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Reuse of solid organic waste to produce biogas and compost as a circular economy process in an underground mining unit

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Abstract– The main objective of the project is to carry out a cost-benefit analysis for the use of organic solid waste generated in a specific mining unit. Likewise, the main parameters that influence the treatment of organic waste to obtain biogas and compost are determined. The proposal evaluates an underground mining operation that generates around 1.35 tons of organic solid waste per day. The process of obtaining biogas requires the evaluation of various factors such as the composition of the waste, temperature, pH of the process, among others. The cost-benefit analysis of the project to implement a biogas plant analyzed is feasible, since two proposals can be implemented. The first one requires a total investment of 54,738 soles, generating an annual profitability of 5,192 soles. The investment recovery time being 10.3 years. A second proposal requires a total investment of 41,738 soles, generating an annual return of 4,914 soles with an investment recovery time of 8.5 years. The first proposal provides a biosol (fertilizer) production of 57.30 m^3 and 0.42 tons of biosol (compost); On the other hand, for the Second proposal it determines that a production of 57.30 m^3 of biol and 0.01 tons of biosol will be obtained.

Keywords—biogas, biosol, compost, organic waste, recycling, solid waste.

I. Introduction

Solid waste has always been linked to all human activity [1]. Currently, these wastes represent a critical problem due to the increase in the speed of their generation [2]. In this context, processes and technologies have been developed for adequate solid waste management throughout the world [3,4]. Sweden leads the process of recycling solid waste (> 99% of household waste) [5]. However, for developing countries, such as Peru, implementing adequate solid waste management represents a challenge for the present generation.

The mining industry generates solid industrial waste (tires, rocks, tailings, etc.) and domestic waste (paper, wires, cardboard, food scraps, etc.) that must be disposed of in an environmentally safe way [6,7]. An adequate management of solid waste is very important for the protection of the environment [8]. On the other hand, solid waste can be reused in various ways [9-11].

Depending on its nature, there are organic and inorganic solid waste [12]. Organic waste can be classified as food waste, manure, plant remains, paper and cardboard, leather and plastics (Figure 1).

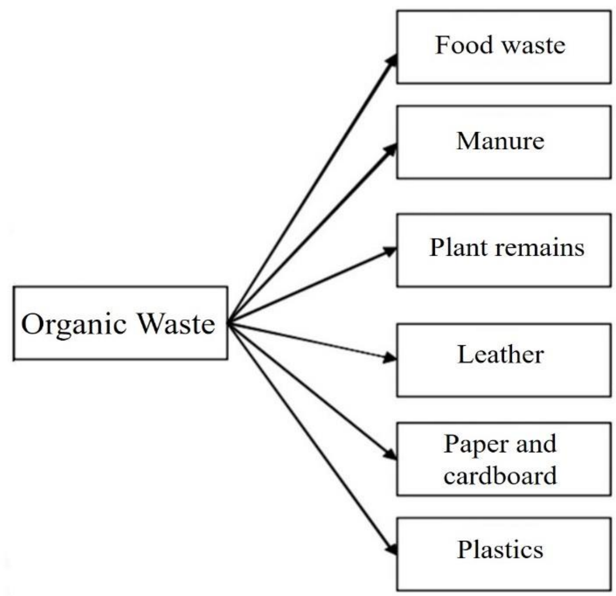

Fig. 1 Classification of organic solid waste.

Organic solid waste is waste of biological origin (vegetable or animal), which decomposes naturally, generating gases (carbon dioxide, methane, among others) and leachate at treatment and final disposal sites [13]. Organic solid waste can be treated to obtain biogas and compost [14-19].

The organic waste can be used in the production of biogas and composting, thus providing added value to this marginal material. Biogas produces methane, which can be collected and burned to produce electricity [20-22]. Biogas can be used to produce electrical energy through gas turbines or generating plants, or to generate heat in ovens, stoves, dryers, boilers or other gas combustion systems, duly adapted for this purpose [23-25]. On the other hand, compost, which is a natural fertilizer, can be used to improve soil fertility and as food for plants in a revegetation process in progressive closures or reclamation of soil in a mining operation [26-29].

On the other hand, for a biogas and compost plant to be implemented, it is necessary to evaluate its technical-economic feasibility.

