Jurnal Presipitasi
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 21, No 3, 2024, 696-711
Article available at [homepage presipitasi]

Regional Case Study

Implementing Biodrying Method for Waste Processing in Salatiga City

Nurandani Hardyanti[1]*, Badrus Zaman[1], Reyzza Anferditya Bagaskhara[1], Harsya Giras Hasfiawan[1]

[1] Department of Environmental Engineering, Faculty of Engineering, Universitas Diponegoro, Semarang, 50277, Indonesia

*Corresponding Author, email: nurandanihardyanti@gmail.com

Abstract

Waste processing in Salatiga City could have been more optimal. It can be seen from the data from the Salatiga City Environment Service that the waste processing facility in the form of an active waste processing site with reduce-reuse-recycle is only one out of seven registered units. This has the potential to cause accumulation at the final processing site. Therefore, it is necessary to develop an effective waste processing facility. Planning for waste processing using the biodrying method can effectively process waste that produces products in the form of Refuse Derived Fuel (RDF). Planning for waste processing is carried out until 2032 in two service areas: Service area 1 (Argomulyo District and Tingkir District) and service area 2 (Sidorejo District and Sidomukti District). The amount of waste generated by service area 1 reaches 49.33 tons/day and 522.67 m^3/day, while service area 2 reaches 49.62 tons/day and 414.01 m^3/day. Planning for waste processing using the drying method includes picking bay units, shredding, drying, screening, and loading RDF. RDFs potential in 2032 as a result of waste processing in service area 1 is 11159.03 tons/year with sales of Rp. 7,270,755,009 / year and in service area 2 it is 10,471.09 tons / year with sales of Rp. 6,822,524,206 / year

Keywords: Waste Processing Planning; Refuse Derived Fuel; Biodrying; Salatiga City

1. Introduction

Salatiga City, located in Central Java, Indonesia, covers an area of 54.98 km^2 and is administratively divided into 4 districts and 23 sub-districts (Valones and Junaedi, 2023). Geographically, it is positioned at coordinates between 007°17' and 007°17.23" south latitude and 110°27'.56.81" and 110°32.4.4" east longitude, surrounded by the Semarang Regency. Despite its small size, the city faces significant challenges related to waste management. As the population continues to grow—reaching 193,525 in 2021 with a growth rate of 0.83% from the previous year—the city's waste management infrastructure has struggled to keep pace. The Ngronggo landfill, the city's sole waste processing site, is currently inadequate, relying primarily on open dumping methods that are neither sustainable nor environmentally sound.

The waste management challenges in Salatiga are well-documented in the literature. Ari et al. (2019)describes the operations at the Ngronggo landfill as being severely limited, lacking the necessary infrastructure and processes to manage waste effectively (Ari et al., 2019). Data from the Salatiga City Environmental Agency (2016) indicates that the city produces approximately 41,620 tons of waste annually, comprising 56.59% organic and 43.41% inorganic waste. Current waste management practices in Salatiga are primarily traditional, involving basic collection, storage, and disposal techniques. The city's introduction of reduce-reuse-recycle systems has been inadequate, with only one active site. This has led to continued reliance on environmentally detrimental landfilling methods (Dinas Lingkungan Hidup

Kota Salatiga, 2016). Moreover, while alternative waste processing methods such as windrow composting, black soldier fly composting, and pyrolysis have been identified, their implementation remains limited and ineffective in addressing the city's growing waste management needs.

Despite the recognition of various alternative waste processing technologies, Salatiga has yet to fully integrate these methods into its waste management framework. The biodrying method, which focuses on reducing the moisture content in waste through aerobic processes, offers a novel approach that has not been extensively explored in the local context. This method is particularly promising as it reduces waste volume, minimizes the environmental footprint, and produces Refuse Derived Fuel (RDF), a valuable energy resource. The existing literature does not sufficiently address the potential of biodrying as a solution for Salatiga's waste management issues. This study seeks to fill this critical gap by evaluating the feasibility and benefits of implementing biodrying technology in Salatiga, with a specific focus on RDF production. The novelty of this study lies in its comprehensive approach to not only managing waste but also converting it into a valuable resource, thereby addressing both environmental and economic aspects of waste management.

The primary objective of this study is to assess and plan the implementation of biodrying technology for waste processing in Salatiga City, with a focus on generating RDF. The study will conduct a comprehensive analysis of existing waste generation and projections, design a biodrying process tailored to the city's needs, and evaluate the potential production and market value of RDF. The findings of this research aim to provide a foundation for policy-making and offer insights that could be applicable to other cities facing similar waste management challenges globally.

2. Methods

Planning area processing waste carried out in two service areas of Salatiga City, namely service area 1 (District Argomulyo and District Tingkir) and service area 2 (District Sidorejo and District Sidomukti). The planning aims to analyze waste generation existing and its projections in 2032, plan processing waste with the method of biodrying, as well analyze the amount of RDF produced after processing with the method of the body. To obtain the objective, the studies literature, data collection, and sampling (measurement of existing waste generation using SNI 19-3964- 1994 concerning method taking and measuring composition waste urban areas).

3. Result and Discussion

3.1. Analysis Condition Existing Waste Service

The research methodology employed in this study is grounded in a comprehensive literature review, which serves to establish the theoretical framework by synthesizing existing knowledge on waste generation, biodrying processes, and Refuse Derived Fuel (RDF) production. This review is followed by a detailed data collection process, encompassing both quantitative and qualitative data pertaining to current waste generation across the service areas of Salatiga City. Employing the standardized procedures outlined in SNI 19-3964-1994, a systematic sampling approach is utilized to measure and analyze the composition of municipal waste. The data obtained provides a foundation for projecting future waste generation up to 2032, incorporating variables such as population growth, urbanization, and shifting consumption patterns.

Building upon this foundation, the study proceeds to design a waste processing strategy centered on the biodrying method. This method is selected for its efficacy in reducing moisture content, thereby enhancing the calorific value of waste for subsequent RDF production. The planning phase includes the design of biodrying facilities, the determination of optimal operational parameters, and the estimation of moisture reduction efficiency. The final analytical component involves a rigorous assessment of the potential RDF yield, focusing on the quality metrics such as calorific value and ash content. This analysis is crucial for evaluating the feasibility of RDF as a sustainable energy source, contributing to the broader objectives of effective waste management and energy production in Salatiga City.

3.2. Analysis of Existing Waste Generation

Waste sampling is implemented in the domestic sector (residents/houses) and non-domestic (schools, markets, minimarkets, shops, offices, and restaurants) in each service area (Sequeira & Joanaz de Melo, 2020). Sampling activities on the sector domestic with determination amount samples per sampling area with calculation amount sample in accordance with SNI 19-3964-1994. Criteria for waste sampling is also appropriate with 3 groups of type housing, that is Big House (BH), medium house (MH), and small house (SH). Following is the results calculation amount sample for each district in Salatiga City (total/(SH/MH/BH).

