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Enhancing Refuse-Derived Dry Fuel Performance: A Comprehensive Impact Assessment of the Tanza Integrated Waste Managementand Treatment Facility Project in Barangay Sahud-Ulan, Cavite

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ABSTRACT

The Refuse-Derived Dry Fuel (RDDF) performance of the Tanza Integrated Waste Management and Treatment Facility Project in Barangay Sahud-Ulan, Cavite was investigated in this paper, utilizing descriptive correlational research approach. It aimed to assess RDDF performance in terms of fuel quality, energy efficiency, economic viability, and environmental effect and looked whether it is affected by facility infrastructure and technology, operational efficiency, sustainability practices, and policy implementation. A total of 378 respondents which consists of waste management professionals, facility managers, legislators, business stakeholders, and community representatives were selected through stratified random sampling.Findings shown that the respondents strongly agreed that facility's infrastructure, technology, and operational systems are very effective in enhancing RDDF performance. It also revealed that facility operational factors and RDDF outcomes had significant relationship leading to the confirmation that modern technology, efficient waste segregation, and effective policy implementation directly amend fuel quality and energy recovery. Additionally, sustainability and environmental management were also known as significant components in lessening emissions and ensuring long-term ecological balance. Thus, the study revealed that Tanza facility positively contributes to sustainable waste management and alternative energy production.

INTRODUCTION

Due to the higher demand for sustainable waste management solutions, an alternative energy source is developed such as the RDDF or what is known as the refuse-derived dry fuel. Based from Anderson and Patel (2022), the said is produced through processing non-recyclable municipal solid waste into high-energy fuel which contributes to alternative conventional fossil fuels. Its effectiveness relies on some factors such as fuel quality, energy efficiency, economic viability and environmental impact. Knowing how waste management facilties like RDDF performance is necessary in managing its benefits and securing long-term sustainability (Garcia & Lee, 2022).

Globally, countries like Sweden and Japan's waste energy technologis gained the attention of the masses and shown that there are really available advanced waste management systems which could reduce landfill dependency and minimize carbon emissions (Brown & Sanchez, 2024). Still, challenges on how to modify RDDF production efficiency and ensuring sustainability appears in different contexts (Torres & Kim, 2023).

Numerous studies were done relative to RDDF but the gaps still were not fill in terms of assessing the effectiveness of integrated waste management facilities in developing RDDF performance. Some recent studies focused on its technological aspects of waste-to-energy conversion but overlooked vital factors like policy implementation, operational efficiency and environmental sustainability (Martinez & Cruz, 2021). Nguyen and Santos (2023) mentioned that there is also a limited research on the economic viability of RDDF in developing countries.

In the Philippines, a policy known as Ecological Solid Waste Management Act of 2000 (RA 9003) promotes waste segregation, recycling, and alternative waste utilization (Santos & Rivera, 2022) but its enforcement remains a problem and a stronger policy implementation and monitoring mechanisms are seen vital to develop RDDF perfromance and sustainability (Cruz & Lim, 2023).

Locally, in Brgy. Sahud-ULan, Cavite, the Tanza Integrated Waste Management and Treatment Facility Project inititiates sustable waste processing. It employs advanced technologies (Torres & Mendoza, 2022) and seeks to support cleaner energy production, concerns about sustainability, operational efficiency, and environmental impact persist (Garcia & Fernandez, 2023). With the present numerous challenges in integrating RDDF production (Nguyen & Torres, 2024) and emission-related risks (Martinez & Santos, 2023), a need to conduct this study is significant in enhacing RDDF performance and lessening environmental damages.

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Objectives

This study examined how the Tanza Integrated Waste Management and Treatment Facility Project affects the performance of refuse-derived dry fuel (RDDF) in Barangay Sahud-Ulan, Cavite. It focused on how facility infrastructure, operational efficiency, sustainability practices, and policy implementation influence RDDF fuel quality, energy efficiency, economic viability, and environmental impact. The findings would help identify challenges in RDDF production and provide recommendations for optimizing waste-to-fuel conversion while ensuring environmental sustainability. Specifically, this aimed to:

1. Assess the demographic profile of the respondents in terms of sex, age, civil status and educational attainment.
2. Identify how do local stakeholders assess the Tanza facility's impact on RDDF performance in terms of facility infrastructure and technology, operational efficiency, sustainability and environmental management and management and policy implementation.
3. Investigate how do local stakeholders evaluate the quality and effectiveness of RDDF in terms of fuel quality, energy efficiency, economic viability and environmental impact.
4. Test the significant difference in how respondents evaluate RDDF performance when grouped according to their demographic profile.
5. Test the significant relationship between the Tanza facility's operational factors (infrastructure, efficiency, sustainability, and policy implementation) and RDDF performance (fuel quality, energy efficiency, economic viability, and environmental impact.