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The economic evaluation is based on calculations of the net present value (NPV) and the internal rate of profitability concepts (IRR) of the design of the corresponding processing plant [30]. For a detailed economic analysis, important aspects such as the operation and investment costs of the proposed processing plant must be considered [31,32]. All parameters and characteristic values of the design of the processing plant based on the feeding of organic waste material must be included in the corresponding mathematical model [33,34,35].

The objective of this research is to carry out a cost-benefit analysis for the use of organic solid waste generated in a certain mining unit. Likewise, establish the main parameters that influence the treatment of organic waste to obtain biogas and compost.

II. Methodology

A. *Case study*

For the case study, an underground polymetallic mine, located in the Chavín District, Chincha Province, Peru, was chosen (Figure 2). The study area is located at 1850 meters above sea level (m.a.s.l.) and at approximately 268 km southeast of Lima and 60 km from the coast. The type of operation of this mining unit is Sub level Stopping.

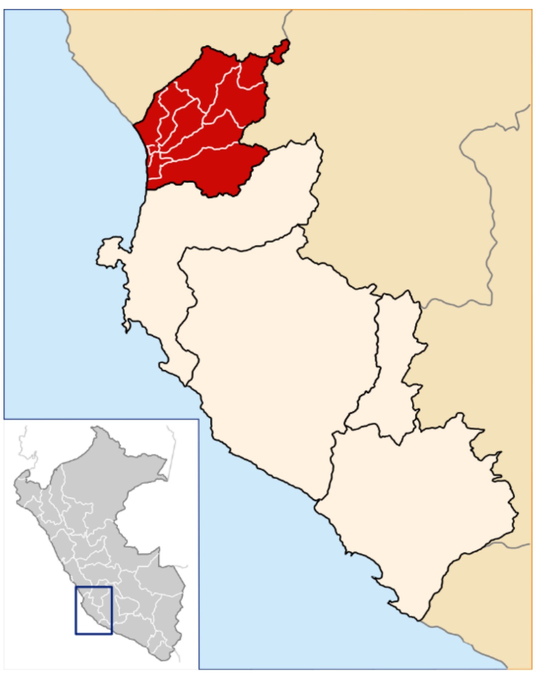

Fig. 2 Location of underground mining operation.

The mining operation has approximately 2,300 workers, including company employees and contractor companies, who provide services in the different stages of the mining process.

The labor regime of workers in the mining unit is variable, being 5 by 2, 10 by 4 and 14 by 7. The mining unit has infrastructure that provides basic services, a dining room module, housing, a medical post, and a recreation area. Likewise, it has infrastructure for extraction, mineral processing and infrastructure for disposal of filtered tailings, storage and disposal of solid waste.

B. *Solid waste production*

The mining unit has six dining rooms and two kitchen areas. The activity generates organic waste such as remains of cooked food, vegetables and meat, as well as inorganic waste including plastic bags, polyethylene bottles, cans, among others. It has been estimated that the organic waste generated is approximately 1.35 tons/day.

The mining operation selected for this study has 95 solid waste collection points. For this first stage of the study, those points that have the highest percentage of solid waste were selected. In this sense, the points were: 1) dining room collection points and 2) kitchen areas.

The average generation of solid waste at the selected points is 361.67 kg per day. The average density of this waste is 509.23 kg/m^3; having a maximum value of 595.63 and a minimum of 432.18 kg/m^3. All the waste generated is composed of 21 components: 17 are inorganic, 3 organic and 1 called other (waste that is difficult to segregate). Table I and Table II provide details of the inorganic and organic solid waste generated, respectively.

Figure 3 details the percentage of solid waste based on its composition.

TABLE I
COMPOSITION OF THE INORGANIC FRACTION OF SOLID WASTE

No.	Components	Average (Kg)	%
1	Paper and paperboard.	7.904	0.55
2	Glass.	2.440	0.17
3	Tin.	6.967	0.48
4	Aluminum.	0.145	0.01
5	PET plastic.	0.917	0.06
6	HDPE plastic	6.616	0.46
7	PVC plastic	0.365	0.03
8	LDPE plastic	25.886	1.79
9	PP plastic	4.901	0.34
10	PS plastic	1.173	0.08
11	Technopor PS (no recyclable)	1.044	0.07
12	Fabrics	1.270	0.09
13	Slab	8.593	0.59
14	Wet napkins	18.624	1.29
15	Latex	0.082	0.06
16	Tetra pack	0.165	0.01
17	Steel	0.282	0.02
	Total inorganic waste	**88.074**	**6.08**

