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Rapid Environmental Impact Assessment (RIAM) Of Proposed Compressed Biogas Plant At Brahmapuram, Kakkanad

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Abstract: Solid wastes generated from various residential and non- residential activities in cities end up in the centralized land fill sites mostly vacant lands or wetland sites in the urban periphery. Sanitary landfills have been and continue to be a social and ecological threat. Brahmapuram Waste treatment plant set up in 2008, spread over 110 acres in Kakkanad is utilized by the Kochi Corporation and the nearby municipalities, but the lack of segregation of the biodegradable and non-bio degradable waste has caused breakdowns in the functioning of the plant turning it into a waste dump site that polluted the surrounding rivers along with air pollution. The plant has been the site of multiples fires in 2013, 2019 and 2023 that burned 16-year-old dumped garbage and released toxic fumes chocking the entire city region for 12 days (India Today, 2023). Following this event a compressed biogas (CBG) plant has been proposed at Brahmapuram by Bharat Petroleum Corporation Ltd. (BPCL) in 2024. RIAM technique has been applied to assess the Environmental impact Assessment of the proposed CBG plant in Brahmapuram and from the study it was found that the proposal has a moderately positive impact. Suitable mitigation measures may be suggested in the future research in order to reduce the adverse impacts so as to create a harmonious environment.

Index Terms **-** Rapid Impact Assessment Matrix (RIAM), Urban Waste dumpsite, Biogas Plant.

I. INTRODUCTION

The Rapid Impact Assessment Matrix (RIAM) is a widely recognized qualitative-quantitative tool designed for evaluating the environmental, social, and economic impacts of development projects. Introduced by Pastakia (1998), RIAM enables systematic comparison of project alternatives and their likely consequences by assigning weighted scores to multiple criteria. The methodology is especially effective in contexts where time and data availability are constrained, making it highly suitable for assessing interventions in complex and degraded urban environments like Brahmapuram, Kochi. Several studies have demonstrated the efficacy of RIAM in evaluating waste management systems. Kuitunen et al. (2008) successfully applied RIAM to assess land use changes and waste treatment projects in Finland, highlighting its transparency and stakeholder involvement benefits. Shweta and Prasad (2013) used RIAM to assess the impact of landfill siting, emphasizing how site-specific conditions influence environmental scores. In a study conducted by Roy and Bose (2016), RIAM was used to evaluate the environmental viability of a composting facility in West Bengal. The results underscored that decentralized, low-emission waste-to-energy solutions generally score positively when RIAM parameters like reversibility, magnitude, and mitigation potential are considered. Similarly, Mohammadi et al. (2014) applied RIAM in Iran to assess different municipal solid waste management options, concluding that anaerobic digestion plants often yield higher environmental scores than incineration or landfilling.

India loses over 1250 hectares of useful land every year to dispose of municipal solid waste (Down To Earth., 2022 July). Further, the National Green Tribunal stated that more than 10,000 hectares of usable urban land are locked up under 3159 legacy waste dumpsites in the country. Swachh Bharat Mission–Urban (2021) and with NITI Aayog, highlights the pressing issue of extensive land locked in legacy dumps and the critical need for scientific solid waste processing. As per census of India, the population of Kochi Corporation in 2001 is 5,95,575 and the population in 2011 is 6, 01,574. The density of the city is 6,340 persons per sq. km against a density of 819 persons per sq. km in Kerala, 382 persons per sq. km in India and a world average of 46 persons per sq. km in 2011 (Census 2011). The city generates 326 tons of waste per day (Wet waste -226 ton/day and Dry waste-100 tons per day) as per the data physically collected by Abhirami et al. (2021). Growing cities like Kochi face pressing waste management challenges due to rapid urbanization and limited land availability. Brahmapuram Waste treatment plant was set up in 2008, spread over 110 acres in Kakkanad is utilized by the Kochi Corporation and the nearby municipalities.