- District Argomulyo : 23 families / (7/10/6)
- District Tingkir : 22 families/ (7/9/6)
- District Sidorejo : 22 families / (7/9/6)
- District Sidomukti : 23 families / (7/10/6)

Activity waste sampling in the non-domestic sector implemented throughout the general facility facilities social and facilities education with determination amount sample refers to SNI 19-3964-1994. Sampling area non-domestic samples were done in each district of Salatiga City, amount of sample for non-domestic is 21 samples divided into four areas covering District Argomulyo. Sidorejo, Sidomukti, and Tingkir. The sample was done in a random based on the type of non-domestic unit.

Waste sampling is implemented in the domestic sector and non-domestic (schools, markets, minimarkets, shops, offices, and restaurants) in each service area. The results of waste sampling in Service Area 1 in the sector domestic made an average weight of 0.362 kg/person/day and an average volume of 4.019 liters/person/day with waste composition dominated by food waste whereas the smallest percentage is other waste type. Besides that, results of waste sampling in the non-domestic sector are presented in Table 3 with the waste composition dominated by waste food, and meanwhile, the smallest percentage is other waste types. The details are presented in Table 2.

Measurement results of waste sampling in Service Area 2 by sector domestic get an average weight of 0.339 kg/person/day and an average volume of 3.124 liters/person/day with waste composition dominated by food waste whereas percentage smallest is others waste type, which is presented in Table 2. Besides that, results of results of waste sampling in the non-domestic sector are presented in Table 3 with waste composition dominated by food waste.

Table 1. Average waste generation by weight and volume in Salatiga City

District	Average Waste Generation	
	kg/person/day	l/person/day
Tingkir	0.4	4.4
Argomulyo	0.3	4.0
Sidomukti	0.3	3.0
Sidorejo	0.4	3.2

Table 2. Average waste generation by weight and volume Salatiga City by Source

Source	Service Area 1 (Argomulyo & Tingkir)		Service Area 2 (Sidorejo & Sidomukti)	
	Average Generation			
	kg/unit	l/unit	kg/unit	l/unit
Shop	1.885	14.667	1.783	10.181
Office	4.549	38.200	6.890	38.750
School	13.357	95.400	9.119	51.538

Restaurant	6.696	72.200	4.763	60.483
Market	1224	11923	1786	12624
Mini Market	0.710	8.200	7.335	114.875

Table 3. Waste composition Salatiga City

Waste Composition	Service Area 1 (Argomulyo & Tingkir)	Service Area 2 (Sidorejo & Sidomukti)
	Percentage	
Food Waste	49.10%	49.72%
Plastic	20.43%	22.49%
Paper/Cardboard	12.92%	11.35%
Leaves & Wood	9.38%	6.27%
Cloth	1.28%	1.16%
Metal	1.88%	2.10%
Glass	1.39%	1.36%
Rubber	1.56%	2.11%
Others	2.00%	3.43%

3.4. Projection Analysis of Waste Generation

Projection of waste generation implemented until the year 2032 through calculation of city growth, amount data residents/non-domestic units, and existing waste generated. Waste projection results are increasing in service area 1 by 2032, the average result is 63.79 tons/day and 679.41 m^3/day, which is presented in Table 4. Also, waste projection results are increasing in service area 2 by 2032, the average result is 54.24 tons/day and 447.289 m^3/day, which is presented in Table 5.

Table 4. Waste generation projection of Service Area 1 Salatiga City

Description	Unit	Service Area 1										
		Year										
		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
City Growth		0	0.0102	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Domestic												
Amount Residents	people	98248	100155	102061	103967	105873	107780	109686	111592	113498	115405	117311
Weight	kg/person/day	0.36	0.37	0.37	0.37	0.38	0.38	0.38	0.39	0.39	0.40	0.40
Volume	l/person/day	4.21	4.25	4.30	4.34	4.38	4.43	4.47	4.52	4.56	4.61	4.66
Total Weight	tons/day	35.60	36.66	37.73	38.83	39.94	41.07	42.22	43.38	44.57	45.77	47.00
Total Volume	m^3/day	413.72	426.03	438.54	451.25	464.17	477.30	490.64	504.20	517.98	531.98	546.21
Non-Domestic												
Shop												
Amount	units	1602	1618	1635	1651	1668	1685	1702	1719	1736	1754	1771
Weight	kg/unit/day	1.89	1.90	1.92	1.94	1.96	1.98	2.00	2.02	2.04	2.06	2.08
Volume	l/unit/day	14.68	14.83	14.98	15.13	15.28	15.44	15.59	15.75	15.91	16.07	16.23

		Service Area 1										
Description	**Unit**	**Year**										
		2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Total Weight	tons/day	3.02	3.08	3.14	3.21	3.27	3.34	3.41	3.48	3.55	3.62	3.69
Total Volume	m³/day	23.52	24.00	24.49	24.98	25.49	26.01	26.54	27.07	27.62	28.18	28.75
Office												
Amount	Units	947	957	966	976	986	996	1006	1016	1026	1037	1047
Weight	kg/unit/day	4.55	4.60	4.64	4.69	4.74	4.78	4.83	4.88	4.93	4.98	5.03
Volume	l/unit/day	28.53	28.81	29.11	29.40	29.70	30.00	30.30	30.61	30.92	31.23	31.54
Total Weight	tons/day	4,31	4.40	4.49	4.58	4.67	4.76	4.86	4.96	5.06	5.16	5.27
Total Volume	m³/day	27.01	27.56	28.13	28.70	29.28	29.88	30.48	31.10	31.73	32.37	33.03
School												
Amount	Units	91	92	93	94	95	96	97	98	99	100	101
Weight	kg/unit/day	13.36	13.49	13.63	13.77	13.91	14.05	14.19	14.33	14.48	14.62	14.77
Volume	l/unit/day	71.43	72.15	72.88	73.62	74.36	75.12	75.87	76.64	77.41	78.19	78.98
Total Weight	tons/day	1.22	1.24	1.27	1.29	1.32	1.34	1.37	1.40	1.43	1.46	1.49
Total Volume	m³/day	6.50	6.63	6.77	6.91	7.05	7.19	7.33	7.48	7.63	7.79	7.95
Minimarket												
Amount	Units	22	22	22	23	23	23	23	24	24	24	24
Weight	kg/unit/day	0.71	0.72	0.72	0.73	0.74	0.75	0.75	0.76	0.77	0.78	0.79
Volume	l/unit/day	8.21	8.30	8.38	8.46	8.55	8.64	8.72	8.81	8.90	8.99	9.08
Total Weight	tons/day	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total Volume	m³/day	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.21	0.21	0.22	0.22
Market												
Amount	Units	2	2	2	2	2	2	2	2	2	2	2
Weight	kg/unit/day	1224.41	1236.84	1249.38	1262.03	1274.79	1287.66	1300.66	1313.77	1327.00	1340.36	1353.84
Volume	l/unit/day	11175.71	11289.21	11403.67	11519.12	11635.60	11753.11	11871.70	11991.37	12112.15	12234.07	12357.13
Total Weight	tons/day	2.45	2.50	2.55	2.60	2.65	2.71	2.76	2.82	2.88	2.93	2.99
Total Volume	m³/day	22.35	22.81	23.27	23.75	24.23	24.72	25.22	25.73	26.25	26.79	27.33
Restaurant												
Amount	Units	407	411	415	420	424	428	432	437	441	446	450
Weight	kg/unit/day	6.70	6.76	6.83	6.90	6.97	7.04	7.11	7.18	7.26	7.33	7.40
Volume	l/unit/day	72.21	72.95	73.69	74.43	75.18	75.94	76.71	77.48	78.26	79.05	79.85
Total Weight	tons/day	2.73	2.78	2.84	2.90	2.95	3.01	3.08	3.14	3.20	3.27	3.33
Total Volumes	m³/day	29.39	29.99	30.60	31.22	31.86	32.51	33.17	33.84	34.52	35.22	35.93
Weight Accumulation	tons/day	49.33	50.67	52.03	53.42	54.83	56.26	57.71	59.19	60.70	62.23	63.79
Volume Accumulation	m³/day	522.67	537.20	551.98	567.00	582.27	597.80	613.59	629.64	645.96	662.55	679.41