PET: Polyethylene Terephthalate; HDPE: High density polyethylene; PVC: Polyvinyl chloride; LDPE: Low density polyethylene; PP: Polypropylene and PS: Polystyrene

TABLE II
COMPOSITION OF THE ORGANIC FRACTION OF SOLID WASTE

No.	Components	Average (Kg)	%
1	Fresh waste	478.307	33.01
2	Leftovers	750.764	51.82
3	Bones and meat	119.787	8.27
	Total	**1348.858**	**93.10**

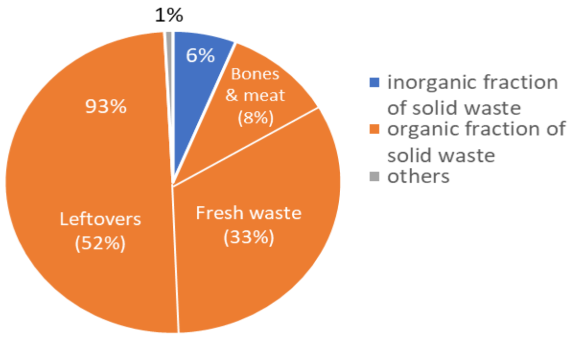

Fig. 3 Solid waste composition

The collected organic waste is segregated based on its physical composition. This waste can be segregated as: fresh waste, food remains and bones and meat. The following table shows the annual average in kilograms and the percentage of these wastes. The collected organic waste is segregated based on its physical composition. This waste can be segregated as: fresh waste, food remains and bones and meat (Figure 4). The following table shows the annual average in kilograms and the percentage of these wastes (Table III).

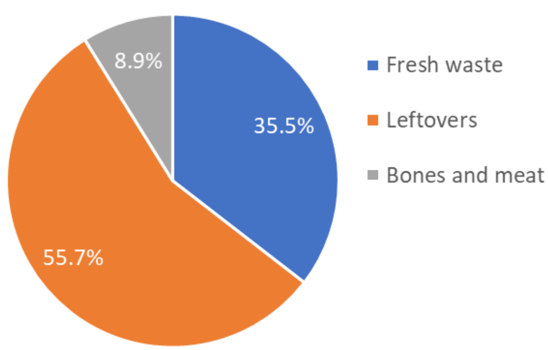

Fig. 4 Physical composition of the organic fraction of solid waste.

TABLE III
ANNUAL AVERAGE IN KILOGRAMS AND THE PERCENTAGE OF ORGANIC SOLID WASTES

Components	Average (Kg)	%	ton/day	ton/month	ton/year
Fresh waste	478.307	35.46	0.478	14.349	172.191
Leftovers	750.764	55.66	0.751	22.523	270.275
Bones and meat	119.787	8.88	0.120	3.594	43.123
Total	**1348.858**	**100**	**1.349**	**40.466**	**485.589**

III. RESULTS

A. *Technical Economic Feasibility Study*

1) *Substrate*

The substrate used in this project is the putrescible organic solid waste generated in the dining rooms and kitchen areas of the mining unit, which, through anaerobic decomposition, will be able to generate biogas.

This organic portion is made up of fresh solid waste (uncooked fruit and vegetable waste), food scraps, bones and meat. Of which, through a chemical evaluation, it will be possible to determine which is the ideal portion that will be used for the generation of biogas.

Currently the mining unit has 2 kitchen areas and 6 dining rooms. In each dining room and kitchen area, there are collection points equipped for the storage of the organic and inorganic waste generated. The solid waste collected at these collection points, in which a high percentage of organic solid waste is recorded, will be the substrate used for the production of biogas.

2) *Substrate Characterization*

The study was carried out based on a methodological adaptation of conventional studies carried out for household solid waste, in which parameters were determined through statistical procedures that will contribute to the optimization of the management and handling of solid waste generated by a population.

For the particular case of the mining unit, the collection points of the kitchen and dining areas have been considered, generating 4 collection points.

a) Per Capita Production

There is an average generation of 0.614 kg of solid waste from cafeterias per worker per day. Likewise, the average generation of solid waste is 361.67 kg/day from the four collection points. The results are shown in Table IV.