MATERIALS AND METHODS

This part presents the methodology the researcher employed in analyzing and interpreting the data about the variables in the study.

Research Design

A descriptive-correlational research design with the integration of regression analysis was utilized in this study to assess the impact of Tanza Integrated Waste Management and Treatment Facility Project on Refuse-Derived Dry Fuel (RDDF) performance in Cavite. The descriptive research was applied to determine how facility infrastructure policies contribute to RDDF production quality. On the otherhand, the correlational component tested the relationship between waste management facility operations and RDDF performance metrics.

Research Locale

Tanza Integrated Waste Management and Treatment Facility (TIWMTF) in Barangay Sahud-Ulan, Cavite as the research locale is known for its its growing waste-to-energy initiatives and integrated waste management strategies. Due to its strategic significance in the country's solid waste management and its roles in the cities in Cavite and nearby provinces, it was chosen as the study's locale. The facility handles municipal solid waste to RDDF.

Respondents of the Study

A total of 378 respondents were selected through stratified random sampling design, samples were equally drawn from the different stakeholders involved in Tanza Integrated Waste Management and Treatment Facility project in Brgy. Sahud-Ulan, Cavite of facility managers and engineers, waste management personnel, environmental officers, local government officials, business stakeholders, and community representatives.

Table 1: Distribution of Respondents According to Sector with Sample Size Using Stratified Random Sampling Technique

Respondent Group	Population	Sample Size
Facility Managers and Engineers	950	25
Operations and Waste Management Personnel	4500	118
Environmental and Sustainability Officers	1200	31
Local Government Officials and Policymakers	1800	47
Business Stakeholders and Investors	2500	65
Community Representatives and Environmental Advocacy Groups	3500	92
Total	14450	378

Source: 2020 Census, Philippine Statistics Authority (PSA)

Research Instrument

For data gathering, a structured questionnaire was used for both quantitative and qualitative data on the effect of the Tanza Integrated Waste Management and Treatment Facility Project on RDDF performance in the research locale. There are three parts of the questionnaire: the first part was designed to collect the demographic profiles of the respondents , the second part dealt with the assessment if the influence of facility infrastructure and technology, operational efficiency, sustainability and environmental management, and management and policy implementation on RDDF performance and the last part contained open-ended questions and semi-structured interviews for the qualitative data.

Data Gathering Procedure

After all the written requests were approved and the instruments were ready for distribution, the researchers' enumerator started the data gathering. A structured data gathering procedure was utilized integrating surveys, interviews and document analysis. Then, when the responses are retrieved, data were encoded, tabulated and analyzed.

Validity and Reliability of Research Instrument

A test-retest was conducted to 30 non-respondents of the study in which results were subjected to Cronbach's alpha to test the reliability of the instruments. Those items whith a threshold of 0.70 and above remained while those who got tlower than 0.70 were either deleted or revised. Also, the instrument underwent validation wherein different experts were asked to validate the instrument through content validation. All the comments and suggestions of the experts were considered and injected for the betterment of the data to be gathered.

Statistical Treatment and Data Analysis

Descriptive statistics were used to gather data on the key characteristics of facility infrastructure, operational efficiency, sustainability measures, and policy implementation at the Tanza Integrated Waste Management and Treatment Facility, while T-tests, ANOVA, Pearson correlation, and regression analysis were used to answer the hypotheses.Semi-structured interviews with facility managers, environmental regulators, and policymakers complemented the quantitative data.

Ethical Considerations

In conducting this research, ethical considerations prioritized the rights, privacy, and well-being of all participants. Participants' informed consent was obtained through a clear explanation of the study's objectives, procedures, and any potential risks or benefits associated with their participation. Confidentiality and anonymity were maintained, ensuring that personal identifiers are not disclosed in any reports or publications. The research also adhered to principles of respect, equality, and cultural sensitivity, particularly in relation to gender inclusivity and socioeconomic factors. Additionally, participants had given the right to withdraw from the study at any point without any repercussions.