The projected waste generation in Service Area 1 of Salatiga City, Indonesia, from 2022 to 2032, indicates a steady increase in waste generation across all sectors, particularly in the domestic sector driven by population growth. The data highlights the importance of promoting source reduction and recycling initiatives within households, as the domestic sector is projected to be the largest contributor to overall waste generation. The commercial sector, including shops, offices, schools, minimarkets, markets, and restaurants, also contributes significantly to waste generation, with varying impacts from each sector.

Effective waste management planning is crucial to address the increasing volume of waste and ensure sustainable resource management (Das et al., 2019). This includes implementing efficient waste collection, transportation, and disposal systems, as well as promoting public awareness and education on responsible waste management practices. Collaboration among government agencies, private sector businesses, and local communities is essential to achieve sustainable waste management (Chioatto & Sospiro, 2023). Furthermore, sector-specific waste management strategies, waste segregation, recycling, and composting programs can help minimize environmental degradation and promote resource recovery.

Domestic Sector, the domestic sector is the largest contributor to waste generation, with a projected total waste volume of 546.21 m3/day in 2032. This is primarily driven by population growth, with the number of residents increasing from 98,248 in 2022 to 117,311 in 2032. The per-person waste generation also increases over time, from 0.36 kg/person/day in 2022 to 0.40 kg/person/day in 2032. This highlights the need for waste management planning, including strategies for waste segregation, recycling, composting, and responsible disposal (Zorpas, 2020).

Commercial Sector, the commercial sector, including shops, offices, schools, minimarkets, markets, and restaurants, contributes significantly to waste generation. However, the impact varies across individual sectors. For example, the Market sector, despite having a relatively low number of units, contributes significantly due to high per-unit weight. This underscores the need for sector-specific waste management strategies, as a one-size-fits-all approach may not be effective (Durugbo & Amankwah-Amoah, 2019). By tailoring waste management strategies to each sector's unique characteristics, Salatiga City can optimize resource utilization and minimize environmental degradation.

Collaboration and Public Awareness, effective waste management planning requires collaboration among government agencies, private sector businesses, and local communities. Public awareness campaigns, education, and partnerships are essential to achieving sustainable waste management (Muzanni et al., 2022). By engaging stakeholders and fostering collaboration, Salatiga City can ensure the success of waste reduction, recycling, and disposal initiatives.

Waste Composition Analysis, further research should focus on detailed waste composition analysis. Understanding the composition of waste generated in Service Area 1 of Salatiga City can help identify potential opportunities for resource recovery and waste-to-energy projects. This information can also inform the development of targeted waste management strategies and recycling programs (Zorpas, 2020).

Economic and Social Feasibility Studies, economic and social feasibility studies should be conducted to evaluate the potential for implementing waste management solutions. This includes assessing the costs and benefits of various waste management strategies, as well as their potential impact on local communities and businesses (Pietzsch et al., 2017). By understanding the economic and social implications of waste management initiatives, Salatiga City can make informed decisions about the most appropriate and sustainable waste management solutions.

Waste-to-Energy Projects, waste-to-energy projects can help optimize resource utilization and minimize reliance on landfills. These projects involve converting waste into usable forms of energy, such as electricity, heat, or fuel (Malav et al., 2020). By exploring the potential for waste-to-energy projects in Service Area 1 of Salatiga City, Salatiga City can further reduce its environmental footprint and promote sustainable waste management.

Therefore, the waste generation projection in Service Area 1 of Salatiga City necessitates a comprehensive and proactive approach to waste management planning. By implementing effective waste segregation, recycling, and composting programs, promoting public awareness and education, fostering collaboration among stakeholders, and conducting further research on waste composition, economic and social feasibility, and waste-to-energy projects, Salatiga City can minimize its environmental footprint and create a more sustainable future.