TABLE IV
CALCULATION OF GENERATION PER CAPITA (GPC) AND GENERATION PER COLLECTION POINT (GPCP) OF SOLID WASTE

Collection point	**Code**	**Number of people**	**GPC (Kg/day)**	**GPA (Kg/day)**
1	P-01	256	0.749	191.74
2	P-02	720	0.756	544.32
3	P-03	508	0.486	246.89
4	P-04	870	0.533	463.71
		Average	0.614	361.67

b) Physical Composition.

The inorganic and organic composition of the waste is presented in Table I and Table II respectively.

c) Density.

An average density of 509.23 kg was obtained for each cubic meter of solid waste generated at the collection points (Table V). The average density of food remains is 876.9 Kg/m^3 and the density of fresh waste is 555.07 Kg/m^3 (Table VI), having a total average of 715.38 Kg/m^3.

TABLE V
OVERALL AVERAGE DENSITY OF SOLID WASTE

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
438.18	488.34	595.63	526.41	538.45	535.36	448.23
					Average (Kg/m^3)	509.23

TABLE VI
AVERAGE DENSITY OF THE ORGANIC COMPONENT.

Days	Fresh Residue	Food Waste
Day 1	561.85	999.97
Day 2	640.17	756.23
Day 3	562.83	831.69
Day 4	480.15	858.34
Day 5	631.11	880.34
Day 6	557.77	923.61
Day 7	451.61	888.10
Average (Kg/m^3)	555.07	876.90

d) Humidity.

The laboratory tests of the analyzed samples determined that the average humidity of the organic component of the waste is 50.71%.

e) Energy Potential of the Substrate.

The estimation of the energy potential of the substrate was determined based on the mathematical model (Equations 1-6), the values of the variables for the calculation of the energy potential are supported by the results of the laboratory tests.

3) Mathematical Models for Estimating Energy Potential

The mathematical model developed is based on the IPPC [34] and Bhattcharya [35] models, taking into account the elemental composition of organic waste, to estimate the amount of methane generated from organic carbon. The decomposition of organic carbon is determined by the following equation:

$$C_aH_bO_cN_d + \left(\frac{4a-b-2c+3d}{4}\right)H_2O + \left(\frac{4a+b-2c-3d}{8}\right)CH_4 + \left(\frac{4a-b+2c+3d}{8}\right)CO_2 + dNH_3 \quad (1)$$

Where: a = sub mole index of carbon, b = sub mole index of hydrogen, c = sub mole index of oxygen, and d = sub mole index of nitrogen.

The model assumes that the methane generated is collected without loss and that the ammonia generated is very little, therefore, the energy power is very low and is considered negligible. Consequently, the power calculation is carried out taking only the energetic power of methane. The structure of the model is defined according to expression (2).

$$EP = M_{osw}\left(\frac{CH_4\ generated}{M_{osw}\ Biodegradable}\right)LHV \quad (2)$$

Where EP = Energy Potential, osw = organic solid waste, Mosw = The mass of osw generated (tons/time) and LHV = Lower Heating Value of Methane (TJ/ton).

$$\left(\frac{CH_4\ generated}{M_{osw}\ Biodegradable}\right) = OF.BCF.BCFM \quad (3)$$

Where OF = Organic Fraction of Solid Waste, BCF = Biodegradable Carbon Fraction and BCFM = Biodegradable Carbon Fraction as Methane. Therefore, the expression for calculating the energy potential is expressed as:

$$EP = M_{osw}\left(OF.BCF.BCFM.\frac{16}{12}\right)LHV \quad (4)$$

The 16/12 factor corresponds to the ratio of the molar mass of methane (16g/mol) to the molar mass of carbon (12g/mol), which allows the amount of biodegradable carbon to be converted into methane.

Variables:

a) Organic Fraction of Solid Waste (OF): This variable depends on the physical properties of the mass of the waste.

b) Biodegradable Carbon Fraction (BCF): This variable is dependent on the chemical characteristics of the organic waste, to determine this variable the following expression is used.

$$BCF = 0.83 - 0.28\left[\left(\frac{lignin}{\%VS}\right)\left(\frac{\%TOC*TS}{10000}\right)\right] \quad (5)$$

Where VS = volatile solid (Kg VS/ Kg OSW), TOC = Total Organic Carbon (Kg TOC/ Kg OSW), and TS = Total Solid (Kg TS/ Kg OSW).

c) Biodegradable Carbon Fraction as Methane (BCFM): This variable is dependent on the physicochemical characteristics, for its determination it is necessary to apply the principle of anaerobic biodigestion, through the expression (6).

$$A = \left(\frac{4a-b-2c+3d}{8a}\right);\ B = \left(\frac{4a+b-2c-3d}{8a}\right);C = \left(\frac{4a-b+2c+3d}{8a}\right) \quad (6)$$

Where A are the moles of water (H_2O), B are the moles of methane (CH_4) and C are the moles of carbon dioxide (CO_2) and in this way calculate the fraction of methane. The waste samples assumed for the project were divided into three classes or substrates, sent to the laboratory for analysis. Table VII shows the results obtained from the analysis.

