the DENR for waste characterization study and survey has to be at least 30. This recommended sample size is based on pre-sampling studies (which made use of the standard sample size demonstration formulas and other statistical tools) (EcoGov Project 2011). All this data is essential in waste development management since this will aid in assessing the success of recycling and initiating trash reduction. Visually assessing waste on this basis will equate to whether recyclables are poorly separated and will enable the researchers to see better target outreach, training, and communication initiatives. (Zhang et al., 2021).

3. Results and Discussion

3.1. Waste Source Generation and Composition

WACS is the process of obtaining data on the quantity (such as tons, cubic meters, and kilograms per household/day) and composition (such as biodegradable and non-biodegradable) of solid wastes generated from various sources. In the Municipality of Datu Saudi Ampatuan, the conduct of WACS incurred a challenging task. After a thorough recording, it is observed on the tabulated data in Table 1 that wastes generated in the municipality amounted to 5,567.22 kg. These composed a large percentage of biodegradable wastes from residential, commercial, institutional, and agro-industries amounting to 3,048.56 kg, while residual wastes ranked second amounting to 2,147.71 kg.

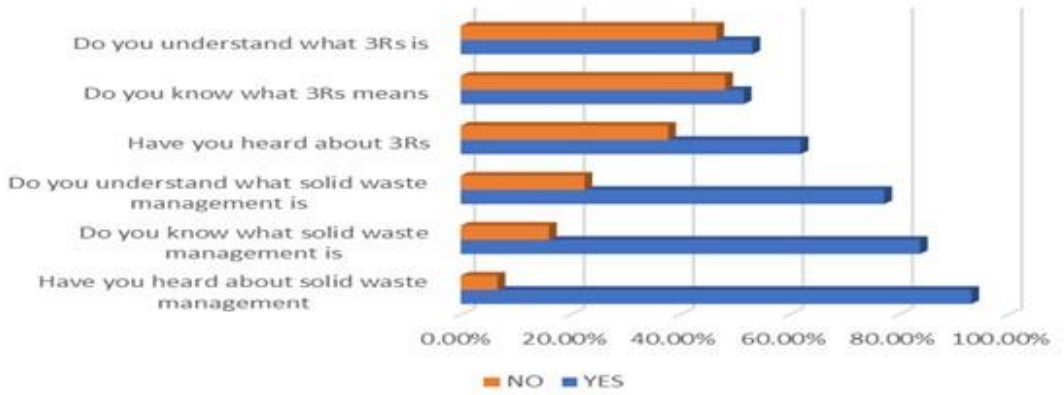

Fig 1. Residents' Perspectives on Solid Waste Management

Table 1. Quantity and composition of disposed waste from different contributing sectors of Municipality of Datu Saudi Ampatuan, Philippines

Major Waste Sources	Total Waste Generated		Composition of Waste Generated (kg/day)			
	kg/day	% Of Total Waste Generation	Biodegradable	Recyclable	Residual	Special Waste
Residential	1,622.73	29.15	828.12	119.24	646.35	29.02
Commercial	1,398.55	25.12	766.14	77.12	546.15	9.14
Institutional	1,445.62	25.97	714.18	70.21	634.18	27.05
Agro-Industries	1,100.32	19.76	740.12	20.15	321.03	19.02
Total	**5,567.22**	**100**	**3,048.56**	**286.72**	**2,147.71**	**84.23**
Total (%)		**100**	**54.76**	**5.15**	**38.58**	**1.51**

The waste composition in the locality based on Table 1 consists of biodegradable, 54.76%; residual, 38.58%; recyclable waste, 5.15%; and special waste, 1.5%. According to the data, the bulk of municipal waste is made up of biodegradable components that can be composted and used as soil conditioners (Fig 1). The WACS results offer a clear roadmap for developing feasible and successful waste diversion initiatives, including trash reduction, source-separation recycling, and backyard composting.

The study findings suggest that the bulk of waste produced in the municipality is biodegradable, and compostable, which can be used as an organic fertilizer for the gardeners or farmers of Datu Saudi Ampatuan. Similar results were reported by Breva (2020) showing that biodegradable waste accounts for the maximum percentage of waste generated, followed by recyclable waste, residual waste, and special waste, with the latter making up the least amount.

Table 2. Projected Quantity of Waste Generated Based on predicted Population of Municipality of Datu Saudi Ampatuan, Philippines

Year	Waste Gen/ Capita/ Day based on WACS (kg/day)	Projected Population	Daily Waste Generated (based on population) (kg/day)
2020	0.18	31,060	5,590.80
2021	0.18	32,134	5,784.12
2022	0.18	33,245	5,984.10
2023	0.18	34,395	6,191.10
2024	0.18	35,585	6,406.30
2025	0.18	36,816	6,626.88
2026	0.18	38,089	6,856.02
2027	0.18	39,406	7,093.08
2028	0.18	40,769	7,338.42
2029	0.18	42,179	7,592.22
2030	0.18	43,638	7,854.84

Fig 2. Environmental Awareness Assessment among the residents of the Municipality of Datu Saudi Ampatuan

On average 0.18 kg of waste per capita is disposed of on daily basis. It includes all discarded materials and waste, whether or not they are later recycled or disposed of in a landfill. Waste generation rates for residential and commercial activities can be used to estimate the impact of new development on the local waste stream (Calrecycle, 2019).