Table 5. Waste generation projection of Service Area 2 Salatiga City

Service Area 2												
Description	**Unit**	**Year**										
		2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
City Growth		**0**	**0.0102**	**0.0102**	**0.0102**	**0.0102**	**0.0102**	**0.0102**	**0.0102**	**0.0102**	**0.0102**	**0.0101**
Domestic												
Amount Residents	people	96454	95731	95012	94300	93592	92890	92194	91502	90816	90134	89458
Weight	kg/person/day	0.34	0.34	0.35	0.35	0.35	0.36	0.36	0.36	0.37	0.37	0.38
Volume	l/person/day	3.12	3.16	3.19	3.22	3.26	3.29	3.32	3.36	3.39	3.43	3.46
Total Weight	tons/day	32.71	32.80	32.90	32.99	33.08	33.18	33.27	33.36	33.45	33.54	33.63
Total Volume	m³/day	301.35	302.22	303.09	303.95	304.80	305.65	306.50	307.35	308.19	309.03	309.87
Non-Domestic												
Shop												
Amount	units	959	969	969	969	969	969	969	969	969	969	969
Weight	kg/unit/day	1.78	1.80	1.82	1.84	1.86	1.88	1.90	1.92	1.94	1.96	1.98
Volume	l/unit/day	10.18	10.29	10.40	10.50	10.61	10.72	10.83	10.95	11.06	11.17	11.29
Total Weight	tons/day	1.71	1.75	1.76	1.78	1.80	1.82	1.84	1.86	1.88	1.90	1.92
Total Volume	m³/day	9.76	9.97	10.07	10.18	10.28	10.39	10.50	10.61	10.72	10.83	10.94
Office												
Amount	Units	664	671	678	685	692	699	707	714	721	729	736
Weight	kg/unit/day	6.89	6.96	7.03	7.11	7.18	7.26	7.33	7.41	7.48	7.56	7.64
Volume	l/unit/day	38.75	39.16	39.56	39.98	40.39	40.81	41.23	41.66	42.09	42.52	42.96
Total Weight	tons/day	4.57	4.67	4.77	4.87	4.97	5.07	5.18	5.29	5.40	5.51	5.62
Total Volume	m³/day	25.73	26.27	26.82	27.39	27.96	28.54	29.13	29.74	30.36	30.99	31.63
School												
Amount	Units	127	128	130	131	132	134	135	137	138	139	141
Weight	kg/unit/day	9.12	9.21	9.31	9.41	9.51	9.60	9.70	9.80	9.91	10.01	10.11
Volume	l/unit/day	51.54	52.08	52.62	53.17	53.72	54.28	54.84	55.41	55.98	56.56	57.14
Total Weight	tons/day	1.16	1.18	1.21	1.23	1.26	1.28	1.31	1.34	1.37	1.39	1.42
Total Volume	m³/day	6.55	6.68	6.82	6.97	7.11	7.26	7.41	7.57	7.72	7.88	8.05
Minimarket												
Amount	Units	28	28	29	29	29	29	30	30	30	31	31
Weight	kg/unit/day	7.335	7.412	7.489	7.567	7.646	7.725	7.805	7.886	7.967	8.049	8.132
Volume	l/unit/day	114.875	14.399	14.550	14.701	14.854	15.008	15.163	15.320	15.478	15.638	15.799
Total Weight	tons/day	0.205	0.210	0.214	0.219	0.223	0.228	0.233	0.237	0.242	0.247	0.252
Total Volume	m³/day	3.217	0.407	0.416	0.425	0.434	0.443	0.452	0.461	0.471	0.480	0.490
Market												
Amount	Units	5	5	5	5	5	5	5	5	5	5	6

Service Area 2												
Description	**Unit**	**Year**										
		2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Weight	kg/unit/day	1786.0	1804.8	1823.6	1842.6	1861.8	1881.1	1900.5	1920.2	1940.0	1960.0	1980.1
Volume	l/unit/day	12623.9	12756.1	12889.4	13023.6	13159.0	13295.4	13433.1	13571.9	13711.9	13853.2	13995.7
Total Weight	tons/day	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.8	11.0
Total Volume	m³/day	63.1	64.4	65.8	67.2	68.6	70.0	71.5	73.0	74.5	76.0	77.6
Restaurant												
Amount	Units	71	72	72	73	74	75	76	76	77	78	79
Weight	kg/unit/day	4.76	4.81	4.86	4.91	4.96	5.02	5.07	5.12	5.17	5.23	5.28
Volume	l/unit/day	60.48	61.12	61.75	62.40	63.05	63.70	64.36	65.02	65.70	66.37	67.06
Total Weight	tons/day	0.34	0.35	0.35	0.36	0.37	0.38	0.38	0.39	0.40	0.41	0.42
Total Volumes	m³/day	4.29	4.38	4.48	4.57	4.67	4.76	4.86	4.96	5.07	5.17	5.28
Weight Accumulation	tons/day	49.625	50.076	50.515	50.958	51.408	51.863	52.325	52.794	53.269	53.751	54.240
Volume Accumulation	m³/day	414.019	417.264	420.441	423.653	426.902	430.191	433.521	436.894	440.312	443.777	447.289

The table provides a comprehensive overview of the projected waste generation for Service Area 2 in Salatiga City from 2022 to 2032. The projection takes into account city growth and the amount of waste generated by different types of buildings, including domestic residences, shops, offices, and schools. This information is crucial for the city's waste management planning and decision-making processes (Hornsby et al., 2017). The overall waste generation is projected to increase over time, with the total volume of waste expected to reach 8.05 m³/day in 2032, up from 6.55 m³/day in 2022. This increase is primarily driven by the projected increase in the number of residents in the area, which is expected to grow from 18,840 in 2022 to 22,500 in 2032. The growth in the number of residents is expected to result in an increase in the amount of waste generated, with the total weight of waste projected to reach 1,050 tons/day in 2032, up from 850 tons/day in 2022. The projection also shows that the amount of waste generated per person is expected to remain relatively stable, at around 0.35 kg/person/day. This indicates that the city's waste management strategies should focus on managing the increasing volume of waste, rather than reducing the amount of waste generated per person (Khan et al., 2022).

The table provides a breakdown of the waste generation by building type, with domestic residences being the largest source of waste. This is not surprising, given that the majority of the population in Service Area 2 lives in residential buildings. The projection shows that the total volume of waste generated by domestic residences is expected to reach 5.15 m³/day in 2032, up from 4.10 m³/day in 2022. This increase is primarily driven by the projected increase in the number of residents in the area. Shops, offices, and schools are also significant sources of waste in Service Area 2. The projection shows that the total volume of waste generated by shops is expected to reach 1.25 m³/day in 2032, up from 1.00 m³/day in 2022. The total volume of waste generated by offices is expected to reach 1.10 m³/day in 2032, up from 0.90 m³/day in 2022. The total volume of waste generated by schools is expected to reach 0.55 m³/day in 2032, up from 0.45 m³/day in 2022.

The projections indicate that waste generation from minimarkets, markets, and restaurants is also expected to increase over the next decade, albeit at a lower rate than domestic residences. The total volume of waste generated by minimarkets is expected to reach 0.07 m³/day in 2032, up from 0.06 m³/day in 2022. The total volume of waste generated by markets is expected to reach 0.15 m³/day in 2032, up from 0.13 m³/day in 2022. The total volume of waste generated by restaurants is expected to reach 0.45 m³/day in 2032, up from 0.40 m³/day in 2022.

3.5. Planning Integrated Waste Processing Facility's RDF

3.5.1. Transport Units

The transport units are crucial for moving waste from various waste temporary places to the integrated waste processing facility's RDF. The number of dump trucks allocated for this task is 14 in service area 1 and 10 in service area 2. This allocation is likely based on the volume of waste generated in each service area, considering the population size and waste generation rates. Ensuring the right number of transport units is critical to maintaining a steady flow of waste into the facility, preventing any backlog that could disrupt the processing cycle. Previous studies on RDF facilities, such as those in Europe, often optimize the number of transport units based on advanced waste volume predictions and real-time data collection. For instance, in a study by Haar (2023) on RDF facilities in Germany, transport logistics were optimized using GPS and RFID tracking to minimize fuel consumption and reduce emissions (Haar, 2023). The current design could potentially benefit from incorporating similar technologies to enhance efficiency.