According to The Solid Waste Management Rules, 2016, from the Ministry of Environment, Forest and Climate Change (MoEFCC) the solid waste has to be collected from door to door and it has to be segregated at source into biodegradable, non-biodegradable, and domestic hazardous waste. The Biodegradable waste should be treated and disposed of on-site through composting or bio-methanation. Residual waste should be given to waste collectors or agencies as directed by the local body. As per the Rules, it is the responsibility of the Waste Generators (householders, event organizers, street vendors, gated communities, restaurants, hotels, etc.) for segregating waste at source and paying a user fee to waste collectors. Only the non-recyclable, non-biodegradable, non-combustible wastes should be allowed to brought to the landfill. In case of Brahmapuram where the lack of waste segregation at source resulted in a pile up of waste in the site and caused breakdowns in the functioning of the plant turning it into a waste dump that polluted the Kadambrayar and Chithrapuzha rivers along with air pollution. The plant has been the site of multiples fires in 2013, 2019 and recently in 2023 that burned 16-year-old dumped garbage and released toxic fumes chocking the entire city region for 12 days (India Today, 2023). The paper aims to assess the impact of the proposed compressed biogas (CBG) plant at Brahmapuram which aims to convert organic waste into energy while reducing methane emissions and landfill volume using the Rapid Impact Assessment Matrix as a holistic assessment tool.

II. OJECTIVES

1. To identify, predict, and evaluate various impacts of the proposed Biogas plant on the environment in Brahmapuram, Kakkanad.
2. To scientifically assess the magnitude of positive and negative impacts of waste management proposal by Rapid Impact Assessment Matrix (RIAM) Method

III. STUDY AREA

Kakkanad is an economically significant area that houses educational institutions, IT-industrial projects, residential neighborhoods and the Brahmapuram Waste Dump. The waste dump site has become a major concern due to the environmental pollution, fire hazards and public health and safety issues. The fire- breakout on March 2023 put the Kochi residents at risk exposing them to toxic fumes generated that spread to the nearby districts of Alleppey and Kottayam within a week.

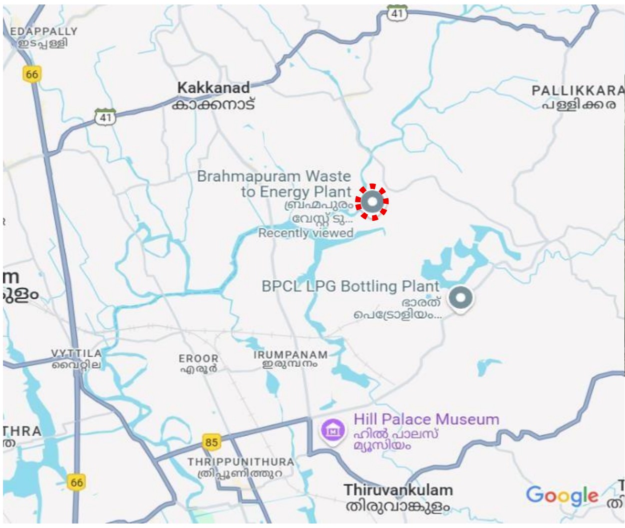

Figure 1. Google Map showing the Brahmapuram waste dump site and its surrounding context, Image Source: Google Maps

Figure 2. Toxic fumes and stench emerging out of the fire breakout at Brahmapuram waste treatment plant on March 2023, Image source: CNN.com

IV. METHODOLOGY

The positive and negative environmental impacts of the proposed Compressed Biogas Plant at Brahmapuram was assessed based on the results of various studies conducted and field survey data. Based on the Rapid Impact Assessment Matrix (RIAM) assessment criteria the crucial components pertaining to the Physical and Chemical components, Biological and Ecological components, Sociological and Cultural components, and Economical and Operational components w.r.t to the landfill site was delineated for the evaluation by five subject experts judgment.

The judgments on each component are made in accordance with the criteria and scales shown in Table 6.1. The important assessment criteria fall into two groups:

(i) Group A: Criteria that are of importance to the condition, and which can individually change the score obtained.