Analyzed Substrates:

a) Substrate 1 (S1) Fresh residue sample - It consists of remains of fruits and vegetables, which have not gone through any cooking treatment.

b) Substrate 2 (S2) Sample of cooked residue or food. - It is made up of food scraps (rice, fruit peels, vegetables, stews) and soups.

c) Substrate 3 (S3) Sample of mixed waste or mixture. - Made up of substrate samples S1, S2 and meat and bone waste respectively.

During the characterization carried out, three daily samples were sent (one for each substrate) for five days. Table VII shows the average results by type of substrate.

TABLE VII
RESULTS OBTAINED FROM THE ANALYSIS

Physicochemical Characteristics				
Parameter	unit	Substrates		
		Fresh	Cooked	Mix
Basic Analysis				
Actual density	Kg/m^3	555.07	876.90	715.38
Humidity	%	58.36	41.77	50.71
Total solids	%	41.64	58.23	49.29
Dry basis analysis				
Volatil material	%	73.00	35.99	42.67
Fixed carbon	%	9.66	4.76	5.65
Ashes	%	3.95	2.44	2.89
Elemental analysis on a dry basis				
Total Organic Carbon (TOC)	%	21.93	32.06	25.56
Hydrogen	%	2.88	4.12	3.35
Oxygen	%	17.63	25.27	20.55
Nitrogen	%	0.91	1.31	1.07
Sulfur	%	0.09	0.13	0.11
Bromatological analysis				
Oils and grease	mg/kg	10672.50	47939.40	42584.00
Lignin	%	4.52	5.21	4.87
Other parameters				
Volatile solid	%	96.05	97.32	97.69
Mass of waste	ton/month	14.34	22.52	40.47
Organic material	%	37.78	55.66	44.08

Figure 5 presents the main chemical parameters of the substrates analyzed.

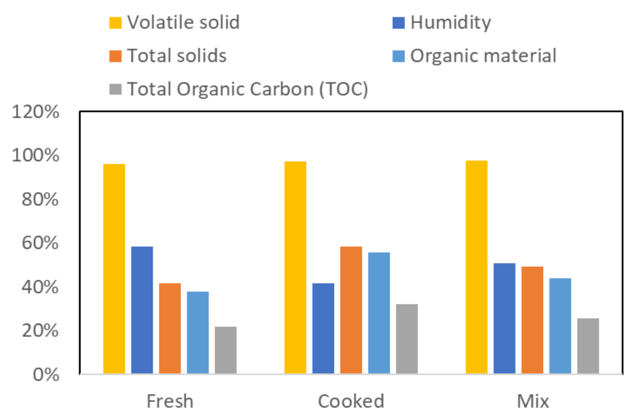

Fig. 5 Main chemical parameters by analyzed substrates

Energy potential variables.

To determine the energy potential (EP), expression 4 will be applied; First the calculation of the value of its variables BCF and BCFM will be carried out.

a) Biodegradable Carbon Fraction (BCF): This variable is determined from the elemental analysis of the substrates (parameter No. 3, 7, 13 and 14 of Table I) obtaining the BCF values (Table VIII), using Expression 5.

TABLE VIII
BIODEGRADABLE ORGANIC CARBON FRACTION OF FRESH, COOKED AND MIX WASTE

BCF for fresh waste (%)	
Total Solids (ST)	41.64
Total Organic Carbon (TOC)	21.93
Lignin	4.52
Volatile Solids (VS)	96.05
BCF	0.07
BCF for cooked waste (%)	
Total Solids (ST)	58.23
Total Organic Carbon (TOC)	32.06
Lignin	5.21
Volatile Solids (VS)	97.32
BCF	0.15
BCF for mixed waste (%)	
Total Solids (ST)	49.29
Total Organic Carbon (TOC)	25.56
Lignin	4.87
Volatile Solids (VS)	97.69
BCF	0.10

b) Biodegradable Carbon Fraction as Methane (BCFM): This variable is determined from expression 5, developing the values of the parameters indicated in expression 6, which links the elemental analysis on a dry basis (parameter No. 7, 8, 9 and 10 of Table I), obtaining the values for the types of substrates shown in Table IX.

c) Organic Fraction (OF): It is a variable determined in the laboratory (parameter No. 16 of Table I), in Table IX the values of the organic fraction are presented.