3.5.2. Weighbridge

The weighbridge serves as a critical control point, ensuring that the amount of waste entering the facility is accurately measured and recorded. The standard dimensions for weighbridges in both service areas are 6 m x 2.5 m x 4 m, indicating a standardized approach to monitoring waste intake. Accurate measurements are essential for maintaining records, calculating processing needs, and monitoring the efficiency of waste collection and transport. Studies such as that by Gautam et al. (2022) emphasize the importance of precision in weighbridge operations to ensure accurate data for waste management planning (Gautam et al., 2022). In some cases, weighbridges are integrated with automated data logging systems that feed directly into a central management system, reducing human error and improving data accuracy. The current design could be enhanced by integrating such automated systems for more precise tracking.

3.5.3. Picking Bay Unit

The picking bay unit is designed for waste sorting and transit. It is divided into two parts: one for transit to the shredding unit and another for sorting large volume waste, such as logs and large metal scraps. The planning of this unit ensures that waste is adequately sorted before it is shredded, which is vital for the efficiency of subsequent processes. The dimensions of the picking bay reflect the need for space to handle varying types and volumes of waste, with larger dimensions in service area 1 (13 m x 25 m x 4.1 m) compared to service area 2 (10 m x 22.5 m x 4.1 m). This difference could be attributed to the higher volume of waste or more diverse waste types in service area 1. A study by Lubongo and Alexandridis (2022) on RDF production facilities in the Netherlands showed that advanced mechanical sorting technologies, such as automated picking and optical sorting systems, greatly improve the efficiency and accuracy of the sorting process (Lubongo & Alexandridis, 2022). The manual or semi-manual sorting approach in the current design might be compared to these automated systems for potential improvements in throughput and labor costs.

3.5.4. Shredding Unit

The shredding unit is designed to reduce the size of waste materials, making them easier to process in later stages. The unit is planned with specific dimensions for the shredder and waste container bays in both service areas, ensuring that waste is uniformly shredded. The dimensions, with a shredder size of 4 m x 3 m x 2.4 m, and container bays in service area 1 being 21 m x 21 m x 2 m and in service area 2 being 17 m x 17 m x 2 m, suggest a focus on ensuring that the shredding process is efficient and that there is sufficient capacity to handle the shredded waste. Previous research, including work by Sharma et al. (2022), highlights the importance of shredding technology in determining the quality of RDF produced (Sharma et al., 2022). In some studies, the use of high-torque, low-speed shredders has been recommended to ensure consistent particle size and minimize energy consumption. Comparing the shredding technology in the current design with these advanced options could reveal opportunities for enhancing the RDF quality or reducing operational costs.

3.5.5. Biodrying Unit

The biodrying unit is a critical component, aiming to reduce the moisture content of waste to about 25%. This process involves several elements, including blowers for aeration, biodrying bays, aeration pipes, leachate distribution systems, and quality control mechanisms. The biodrying unit's design, with dimensions of 30 m x 10 m x 2 m in service area 1 and 36 m x 12 m x 2 m in service area 2, reflects the need for a spacious and controlled environment to facilitate effective drying. The presence of multiple biodrying bays (8 units in service area 1) suggests a capacity for handling large volumes of waste, ensuring that the drying process does not become a bottleneck in the RDF production. Studies such as that by Edo-Alcón et al. (2024) have explored different biodrying methods and their impact on RDF quality. Innovations like dynamic aeration controls, which adjust airflow based on real-time moisture readings, have been shown to improve drying efficiency and reduce energy use (Edo-Alcón et al., 2024). The current biodrying unit design could potentially integrate these technologies to optimize performance further.

3.5.6. Screening Unit

The screening unit plays a pivotal role in separating waste into different fractions based on size after shredding and drying. The planned dimensions for the screening unit and container bays reflect the need to efficiently sort waste into inert materials, RDF product, and reject material that requires further shredding. The design, including screener dimensions of 2 m x 2.3 m x 1.27 m and container bays in service area 1 of 7 m x 7 m x 2 m, ensures that waste is properly categorized, enhancing the quality of the final RDF product and optimizing the overall efficiency of the facility. A study by Santos et al. (2023) on RDF facilities in Spain showed that integrating screening with advanced material separation technologies, such as ballistic separators and air classifiers, can improve the segregation of RDF from inert materials, enhancing the calorific value of the RDF produced (Santos et al., 2023). The current design could be compared to these technologies to determine if additional screening methods could enhance RDF quality.

3.5.7. RDF Loading Unit

Finally, the RDF loading unit is responsible for transporting the RDF product to companies that will utilize it as fuel. With a capacity of 20 tons per truck and planning for 2 trucks in each service area, this unit is crucial for ensuring that the RDF is promptly delivered to its final destination. The efficient design of this unit ensures that the facility can maintain a continuous output of RDF, supporting its role in waste-to-energy conversion. Previous studies, such as those by Chingono and Mbohwa (2023), highlight the importance of RDF loading units in maintaining the supply chain's efficiency. Automated loading systems that reduce the turnaround time of trucks and improve the safety of operations have been implemented in various facilities (Chingono & Mbohwa, 2023). Comparing the current design with such automated systems might reveal opportunities to increase operational efficiency and safety.

3.5.8. Leachate Treatment

Leachate Treatment planning aims to treat of removed water level from the biodrying process that became leachate. The results of IPL planning in service area 1 and service area 2 are presented in Table 6

The detailed planning of each unit within the integrated waste processing facility’s RDF facility highlights the complexity and precision required to manage waste effectively and produce RDF. Each unit's dimensions and capacities are carefully calculated to meet the specific needs of the service areas, considering factors like waste volume, type, and processing requirements. This integrated approach not only ensures that the facility operates smoothly but also maximizes the efficiency of waste processing and RDF production, contributing to sustainable waste management and energy recovery.

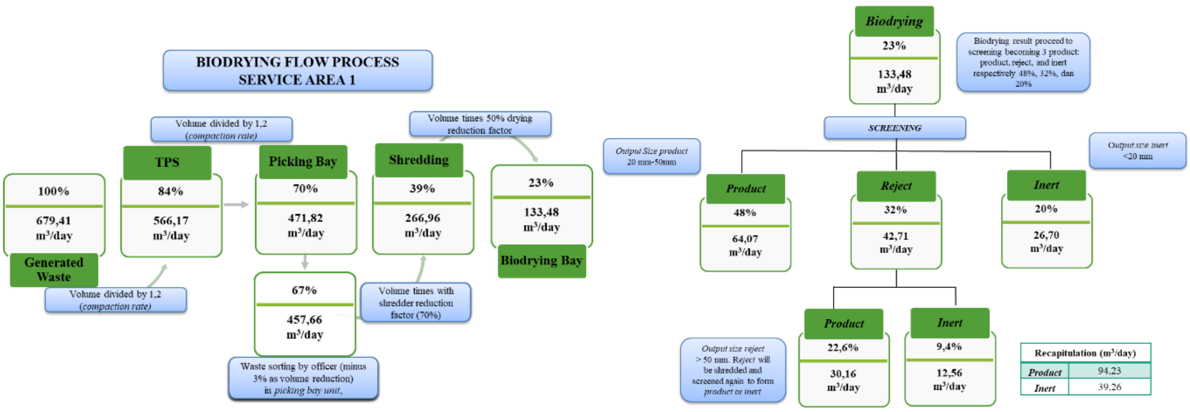
Table 6. Dimensions integrated waste processing facility's RDF Unit Planning for Service Area 1 and Service Area 2