(ii) Group B: Criteria that are of value to the situation, but should not be individually capable of changing the score obtained.

	Criteria	Scale	Description
A_1	Importance of condition	4	Important to national/international Interest
		3	Regional or national interests are related
		2	Significant to outside areas
		1	Only related to local conditions
A_2	Magnitude of change/effect	3	Major positive benefit
		2	Significant improvement
		1	Improvement in status quo
		0	No impact
		−1	Negative transformation
		−2	Substantial negative outcome
		−3	Major consequence
B_1	Permanence	1	Not applicable or neutral
		2	Provisional
B_2	Reversibility	1	Not applicable or neutral
		2	Changeable
		3	Unalterable
B_3	Cumulative	1	No developments or not applicable
		2	Single
		3	Synergistic

Table 1. RIAM Evaluation Criteria, Source: Pastakia & Jensen, 1998

The value ascribed to each of these groups of criteria is determined by the use of a series of simple formulae. These formulae allow the scores for the individual components to be determined on a defined basis. The process for the RIAM in its present form can be expressed as:

Where,

- $A_1 \times A_2 = A_T$ (1) criteria scores for group
plication of all (A) scores
- $B_1 + B_2 + B_3 = B_T$ (2) e individual criteria scores for group (B) and BT is the result of summation
- $A_T \times B_T = ES$ (3) r the condition (Pastakia & Jensen, 1998)

IV. Environmental components in Rapid Impact Assessment Matrix (RIAM)

Expert evaluation has been collected using matrix circulated to experts. The different impact assessment criteria pertaining to each aspect were developed to formulate the Environmental score for a standardized way to interpret the magnitude and significance of impacts. RIAM requires specific assessment components to be defined through a process of scoping, and these environmental components fall into one of four categories which are defined as follows:

1. **PC: Physical and Chemical components: -**

It Covers all physical and chemical aspects of the environment.

PC1. Soil Health: Effects of biofertilizer application on local soil properties; potential pollution risks.

PC2. Water Resource: Risk of contamination from wastewater discharge; efficiency of leachate treatment systems.

PC3. Air Quality: Impact of emissions during construction and operation (e.g., methane leaks, odor control, reduction of open waste burning)

PC4. Waste Management: Reduction in untreated waste at the dump site; capacity to handle biodegradable waste effectively.

2. BE: Biological and Ecological components: -

It Covers all biological aspects of the environment.

BE1. Biodiversity: Impact on local flora and fauna due to construction activities and operational disturbances.

BE2. Ecosystem Services: Restoration of nearby ecosystems by reducing pollution levels in air, water, & soil

BE3. Wildlife Habitats: Potential risks to wildlife from operational noise, light, or waste byproducts.

BE4. Carbon Footprint: Reduction in greenhouse gas emissions from biogas production compared to traditional waste disposal methods.

3. SC: Sociological and Cultural components: -

It Covers all human aspects of the environment, including cultural aspects.

SC1. Health & Safety: Improvements in public health due to reduced waste burning and better waste management; potential risks from plant operations (e.g., accidents, odor).

SC2. Community Acceptance: Local perception and willingness to support the biogas plant; involvement in decision-making

SC3. Quality Of Life: Impact on nearby residents' daily lives due to odor, noise, or traffic related to plant operations.

SC4. Cultural Sensitivity: Consideration of cultural or historical significance of the site and its surroundings.

4. EO: Economical and Operational components: -

It Covers the economic consequences of environmental change, both temporary and permanent.

EO1. Cost Benefit Analysis: Financial viability of the project versus the societal and environmental benefits.

EO2. JOB CREATION: Employment opportunities during construction and operational phases.

EO3. Energy Output: Efficiency and economic returns from the biogas produced and its usage (e.g., as fuel or electricity generation)

EO4. Waste Management Costs: Savings for the municipality in waste transportation, tipping fees, and landfill management.