The growing population of the Municipality of Datu Saudi Ampatuan leads to an increase in the amount of solid waste, which poses serious threats to the environment including underground water. It has a direct impact on the availability of resources and contributes to waste generation. With a current population of 31,060 as of the 2020 Census of Population and an annual population growth rate of 3.46%, Table 2 displays the predicted amount of garbage generated based on population predictions.

3.2. Solid Waste Participation of Residents

The data gathered in this survey constitute the perception of the residents regarding their solid waste management and its current status within their households and in the community. A structured solid waste management practices indicators statement was used in this study. The survey results imply that 51.6% of the respondents are the head of the household with 41.9% of their household members within the range of five to eight persons per family.

This indicates larger family sizes in the area leading to higher solid waste generation. In such areas, the 3Rs (Reduce, Reuse, and Recycle) strategy must be implemented for proper waste disposal and management. However, only 62.1% of the respondents know about 3Rs, and 53.3% understand what it means. Residents' concerns in the area lie in solid waste littering and its effect on human health and the environment. Furthermore, they also have complaints about waste odors, rats, and flies.

Solid waste disposal is mainly collected through a public collection service every once a week, but only 17.2% anticipate the garbage truck and 34.5% use a large public bin for their disposal, 51.7% of the respondents admit that they use an open space area as their waste disposal or disposed it near their residential home. Additionally, it was found that people in the municipality dump their waste alongside the garbage bins instead of putting it inside because they are accustomed to seeing the unsegregated bins and the widespread litter around the bins.

The survey also assesses the residents' environmental awareness (Fig. 2) with 74.2% of the respondents have participated in any clean-up drive activities in the area this year. They also agree that waste management is an environmental problem and can be lessened if managed properly. The most common suggestion is the proper relaying of information from the LGU down to the BLGU. Some residents also proposed that proper waste management advocacy can be one of the solutions, while others state that solid waste implementation should be tightened and correctly pursued.

Table 3. Recommended Waste Reduction Scheme by Waste Sources

Source of Waste	Waste Reduction Scheme	Implementation Schedule
Public Market	Adoption of 3Rs Promotion of reusable packs for items Large bin disposal must be designated in the corners of the market	1st quarter of the year, followed by the assessment of 2nd quarter
Business Establishments	Strategically adopt the 3Rs principle Establish an onsite sub-MRFs	1st quarter of the year, followed by the assessment of 2nd quarter
Schools	Discourage the selling and buying of junk foods within the school premises Strategically adopt the 3Rs principle Establish MRF and composting facilities	2nd quarter of the year, followed by the assessment of 3rd quarter
Rural Health Unit	Strategically adopt the 3Rs principle Segregate and dispose special wastes in the septic vault	3rd quarter of the year, followed by the assessment of 4th quarter
Institutions	Strategically adopt the 3Rs principle Adopt segregation at the source	3rd quarter of the year, followed by the assessment of 4th quarter
Households	Strategically adopt the 3Rs principle Practice waste reduction and segregation at source Purok Composting and clean up drive Promote the Barangay vegetation Program	4th quarter, followed by monthly assessment of the barangay by purok

3.3. Solid Waste Management Strategies for Policy Development

3.3.1. Waste Reduction

Source reduction must be promoted through targeted strategies and activities directed at major waste generators such as public markets, business districts, institutions, and households. The researcher will recommend waste reduction schemes to waste generators, as shown in the Table 3.

Among Among other recommendations, the adoption of 3Rs strategy in urban areas, especially public spaces, has been very helpful in waste reduction. Therefore, it can play a vital role in environmental protection by reducing greenhouse gas emissions and turning waste into valuable resources (Chowdhury et al., 2014). Another strategy is the promotion of reusable packaging which can demonstrate environmental and potential economic benefits over single-use packaging (Fernandez et al., 2021; Ibrahim et al., 2022; Kan and Miller, 2022). Potential markets for reusable or biodegradable packaging are food and beverages, agriculture, household goods, industrial products, and e-commerce (Moraczewski et al., 2020; Serrano-Ruiz et al., 2021).

Reusable packaging can help to combat plastic pollution and its catastrophic impacts on the environment, wildlife, and humans (Coelho et al., 2020; Gunaalan et al., 2020; Rodrigues et al., 2019). The segregation at source and composting are also considered in this study as recommendations because waste segregation can help to preserve the value of recyclable materials, can make them more accessible to informal recycling workers, and can reduce overall waste flow. Additionally, the waste source can differentiate biodegradable materials that can be used in the composting process. (Otitoju and Send, 2014).