Processing Units	Dimensions	
	Service Area 1	Service Area 2
Collector Pool	10m x 10m x 0.6m	9m x 9m x 0,6m
Anaerobic Pool	4.7m x 9.4m x 3m	4.4m x 8,4m x 3m
Facultative Pool	14.3m x 28,6m x 2m	13,2m x 26.4m x 2m
Maturation Pool	10.6m x 21,2m x 1m	9.8m x 19.5m x 1m
Wetlands	8.3m x 16.6m x 0.85m	7.7m x 15.4m x 0.85m

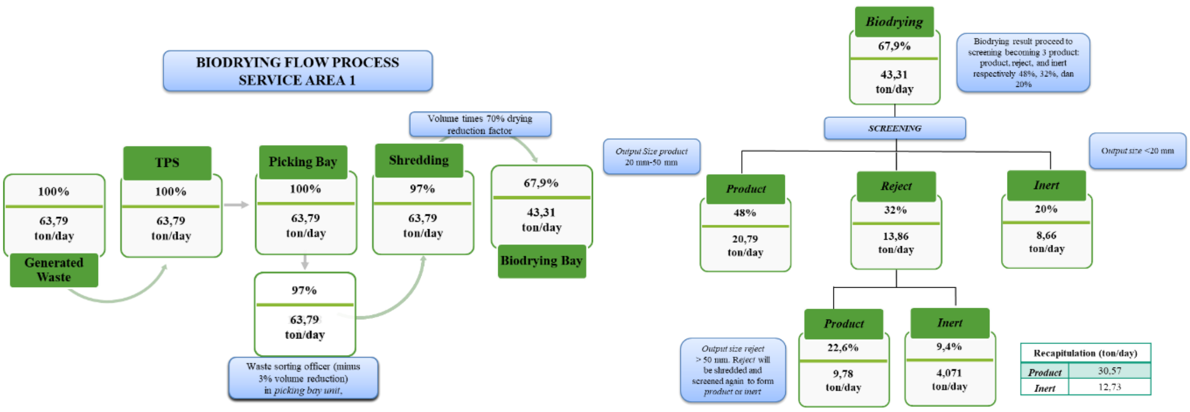
3.6. Material Balance

In each processing waste process through the units up planned there are always changes in the amount of weight and volume. The changes through each unit processing are presented in the balance sheet material. The material balance in service area 1 and service area 2 in Figure 3 and Figure 4, respectively. The provided figures depict a material balance analysis for a biodrying process in a specific service area, focusing on the transformation of waste material into different products. The process begins with waste generation, followed by sorting and shredding. The shredded material then undergoes biodrying, reducing its volume and transforming it into a more stable form (Zaman et al.). The biodried material is then screened to separate it into three products: product, reject, and inert.

The analysis presents two perspectives: by volume and by weight. The volume analysis shows the flow of waste through different stages, including generation, sorting, shredding, biodrying, screening, and product output. The analysis highlights the volume reduction achieved through biodrying and screening processes, as well as the distribution of the final product, reject, and inert materials. The weight analysis focuses on the mass flow of waste, tracking its transformation from the initial generation stage through to the final product output. The analysis demonstrates the weight reduction achieved through biodrying and screening processes, as well as the distribution of the final product, reject, and inert materials in terms of weight. The analysis provides valuable information on the efficiency and effectiveness of the biodrying process. It reveals the volume and weight reduction achieved, as well as the distribution of the final products. This information can be used to optimize the process, improve resource utilization, and reduce the environmental impact of waste management (Jalaei et al., 2021).

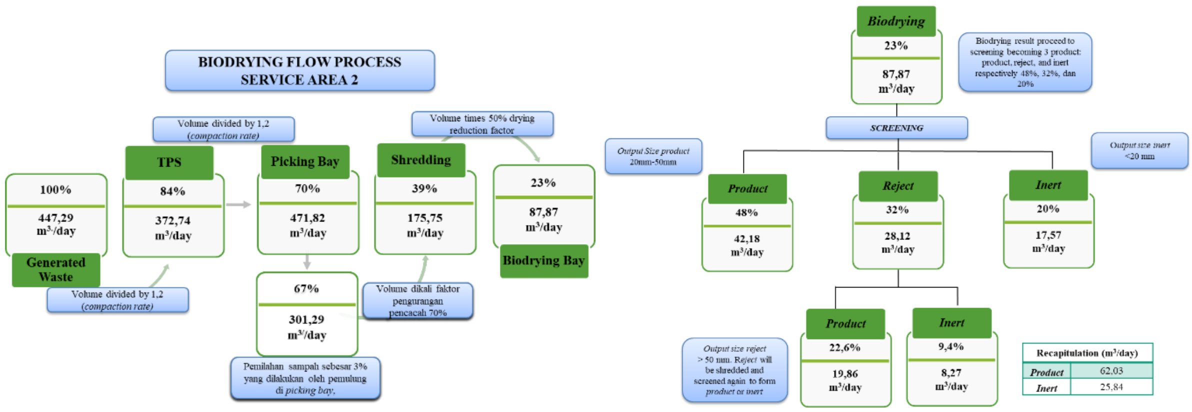


(a)

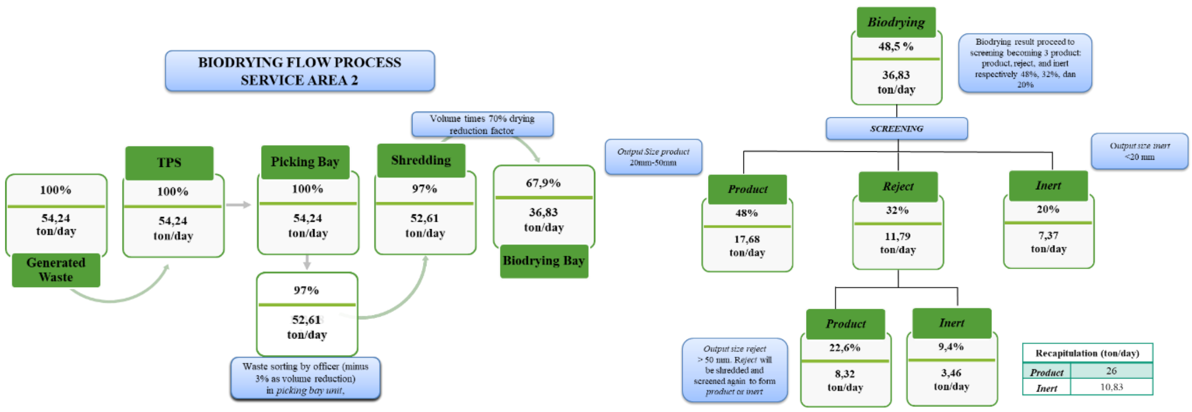


(b)