EO5. Operational Sustainability: Reliability of technology and maintenance costs over time; adaptability to future waste management challenges.

V. RESULTS

Based on the survey from five experts, the following results were obtained as shown in table below.

a1 importance of condition								
Physical/Chemical (PC)		Expert1	Expert2	Expert3	Expert4	Expert5	Average	Roundoff
PC1	SOIL HEALTH:	2	2	2	2	1	1.8	2
PC2	WATER RESOURCE	2	2	2	2	2	2	2
PC3	AIR QUALITY:	2	2	3	2	2	2.2	2
PC4	WASTE MANAGEMENT	2	2	3	2	3	2.4	2
Biological/Ecological (BE)								
BE1	BIODIVERSITY:	1	2	2	3	1	1.8	2
BE2	EOSYSTEM SERVICES:	2	2	2	2	2	2	2
BE3	WILDLIFE HABITATS:	3	1	1	3	2	2	2
BE4	CARBON FOOTPRINT:	3	2	3	4	3	3	3
Sociological/Cultural (SC)								
SC1	HEALTH & SAFETY:	2	2	3	2	2	2.2	2
SC2	COMMUNITY ACCEPTAANCE	1	2	2	1	2	1.6	2
SC3	QUALITY OF LIFE	1	2	3	2	2	2	2
SC4	CULTURAL SENSITIVITY:	1	2	3	2	0	1.6	2
Economic/Operational (EO)								
EO1	COST BENEFIT ANALYSIS	2	2	3	3	2	2.4	2
EO2	JOB CREATION	3	3	2	2	2	2.4	2
EO3	ENERGY OUTPUT	2	3	3	2	2	2.4	2
EO4	WASTE MANAGEMENT COSTS	1	2	3	2	2	2	2
EO5	OPERATIONAL SUSTAINABILITY:	2	2	4	2	3	2.6	3
							A1=	2.12

a2 magnitude of change								
Physical/Chemical (PC)		Expert1	Expert2	Expert3	Expert4	Expert5	Average	Roundoff
PC1	SOIL HEALTH:	3	2	1	-2	-2	0.4	0
PC2	WATER RESOURCE	3	3	0	-2	-2	0.4	0
PC3	AIR QUALITY:	2	2	-1	-2	-2	-0.2	0
PC4	WASTE MANAGEMENT	3	3	2	-2	3	1.8	2
Biological/Ecological (BE)								
BE1	BIODIVERSITY:	3	2	0	-2	-1	0.4	0
BE2	EOSYSTEM SERVICES:	2	2	-1	-1	3	1	1
BE3	WILDLIFE HABITATS:	1	1	-1	-2	-1	-0.4	0
BE4	CARBON FOOTPRINT:	2	1	1	-1	3	1.2	1
Sociological/Cultural (SC)								
SC1	HEALTH & SAFETY:	2	3	3	-1	3	2	2
SC2	COMMUNITY ACCEPTAANCE	1	3	2	0	2	1.6	2
SC3	QUALITY OF LIFE	1	3	3	-2	-2	0.6	1
SC4	CULTURAL SENSITIVITY:	1	3	0	-2	0	0.4	0
Economic/Operational (EO)								
EO1	COST BENEFIT ANALYSIS	2	2	2	1	2	1.8	2
EO2	JOB CREATION	2	1	3	2	1	1.8	2
EO3	ENERGY OUTPUT	3	2	3	2	2	2.4	2
EO4	WASTE MANAGEMENT COSTS	3	3	2	1	2	2.2	2
EO5	OPERATIONAL SUSTAINABILITY:	2	2	2	0	3	1.8	2
							A2=	1.12