TABLE IX
BIODEGRADABLE ORGANIC CARBON FRACTION AS METHANE AND BIODEGRADABLE ORGANIC FRACTION

Substrate	BCFM	BOF
Fresh waste	0.52	0.38
Cooked waste	0.51	0.56
Mixed waste	0.51	0.44

d) Energy Potential of Organic Waste: to determine the Energy Potential (EP) of the selected substrates, calculations must be carried out with the values obtained. Table X show the calculation of the energy potential by type of substrate analyzed; it is observed that the cooked residue has the highest EP. Figure 6 presents the Biodegradable Organic Carbon Fraction as Methane and Biodegradable Organic Fraction.

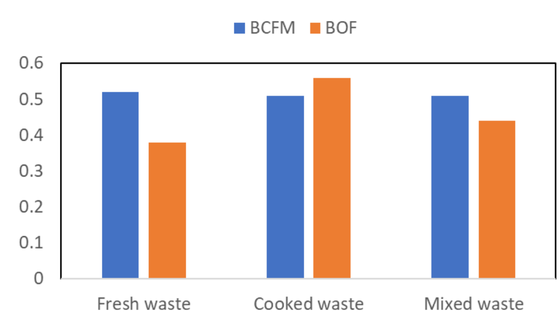

Fig. 6 Biodegradable Organic Carbon Fraction as Methane and Biodegradable Organic Fraction

TABLE X
ENERGETIC POTENTIAL OF FRESH, COOKED AND MIX WASTE

WASTE	PARAMETER	VARIABLE	UNIT	EXPRESSION (MODEL MATHEMATICAL)
FRESH	M_{OSW}	14.3400	TON/MONTH	---
	OF	0.3800	DIMENSIONLESS	---
	BCF	0.0700	DIMENSIONLESS	EQUATION 5
	LHV	0.0500	TJ/TON	---
	BCFM	0.5200	DIMENSIONLESS	EQUATION 1
	EP	0.0144	TJ/MONTH	EQUATION 3
COOKED	M_{OSW}	22.5200	TON/MONTH	---
	OF	0.5600	DIMENSIONLESS	---
	BCF	0.1500	DIMENSIONLESS	EQUATION 5
	LHV	0.0500	TJ/TON	
	BCFM	0.5100	DIMENSIONLESS	EQUATION 1
	EP	0.0670	TJ/MONTH	EQUATION 3
MIX	M_{OSW}	40.4700	TON/MONTH	---
	OF	0.4400	DIMENSIONLESS	---
	BCF	0.1000	DIMENSIONLESS	EQUATION 5
	LHV	0.0500	TJ/TON	---
	BCFM	0.5100	DIMENSIONLESS	EQUATION 1
	EP	0.0644	TJ/MONTH	EQUATION 3

Figure 7 presents the Energy Potential of organic solid waste.

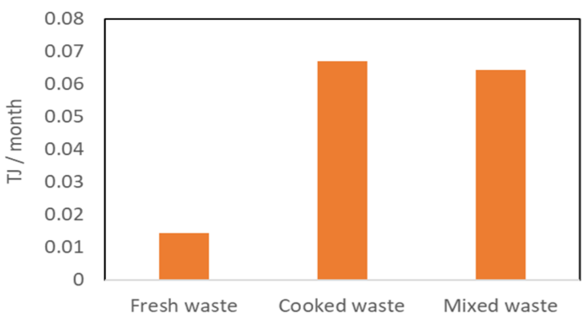

Fig. 7 Energy Potential of organic solid waste

In Table XI, it is observed that treating 14.34 ton/month of fresh waste (S1) produces 0.550 liters of oil per hour, treating 22.52 ton/month of cooked waste (S2) produces 2.650 liters of oil per hour and treating 40.47 ton/month of mixed waste (S3) produces 2,462 liters of oil per hour.