Figure 3. Material Balance RDF Service Area 1. (a) By Volume. (b) By Weight



(a)



(b)

Figure 4. Material Balance RDF Service Area 1. (a) By Volume. (b) By Weight

3.7. RDF Yield and Selling Value

Waste processing with biodrying method produces a product in the form of RDF that can benefit as the material burn alternative to coal, so own sell values. Following results analysis of product and value selling RDF in Region 1, which is presented in Table 7. Analysis results in product and value selling RDF in Region 2, which is presented in Table 8.

Table 7. Results of RDF Sales in Service Area 1

Year	RDF results (ton)	Price Sell / Ton (IDR)	Total Sales (IDR)
2023	26.48	420,000.00	3,722,985,436.13
2024	26.69	441,000.00	4,014,213,832.42
2025	26.90	463,050.00	4,327,111,765.21
2026	27.12	486,202.50	4,663,246,617.96
2027	27.33	510,512.63	5,024,296,333.85

Table 8. Results of RDF Sales in Service Area 2

Year	RDF results (ton)	Price Sell / Ton (IDR)	Total Sales (IDR)
2023	26.69	420,000.00	4,091,941,318.58
2024	26.90	441,000.00	4,330,350,871.62
2025	27.12	463,050.00	4,582,815,173.99
2026	27.33	486,202.50	4,850,190,016.62
2027	27.55	510,512.63	5,133,383,494.25

4. Conclusions

This study concludes the planning of waste processing with biodrying method in two service areas of Salatiga City District in Salatiga City, which the amount of existing waste generation in service area 1 (District Tingkir and District Argomulyo District) in the domestic sector is 0.362 kg/person/day and 4.019 liters/person/day and in the non-domestic sector is 208.6 kg/unit/day and 1895.12 m^3/unit/day, while the projected waste generation in service area 1 in 2032 is 63.79 tons/day and 679.41 m^3/day. The amount of existing waste generation in service area 2 (District Sidorejo and District Sidomukti) in the domestic sector is 0.339 kg/person/day and 3.124 m^3/person/day and in the non-domestic sector as much as 302.65 kg/unit/day and 2149.95 m^3/unit /day, while the projected waste generation in service area 2 in 2032 is 54.24 tons/day and 447.28 m^3/day. Waste processing planning with the biodrying method (TPST RDF) in the two service areas of Salatiga City is equipped with internal processing units, namely the Transport Units, Weighbridge, Picking Bay, Shredding Unit, Biodrying Unit, Screening Unit, RDF Loading Units, and Leachate Treatment Unit (IPL). In planning in service area 1 in 2032, it has a potential RDF production of 11159.03 tons/year with a sales value of IDR 7,270,755,009 / year. In planning in service area 1 in 2032, it has a potential RDF production of 10471.09 tons/year with a sales value of IDR 6,822,524,206/year

Acknowledgment

The authors received funding from Universitas Diponegoro through High Reputation of International Publication (RPIBT) UNDIP under Grant Number 225-50/UN7.6.1/PP/2022 for this research.

References

Ari PMS, Rahadian R and Tarwotjo U. (2019) Community structure of soil microarthropods in active and passive zones of Ngronggo landfill Salatiga. NICHE Journal of Tropical Biology 2: 1-6.

Bismi, A. 2015. Asesmen Potensi Recovery Energi Dari Sampah Perkotaan di TPA (Tempat Pemrosesan Akhir) Sampah Untuk Infrastruktur Persampahan Berkelanjutan. Annual Civil Engineering Seminar, 235-242.

Badan Standarisasi Nasional. 2008. Standar Nasional Indonesia Nomor SNI 3242:2008 tentang Pengelolaan Sampah di Permukiman. Standar Nasional Indonesia, 1-17

Bialowiec, A. 2014. Method of treatment and reducing the mass of landfilled municipal waste. European Patent Office, EP 3017886A1, 1-27

Bilgin, M., and Tulun, S. 2015. Biodrying for Municipal Solid Waste: Volume and Weight Reduction. Environmental Technology 36(13), 1691–1697.

Caputo, A.C., and Pelagagge, P.M. 2002. RDF production plants: I Design and costs. Applied Thermal Engineering 22(4), 423–437.

Chingono, T.T., Mbohwa, C. 2023. Humanitarian Logistics in the Industry 4.0. in: Supply Networks in Developing Countries: Sustainable and Humanitarian Logistics in Growing Consumer Markets, Emerald Publishing Limited, pp. 99-127.

Chioatto, E., Sospiro, P. 2023. Transition from waste management to circular economy: the European Union roadmap. Environment, Development and Sustainability, **25**(1), 249-276.

Damanhuri, E. 2010. Diktat Pengelolaan Sampah. Teknik Lingkungan Institut Teknologi Bandung (ITB), 1-30.

Damanhuri, E., and Padmi, T. 2016. Pengelolaan Sampah Terpadu. Teknik Lingkungan Institut Teknologi Bandung (ITB). 1-60.

Damanhuri, E., and Padmi, T. 2010. Pengelolaan Sampah Edisi Semester I–2010/2011. Institut Teknologi Bandung, 1-30.

Darmasetiawan, M. 2004. Sarana Sanitasi Perkotaan. Ekamitra Engineering.

Das, S., Lee, S.-H., Kumar, P., Kim, K.-H., Lee, S.S., Bhattacharya, S.S. 2019. Solid waste management: Scope and the challenge of sustainability. Journal of cleaner production, **228**, 658-678.

Dinas Cipta Karya. 2016. Tentang Organisasi dan Tata Kerja Dinas Pekerjaan Umum.

Dinas Lingkungan Hidup Kota Salatiga. 2016. Laporan Akhir Penyusunan Rencana Induk Persampahan Kota Salatiga, 1-325

Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum dan Perumahan Rakyat. 2019. Tentang Alokasi Dana Perencanaan TPST Melalui Bantuan Pemerintah.

Direktorat Jenderal Cipta Karya. 2017. Tentang Tata Cara Penilaian TPS3R.

Durugbo, C., Amankwah-Amoah, J. 2019. Global sustainability under uncertainty: How do multinationals craft regulatory policies? Corporate Social Responsibility and Environmental Management, **26**(6), 1500-1516.