Table 2. RIAM Calculation for A1- Importance of Condition and A2- Magnitude of Change as per the expert survey
Source: Author

b1 Permanance								
Physical/Chemical (PC)		Expert1	Expert2	Expert3	Expert4	Expert5	Average	Roundoff
PC1	SOIL HEALTH:	4	3	4	2	3	3.2	3
PC2	WATER RESOURCE	3	3	3	3	3	3	3
PC3	AIR QUALITY:	4	2	3	3	2	2.8	3
PC4	WASTE MANAGEMENT	4	3	4	2	4	3.4	3
Biological/Ecological (BE)								
BE1	BIODIVERSITY:	3	2	3	3	3	2.8	3
BE2	EOSYSTEM SERVICES:	3	2	3	2	4	2.8	3
BE3	WILDLIFE HABITATS:	2	1	2	3	3	2.2	2
BE4	CARBON FOOTPRINT:	3	1	2	3	4	2.6	3
Sociological/Cultural (SC)								
SC1	HEALTH & SAFETY:	4	3	4	2	4	3.4	3
SC2	COMMUNITY ACCEPTAANCE	3	3	3	2	3	2.8	3
SC3	QUALITY OF LIFE	4	3	4	2	3	3.2	3
SC4	CULTURAL SENSITIVITY:	4	3	3	2	1	2.6	3
Economic/Operational (EO)								
EO1	COST BENEFIT ANALYSIS	3	3	4	3	4	3.4	3
EO2	JOB CREATION	4	1	3	4	3	3	3
EO3	ENERGY OUTPUT	4	2	3	4	3	3.2	3
EO4	WASTE MANAGEMENT COSTS	4	3	4	2	4	3.4	3
EO5	OPERATIONAL SUSTAINABILITY:	4	2	3	2	4	3	3
							B1=	2.94

b2 reversibility								
Physical/Chemical (PC)		Expert1	Expert2	Expert3	Expert4	Expert5	Average	Roundoff
PC1	SOIL HEALTH:	3	3	3	3	2	2.8	3
PC2	WATER RESOURCE	3	3	3	3	2	2.8	3
PC3	AIR QUALITY:	3	3	4	3	2	3	3
PC4	WASTE MANAGEMENT	2	3	1	3	2	2.2	2
Biological/Ecological (BE)								
BE1	BIODIVERSITY:	3	3	3	4	2	3	3
BE2	EOSYSTEM SERVICES:	2	3	2	3	2	2.4	2
BE3	WILDLIFE HABITATS:	2	2	4	4	2	2.8	3
BE4	CARBON FOOTPRINT:	3	2	1	4	3	2.6	3
Sociological/Cultural (SC)								
SC1	HEALTH & SAFETY:	1	3	2	2	3	2.2	2
SC2	COMMUNITY ACCEPTAANCE	1	3	1	2	3	2	2
SC3	QUALITY OF LIFE	1	3	2	2	3	2.2	2
SC4	CULTURAL SENSITIVITY:	1	3	1	2	1	1.6	2
Economic/Operational (EO)								
EO1	COST BENEFIT ANALYSIS	1	3	1	1	3	1.8	2
EO2	JOB CREATION	1	3	1	1	3	1.8	2
EO3	ENERGY OUTPUT	1	3	1	1	4	2	2
EO4	WASTE MANAGEMENT COSTS	1	3	1	1	4	2	2
EO5	OPERATIONAL SUSTAINABILITY:	1	3	1	1	4	2	2
							B2=	2.35