TABLE XI
BIODEGRADABLE ORGANIC FRACTION

ENERGY FACTOR	EQUIVALENCE		
	FRESH	COOKED	MIX
ENERGY POTENTIAL (TJ/MONTH)	0.014400	0.067000	0.064400
TJ/H	0.000019	0.000093	0.000089
MJ/H	19.992	93.017	89.489
KW/H	5.553	25.838	24.858
LITERS OF OIL (H)	0.550	2.650	2.462

Substrate selected for the production of Biogas

The leftover food or cooked waste will be used for the production of biogas, because they would generate greater energy potential.

Substrate for Biogas production.

From the analysis of the energy potential, the substrate that corresponds to food or cooked waste (S2) is suitable to be biodigested, generating approximately 25,838kW/h. Table XII shows the energy equivalence of cooked waste expressed per day of biodigestion. For the generation of biogas, a period of 60 days of system start-up is required, after which 620,112 kW/day can be generated.

TABLE XII
ENERGY EQUIVALENCE OF FOOD WASTE (S2)

ENERGETIC FACTOR	EQUIVALENCE
ENERGETIC POTENTIAL (EP)	0.067000
TJ/DAY	0.002232
MJ/DAY	2232.408
KW/DAY	620.112
OIL (LITERS PER DAY)	63.60

Substrate for Compost production.

From the analysis carried out on the selected samples to determine the quality of the waste, and its potential to generate biogas. It was observed that 35.46% of the organic waste, made up of fresh waste, does not present an adequate index for the generation of biogas. Therefore, it is advisable to give it a different management, that is, continue with the production of compost, but taking into account new procedures and considerations that will be detailed in the compost section.

B. *Economic analysis of solid waste treatment in the mining unit*

1) Cost-Benefit Analysis for biogas.

The cost-benefit analysis was carried out under two proposals: Proposal 1 (Energy production through an engine for electricity generation) and Proposal 2 (Methane burning through an atmospheric burner). Both proposals show the equipment to be used, the investment costs, as well as the environmental benefits involved in the implementation of each proposal.

Total Investment Costs

This cost is defined according to the relationship of costs and capacity of the plant. According to the methodologies applied for the technical-economic evaluation of the implementation of anaerobic treatment systems, this is based on the cost of fixed investment (FI) and work investment (WI), defining the latter as 15% of the fixed investment.

$$Total\ investment\ (TI) = Fixed\ investment\ (FI) + Work\ investment\ (WI) \quad (7)$$

Calculation of Plant Investment (PI): The fixed investment is determined in function to the direct (DI) and indirect (II) investment expenses that generally links costs of equipment, installation and infrastructure and unforeseen events the latter being considered 10% of the indirect costs.

$$Fixed\ investment\ (FI) = Direct\ investment\ (DI) + Indirect\ investment\ (II) \quad (8)$$

Work investment (IW): The work investment is based on the fixed investment, and can be calculated using the following expression:

$$Work\ investment\ (WI) = \frac{Fixed\ Investment\ (FI) * 15}{85} \quad (9)$$

a) Analysis of Proposal 1 – Energy Production

Investment Cost: Table XIII shows the total investment costs for the implementation of the biogas production plant with energy use.

TABLE XIII

TOTAL INVESTMENT COST FOR THE CONSTRUCTION OF THE ENERGY PRODUCTION PLANT

PROPOSAL 1: PLANT CONSTRUCTION						
DIRECT COSTS						
EQUIPMENT	AMT.	CAP.	UNIT	TOTAL CAP.	UNIT COST (USD)	TOTAL COST (USD)
BIODIGESTER (INCLUDING BIOL RESERVOIRS AND INLETS)	7	15.7	m^3	102.8	565.82	3,959.97
BIOGAS WAREHOUSE	1	16	m^3	16	208.78	208.78
IMPLEMENTATION ADVICE	1		ppl.		1063.83	1063.83
B4T-5000 ENGINE	1	9	kW		3191.49	3191.49
VACUUM TUBE HEATER	1	200	lT		1063.83	1063.83
					SUBTOTAL (USD)	9487.90
INDIRECT COSTS.						
CIVIL OR UNFORESEEN WORKS (USD)						2659.57
					SUBTOTAL (USD)	2659.57
FIXED INVESTMENT (USD)						12148.27
WORK INVESTMENT (USD)						2143.81
TOTAL INVERSION (USD)						14292.09

1 USD = S/. 3.76

Table XIV shows the monthly maintenance costs of the biogas production plan. Likewise, the income from the products and by-products of the process, taking into account environmental benefits such as the reduction of Greenhouse Gas emissions, which have a cost called carbon credit provided by the International Bank. The associated cost also decreases. to the disposal of waste that would be necessary if it were disposed of in a landfill.