3.3.2. Collection Scheme

The municipality's garbage collection service covers the urban barangays of Salbu, Kitango, and Dapiawan. According to the municipality, they are in the process of establishing additional MRFs in pilot sites, which includes conducting capacity building for partners and other stakeholders, allocating personnel, resources, and equipment, and identifying potential and suitable locations for SLF development. It is still difficult for them to conduct simultaneous collections every week. To effectively generate an active and efficient garbage collection operation, the collection coverage, route, collection method, availability of manpower, resources, and facilities should be given great emphasis by the municipality and the Solid Waste Management Board. A suited proposal like an enactment of local policies on "Waste Reduction at Source", Backyard Composting", and "No Segregation, No Collection" would strengthen the campaign and initiative to attain diversion targets and transformation of community perspective in helping the municipality to be developed and productive.

3.3.3. Segregation, Recycling, and Composting

The municipalities have an advocacy and strategic initiative on segregating, recycling, and composting from urban to rural barangays. It is a continuous endeavor to assess the reception and degree of involvement and participation of the communities. Without segregation, garbage collection is impacted by the amount of labor needed, the number of trips made each day, the need for additional buildings and equipment to manage housing and storage issues, and maintenance issues with disposal facilities. The researcher's strategy for segregation consists of creating an incentive program for barangays to follow best practices for waste reduction and segregation at source, which would be backed by the adoption of local ordinances.

3.3.4. Composting/Management of Biodegradable Wastes

The Overall Strategies for Managing Biodegradable Wastes. Proposal, enactment, and implementation of the followings:

- Municipal Ordinance on Regulating the Burning of Agricultural Wastes
- Municipal Ordinance Prohibiting Littering in Public Places
- The 3Rs Principle to all waste generators
- The Environment Code of Datu Saudi Ampatuan and for Other Purposes
- "No Segregation, No Collection" Policy
- Municipal Ordinance on Mandatory Backyard Composting
- The strategies for start-up implementation, monitoring, and enforcement of the recommended management of biodegradable waste are the following:
- Advocate for proper instruction on effective composting and provide the households, people, and groups with the objectives of fostering unity and cooperation
- Propose, enact and implement local policy on mandatory backyard composting
- Launch a contest on backyard composting, gardening, and vegetation
- Establish market support for the produce from composting.

3.3.5. Composting/Management of Biodegradable Wastes

To continually support the barangays for the attainment of goals in solid waste management, technical and financial assistance through training, provision of facilities and motivational incentives must be provided. Showcasing good practices at the barangay level through collaboration with partner agencies is the first step in the pursuit of good governance. The proposed acquisition of heavy equipment and other facilities will help fast-track the job in relation to solid waste management services to barangays and communities.

3.3.6. Performance Monitoring

The An annual SWM plan of activities should be created to monitor the performance of solid waste management. In terms of garbage collection, including its route, schedule, and disposal, waste reduction and source segregation, recycling, the presence of junk shops or ambulant junk buyers, composting, the creation of processed materials, advocacy, and waste reduction and source segregation will all be monitored and evaluated according to standards and parameters that are established. These key result areas need to be monitored and evaluated in order to determine their progress and development in the performance of the mandate pursuant to RA 9003.

3.3.7. Incentive Program

The Municipality of Datu Saudi Ampatuan should promote and develop a semi-annual program with motivational incentive components for individuals, households, barangays, and institutions. The semi-annual conduct in a contest form on "Backyard Gardening", "Segregation and Composting", "Recycling and Marketing", and "Enforcement" program is an initiative that truly encourages stakeholders to be involved, participate, and understand that solid waste management is an everybody's concern.

4. Conclusion

WACS The waste characterization information helps in planning waste reduction, recycling programs, and conserving money and resources which can evidently aid the municipality in its present solid waste management problems. The effort in solid waste reduction is not mainly the responsibility of the local government of Datu Saudi Ampatuan but also of the local community. A simple act of the 3Rs and composting method can easily be done at home. The community can help as the government pursues solid waste management planning, such as enacting policies regarding waste management, efficient IEC campaigns, segregation at source, and even a reward system, by essentially supporting the policies and adhering to the rules and regulations in their upcoming

solid waste management implementations. Finally, let us be reminded to be a part of the solution, not a part of the pollution.

Competing Interest Statement: All authors have read and agreed to the published version of the manuscript.

List of Abbreviations: WACS = Waste Analysis and Characterization Study; PENRO = Provincial Environment and Natural Resources Office; CHED = Commission on Higher education; MRF = Material Recovery Facilities, 3R's =Reduce Reuse Recycle; SWM = Solid Waste Management; LGU = Local Government Unit and BLGU = Barangay Local Government Unit.

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