b3 cumulative								
Physical/Chemical (PC)		Expert1	Expert2	Expert3	Expert4	Expert5	Average	Roundoff
	SOIL HEALTH:	3	3	3	3	2	2.8	3
	WATER RESOURCE	3	3	3	3	3	3	3
PC3	AIR QUALITY:	4	3	4	3	3	3.4	3
PC4	WASTE MANAGEMENT	3	3	4	3	4	3.4	3
Biological/Ecological (BE)								
BE1	BIODIVERSITY:	3	4	3	4	3	3.4	3
BE2	EOSYSTEM SERVICES:	3	4	3	3	3	3.2	3
BE3	WILDLIFE HABITATS:	3	3	2	3	3	2.8	3
BE4	CARBON FOOTPRINT:	3	3	3	4	3	3.2	3
Sociological/Cultural (SC)								
SC1	HEALTH & SAFETY:	3	4	3	3	3	3.2	3
SC2	COMMUNITY ACCEPTAANCE	2	4	3	3	3	3	3
SC3	QUALITY OF LIFE	1	4	3	3	3	2.8	3
SC4	CULTURAL SENSITIVITY:	2	4	2	3	1	2.4	2
Economic/Operational (EO)								
EO1	COST BENEFIT ANALYSIS	3	3	3	3	3	3	3
EO2	JOB CREATION	2	3	2	3	3	2.6	3
EO3	ENERGY OUTPUT	2	3	3	4	3	3	3
EO4	WASTE MANAGEMENT COSTS	2	3	3	4	4	3.2	3
EO5	OPERATIONAL SUSTAINABILITY:	2	3	4	4	4	3.4	3
							B3=	2.94

Table 3. Calculation of B1- Permanence, B2- Reversibility & B3- Cumulative as per the expert survey
Source: Author

Based on the expert survey each criterion A1, A2, and B1, B2 and B3 is calculated A1 = 2.12 and A2= 1.12

Therefore, A1 X A2 = AT =2.37

B1=2.94, B2= 2.35 and B3 =2.94

Therefore, B1+B2+B3 =BT= 8.23

Hence, Environmental Score (ES) = AT X BT = 2.37 x 8.23 = + 19.5

Environmental Score (ES)	Range Bands (RB)	Range Value (RV)	Description of Range Value
+72 to +108	+E	5	Major positive change/impacts.
+36 to +71	+D	4	Significant positive change/impacts.
+19 to + 35	+C	3	Moderately positive change/impacts.
+10 to +18	+B	2	Positive change/impacts.
+1 to +9	+A	1	Slightly positive change/impacts.
0	N	0	No change/status quo/not applicable.
-1 to -9	-A	-1	Slightly negative change/impacts.
-10 to -18	-B	-2	Negative change/impacts.
-19 to -35	-C	-3	Moderately negative change/impacts.
-36 to -71	-D	-4	Significant negative change/impacts.
-71 to -108	-E	-5	Major negative change/impacts.

Table 4. Conversion of Environmental Scores to Range Bands, Image Source: Pastakia & Jensen, 1998

The Rapid Impact Assessment Matrix (RIAM) analysis of the project yielded an Environmental Score (ES) of +19.5 indicates a Moderately Positive impact. The score reflects potential benefits, indicating that the project is environmentally beneficial, though not significantly transformative enough to qualify as "moderate" or "major" environmental improvement. Key parameters such as permanence of impact (B1), and reversibility (B2) and cumulative effects (B3) contributed to this favorable assessment. Compared to traditional landfill disposal and open burning which often receive negative environmental scores the biogas plant emerges as a comparatively sustainable waste management alternative.

VI. CONCLUSION

The RIAM assessment suggests that the proposed biogas plant at Brahmapuram offers slight to moderate environmental benefits, making it a promising solution to mitigate the adverse impacts of the existing landfill. The proposed Brahmapuram biogas plant project is expected to have a generally beneficial effect on the environmental aspects such as air quality, soil health, odor control, and methane management by managing the organic bio-degradable waste. The measures to tackle the non-biodegradable waste is still unaddressed with the legacy waste still remining in the site. This scenario demands stronger mitigation strategies along with technology improvements to push the score higher. It is recommended to have a robust Environmental Management Plan (EMP) to address residual impacts and to maximize environmental performance through implementation of leachate treatment systems and continuous emissions monitoring to elevate the project's environmental benefits. Compared to conventional waste disposal methods such as uncontrolled landfilling or open burning which often result in negative RIAM scores, the biogas plant represents a more sustainable alternative, albeit one that still needs improvement in design and operational planning to achieve higher environmental gains. The biogas plant thus represents a critical step forward in improving Kochi's waste infrastructure, but ongoing evaluation and adaptive management will be vital to enhance its long-term sustainability and community acceptance.

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