RESULTS AND DISCUSSIONS

Demographic Profiles of the Respondents

Table 2: Frequency and Percentage Distribution of the Demographic Profile of the Respondents

Demographic Profile	Category	Frequency (f)	Percentage (%)
Sex	Male	254	67.2
	Female	124	32.8
	Total	378	100
Age	18–21 years old	46	12.2
	22–25 years old	109	28.8
	26–29 years old	82	21.7
	30 and above	141	37.3
	Total	378	100
Civil Status	Single	256	67.7
	Married	122	32.3
	Total	378	100
Educational Attainment	Elementary	22	5.8
	High School	204	54.0
	College	124	32.8
	Post Graduate	28	7.4
Total		378	100

Table 2 shows the frequency and percentage distribution of the demographic profile of the respondents. Based from the data, majority of the respondents are male with 67.2 % of the total number of respondents while females are 32.8%. This shown that the general population of the sample and the area is predominated by males. The distribution of respondents' sex shows a majority of male respondents (67.2%) compared to female respondents (32.8%). In terms of age, 37.3% are those aged 30 and above which is the highest, followed by thos aged 22 to 25 years old with 28.8%, then aged 26-29 which got 21.7% and the lowest are those who aged 18-21 years old with 12.2%. It revealed that older individuals are more matured to handle greater interest or responsibility in waste management programs or matters. On the other hand, in terms of civil status, a majority (67.7%) are single, while a smaller percentage (32.3%) are married. Lastly, educational attainment of the respondents reveals

that the majority have completed high school (54.0%), followed by those with a college education (32.8%) and a smaller proportion with post-graduate education (7.4%). A relatively small portion (5.8%) has only elementary education.

How the Local Stakeholders Assess The Tanza Facility's Impact on RDDF

Table 3: Summary of Local Stakeholders' Assessment of the Tanza Facility's Impact on RDDF Performance

Indicators	Mean	Std. Deviation	Response	Interpretation
Facility infrastructure and technology	3.77	0.42	Strongly Agree	Very Effective
Operational efficiency	3.78	0.40	Strongly Agree	Very Effective
Sustainability and environmental management	3.78	0.41	Strongly Agree	Very Effective
Management and policy implementation	3.69	0.46	Strongly Agree	Very Effective
Overall	3.76	0.42	Strongly Agree	Very Effective

Legend: 1.00–1.75 Strongly Disagree (Very Ineffective), 1.76–2.50 Disagree (Ineffective), 2.51–3.25 Agree (Effective), and 3.26–4.00 Strongly Agree (Very Effective).

Table 3 presents the local stakeholders' assessment of the Tanza facility's impact on RDDF performance. The items "Operational efficiency" and "Sustainability and environmental management" got the highest mean of 3.78 which has a verbal description of Strongly Agree and corresponds to interpretation of Very Effective. Both items had been revealed to be very effecive for RDDF performance due to its being timely, systematic and effective. Next in rank is the "Facility Infrastructure and Technology" with a mean of 3.77, described as Strongly Agree and is interpreted as Very Effective. With this, it is implied that the respondents believed that the facility is well-equipped and is efficient in waste processing. Lastly, the item "manangement an Policy Implementation" got the lowest meanscore of 3.69 but still interpreted as Very Effective. It showed that the respondents appreciate the existing policies and how these are implemented but gaining the lowest score means the need to review policies and still implement continuous improvement. Finally, the overall grand meanscore of 3.76 revealed that the hollistic RDDF performance is very effective.

Table 4: The Summary of Local Stakeholders Evaluated the Quality and Effectiveness of RDDF

Indicators	Mean	Std. Deviation	Response	Interpretation
Fuel Quality	3.54	0.49	Strongly Agree	Very Good
Energy Efficiency	3.52	0.71	Strongly Agree	Very Good
Economic Viability	3.55	0.49	Strongly Agree	Very Good
Environmental Impact	3.61	0.47	Strongly Agree	Very Good
Overall	3.56	0.54	Strongly Agree	Very Good

Legend: 1.00-1.75 Strongly Disagree(Very Poor), 1.76-2.50 Disagree(Poor), 2.51-3.25 Agree(Good), and 3.26-4.00 Strongly Agree(Very Good)

How Local Stakeholders Evaluate The Quality And Effectiveness of RDDF

It can be gleaned from Table 4 that the overall mean score of 3.56 on stakeholders' evaluation on the quality and effectiveness of RDDF is described as Strongly agree and interpreted as Very Good, this means that they perceived the RDDFquality as very good and effective and it met the expectations they have. This result is in consonance to what Johnson and Lee (2021) stated that "when stakeholders provide similar evaluations, it reflects an accurate reflection of organizational performance, which can reinforce support for continued development".

Environmental Impact achieved the highest mean score of 3.61 which is interpreted as Very Good. With this, it is proven that the respondents belived that RDDF could really help mitigate environmental problems related to waste problems. It is of relevance to the idea of Garcia *et al.* (2022) that when stakeholders prioritize eco-friendly practices, there will be environmental sustainability in facilty management.