Gendebien, A. 2003. Refuse Derived Fuel, Current Practice and Perspectives Final Report. European Commission Directorate General Environment, 1-218.

He, P. 2010. Release of Volatile Organic Compounds During Bio-drying of Municipal Solid Waste. Journal of Environmental Sciences 22(5), 752–759.

Basri, H. 2016. Biodrying Of Municipal Solid Waste Under Different Ventilation Periods. Environmental Engineering Research 2(2), 145–151.

Liu, D.C., Lin, Y.K., and Chen, M.T. 2001. Optimum Condition of extracting collagen from Chicken feet and its characteristics. Asian-Australasian Journal of Animal Science 14(11), 1638–1644.

Murtadho, D., and Gumbira, S. 1987. Penanganan dan Pemanfaatan Limbah. Padat. Mediyatama Sarana Perkasa.

Pang S., Asngari, Tjitropranoto, Prabowo, and Susanto, D. 2008. Kapasitas Petani dalam Mewujudkan Keberhasilan Usaha Pertanian: Kasus Petani Sayuran di Kabupaten Pasuruan dan Kabupaten Malang Provinsi Jawa Timur. Jurnal Penyuluhan Institut Pertanian Bogor 4(1), 11-20

Prihandana, R. 2007. Bioenergi Ubi Kayu Bahan Bakar Masa Depan. Agromedia Pustaka.

Rada, E.C. 2007. Lower Heating Value Dynamics during Municipal Solid Waste Bio-Drying. Environmental Technology 28(4), 463–469.

Rahmawati. 2017. Partisipasi Masyarakat Dalam Pengelolaan Sampah Di Lingkungan Margaluyu Kelurahan Cicurug. Share Social Work Jurnal 5(1), 2339–0042.

Sadaka, S. 2010. Partial. Composting for Biodrying Organic. Materials Agriculture and Natural Resources Research & Extension FSA1055, 1-4.

Shah, R., and Ward, P.T. 2007. Defining and developing measures of lean production. Journal of Operations Management 25 (4), 785–805.

Shao, L.M. 2015. Biodrying of Municipal Solid Waste Under Different Ventilation Modes: Drying Efficiency and Aqueous Pollution. Waste Manag 30(12), 1272–1280.

Shuqing, Z. 2014. The effect of bio-drying pretreatment on Heating Values of Municipal Solid Waste. Advanced Material Research 1010-1012, 537-546

Tom, A.P. 2016. Biodrying process: A Sustainable Technology for Treatment of Municipal Solid Waste with High Moisture Content. Waste Management 49, 64–72.

Undang-undang Republik Indonesia Nomor 18 Tahun 2008 tentang Pengelolaan Sampah. Sekretariat Negara.

Valones AGM and Junaedi UA. (2023) Urban Green Space Policy Reform in Indonesia: Breathing in the Middle of Development. Journal of Law and Legal Reform 4: 183-210.

Velis, C.A. 2009. Biodrying for mechanical biological treatment of wastes: A review of process science and engineering. Bioresource Technology 100(11), 2747-2761.

Yuan, J. 2018. Effects of The Aeration Pattern, Aeration Rate, and Turning Frequency on Municipal Solid Waste Biodrying Performance. Journal of Environmental Management 218, 416–424.

Zhang, D. 2008. Biodrying of municipal solid waste with high water content by combined hydrolytic-aerobic technology. Journal of Environmental Management 20(12), 1534–1540.

Edo-Alcón, N., Gallardo, A., Colomer-Mendoza, F.J., Lobo, A. 2024. Efficiency of biological and mechanical-biological treatment plants for MSW: The case of Spain. Heliyon, **10**(4).

Gautam, H.C., Yadav, V., Singh, V. 2022. IoT-Enabled Services for Sustainable Municipal Solid Waste Management in India. in: IoT-Based Smart Waste Management for Environmental Sustainability, CRC Press, pp. 83-98.

Haar, Q. 2023. Refuse Derived Fuels (RDF) and Solid Recovered Fuels (SRF) A case study of characteristics and opportunities, NTNU.

Hornsby, C., Ripa, M., Vassillo, C., Ulgiati, S. 2017. A roadmap towards integrated assessment and participatory strategies in support of decision-making processes. The case of urban waste management. Journal of Cleaner Production, **142**, 157-172.

Jalaei, F., Zoghi, M., Khoshand, A. 2021. Life cycle environmental impact assessment to manage and optimize construction waste using Building Information Modeling (BIM). International Journal of Construction Management, **21**(8), 784-801.

Khan, S., Anjum, R., Raza, S.T., Bazai, N.A., Ihtisham, M. 2022. Technologies for municipal solid waste management: Current status, challenges, and future perspectives. Chemosphere, **288**, 132403.

Lubongo, C., Alexandridis, P. 2022. Assessment of performance and challenges in use of commercial automated sorting technology for plastic waste. Recycling, **7**(2), 11.

Malav, L.C., Yadav, K.K., Gupta, N., Kumar, S., Sharma, G.K., Krishnan, S., Rezania, S., Kamyab, H., Pham, Q.B., Yadav, S. 2020. A review on municipal solid waste as a renewable source for waste-to-energy project in India: Current practices, challenges, and future opportunities. Journal of Cleaner Production, **277**, 123227.

Muzanni, A., Lestari, F., Chalid, M., Wardani, W.K., Satyawardhani, S.A., Kristanto, G.A., Zulys, A. 2022. Multi-Sectoral Partnership for Waste Management Evaluation and Awards Recognition in Higher Education. International Journal of Sustainable Development and Planning, **17**(4), 1205-1213.

Pietzsch, N., Ribeiro, J.L.D., de Medeiros, J.F. 2017. Benefits, challenges and critical factors of success for Zero Waste: A systematic literature review. Waste management, **67**, 324-353.

Santos, S.M., Nobre, C., Brito, P., Gonçalves, M. 2023. Brief Overview of Refuse-Derived Fuel Production and Energetic Valorization: Applied Technology and Main Challenges. Sustainability, **15**(13), 10342.

Sequeira, M., Joanaz de Melo, J. 2020. Energy saving potential in the small business service sector: Case study Telheiras neighborhood, Portugal. Energy Efficiency, **13**(4), 551-569.

Sharma, P., Sheth, P.N., Mohapatra, B. 2022. Recent progress in refuse derived fuel (RDF) co-processing in cement production: direct firing in kiln/calciner vs process integration of RDF gasification. Waste and Biomass Valorization, **13**(11), 4347-4374.

Zaman, B., Priyambada, I.B., Budiharjo, M.A., Ramadan, B.S., Puspita, A.S., Cahyati, A.P. Waste Management Strategy as an Effort to Reduce Emissions Due to Open Waste Burning: Demak Regency Case Study. Polish Journal of Environmental Studies.

Zorpas, A.A. 2020. Strategy development in the framework of waste management. Science of the total environment, **716**, 137088.