Moreover, Energy efficiency got the lowest mean score of 3.52, although still categorized as "very good," shows it is the least highly rated among the indicators. Thus, there is still a need to be developed in this area.

Significant Difference in How Respondents Evaluate RDDF Performance When Grouped According to Their Demographic Profile

As gleaned from Table 5, it can be seen that sex and civil status signifcantly influence hoe respondents evaluate the RDDF performance. The data revealed that male and single respondents had higher mean evaluations compared to female and married respondents which implied that perceptions could really be potentially

Table 5: Test of Significant Difference in how Respondents Evaluated RDDF Performance when Grouped According to their Demographic Profile

Demographic Profile	Category	Mean	f-value	t-value / p-value	Remarks	Decision on Ho
Sex	Male	3.82	6.412	0.000	Significant	Rejected
	Female	3.52				
Age	18–21	3.83	0.378	0.769	Not Significant	Failed to Reject
	22–25	3.80				
	26–29	3.77				
	30 and above	3.82				
Civil Status	Single	3.82	6.313	0.000	Significant	Rejected
	Married	3.52				
Educational Attainment	Elementary	3.91	1.546	0.202	Not Significant	Failed to Reject
	High School	3.77				
	College	3.85				
	Post Graduate	3.75				

affected by gender roles and lifestyle factors. Then, age and educational attainment had no significant differences which suggested that both indicators had similar views on RFFD operations and effectiveness.

Significant Relationship Between The Tanza Facility's Operational Factors and RDDF Performance

As depicted in Table 6, there is a negative relationship between operational efficiency and energy efficiency

Table 6: Test of Significant Relationship between the Tanza Facility's Operational Factors and RDDF Performance

Operational Factors	RDDF Performance											
	Fuel Quality			Energy Efficiency			Economic Viability			Environmental Impact		
	R	p-value	Ho	R	p-value	Ho	R	p-value	Ho	R	p-value	Ho
Facility Infrastructure and Technology	.069	.180	NS	-.061	.235	NS	-.037	.475	NS	-.007	.897	NS
Operational Efficiency	-.062	.226	NS	-.147**	.004	S	-.096	.062	NS	.029	.568	NS
Sustainability and Environmental Management	.036	.488	NS	-.054	.293	NS	-.062	.228	NS	-.010	.849	NS
Management and Policy Implementation	.024	.637	NS	-.007	.895	NS	.016	.750	NS	.134**	.009	S

Significant if p-value <0.05
Legend: Ho is rejected if Significant

which can be concluded that higher operational efficiency caused the decrease in energy recovery efficiency. Though operational efficiency is vital in smooth processing if waste, it might affect the energy output due to increased attention on streamlining processes. Moreover, no significant relationships were found between other operational factors, such as facility infrastructure, sustainability, and management policies, and RDDF performance. This proved that these factors do not have direct effect on performance as operational efficiency does.

Significant Affect of Tanza Integrated Waste Management and Treatment Facility to RDDF Performance

Table 7: Test of Significant Affect of the Tanza Integrated Waste Management and Treatment Facility to RDDF Performance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.718	.431		13.254	.000
	Facility Infrastructure and Technology	-.124	.086	-.077	-1.437	.152
	Operational Efficiency	-.168	.079	-.112	-2.135	.033
	Sustainability and Environmental Management	-.146	.071	-.110	-2.058	.040
	Management and Policy Implementation	-.076	.059	-.067	-1.279	.202

Note: Adjusted r2=.056 ANOVA for Regression F= 5.549, p=.000

Table 7 shows that the facility's operational factors, particularly sustainability and environmental management, have a significant adverse effect on RDDF performance. This only proved that operational strategies like sustainability and environmental management practices, might not be fully aligned with or supportive of optimizing RDF production and energy recovery.

Policies and strategies can be recommended to improve RDDF production, enhance fuel quality, and promote sustainability in waste-to-energy conversion

1. Enhancing Operational Efficiency
2. Continuous Investment in Technology and Infrastructure
3. Strengthening Waste Segregation and Recycling Programs
4. Balancing Sustainability with Operational Goals
5. Improving Policy Transparency and Communication
6. Developing Community-Based Education Programs

CONCLUSIONS

Based from the results, the study concluded that there is a need to have a well-balanced efficiency and sustainability to continue improve the RDDF production of the said facility. Overall, the facility performs well but the need to improve waste segragation, RDDF quality and alignment of environmental and operational goals are highly necessitated. Thus, government agencies are encouraged to stregthen waste-to-energy policies and design programs that would increase the community's awareness and participation to waste management. Also, there is a need to invest on better sorting facilities. For the future researchers who would be interested in the same study, focus on some other areas that would enhance energy recovery and sustainability.

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