TABLE XIV

INVESTMENT RECOVERY COST – PROPOSAL 1.

PROPOSAL 1 – RECOVERY COST				
PARAMETER	UNIT		UNIT COST (USD)	TOTAL COST (USD)
INVESTMENT				
PLANT CONSTRUCTION				14292.09
MONTHLY MAINTENANCE COST				
WATER	M^3	44.70	0.17	7.59
ENERGY	KW/H	288	0.01	2.9
LABOUR	PEOPLE	1.0	21.22	21.22
			SUBTOTAL (USD)	115.39
ENERGY PRODUCTION AND ENVIRONMENTAL BENEFIT				
ENERGY	KW/H	33.72	0.01	0.31
BIOL (FERTILIZER)	M^3	57.30	0.14	8.11
BIOSOL (COMPOST)	TON	0.42	3.25	1.38
INTERNMENT IN FILLING	TON	26.11	1.77	46.17
CARBON BONUS	TON	7.12	0.85	6.04
			SUBTOTAL (USD)	62.01
			MONTHLY SURPLUS (USD)	30.61
			ANNUAL SURPLUS (USD)	367.31
RECOVERY TIME (YEARS)				10.3

1 USD = S/. 3.76

b) Analysis of Proposal – Methane Flaring

Table XV shows the total investment costs for the implementation of the biogas production plant for methane Flaring.

TABLE XV

TOTAL INVESTMENT COST FOR THE CONSTRUCTION OF METHANE FLARING PRODUCTION PLANT

PROPOSAL 2: PLANT CONSTRUCTION						
DIRECT COSTS						
EQUIPMENT	AMT.	CAP.	UNIT	TOTAL CAP.	UNIT COST (USD)	TOTAL COST (USD)
BIODIGESTER (INCLUDING BIOL RESERVOIRS AND INLETS)	7	14.6	m^3	102.8	565.82	3959.97
BIOGAS WAREHOUSE	1	16	m^3	16	208.78	208.78
IMPLEMENTATI ON ADVICE	1		ppl.		1063.83	1063.83
BURNER BIOGAS EQA	1		kW		478.72	478.72
VACUUM TUBE HEATER	1	200	lT		1063.83	1063.83
					SUBTOTAL (USD)	6775.93
INDIRECT COSTS.						
CIVIL OR UNFORESEEN WORKS (USD)						2659.57
					SUBTOTAL (USD)	2659.57
FIXED INVESTMENT (USD)						9435.51
WORK INVESTMENT (USD)						1665.09
TOTAL INVERSION (USD)						11100.60

1 USD = S/. 3.76

TABLE XVI
INVESTMENT RECOVERY COST – PROPOSAL 2.

PROPOSAL 2 – RECOVERY COST				
PARAMETER	UNIT		UNIT COST (USD)	TOTAL COST (USD)
INVESTMENT				
PLANT CONSTRUCTION				11100.60
MONTHLY MAINTENANCE COST				
WATER	L	44.70	0.64	28.53
ENERGY	KW/H	288	0.03	9.73
LABOUR	H	60	1.33	79.79
			SUBTOTAL (USD)	115.39
ENERGY PRODUCTION AND ENVIRONMENTAL BENEFIT				
BIOL (FERTILIZER)	M^3	57.30	0.53	30.48
BIOSOL (COMPOST)	TON	0.01	12.23	0.17
INTERNMENT IN FILLING	TON	26.11	6.65	173.60
CARBON BONUS	TON	7.12	3.19	22.72
			SUBTOTAL (USD)	226.98
			MONTHLY SURPLUS (USD)	108.93
			ANNUAL SURPLUS (USD)	1307.18
RECOVERY TIME (YEARS)				8.5

1 USD = S/. 3.76

2) Cost-Benefit Analysis for compost.

To improve the composting and process control system, it is recommended to acquire the equipment presented in the following table, which shows the cost of this improvement carried out in the current process.

TABLE XVII
COST OF EQUIPMENT FOR THE IMPROVEMENT AND CONTROL OF THE COMPOSTING PROCESS.

	AMT.	CAP.	UNIT COST (USD)
MOISTURE METER HH2 WITH WET SENSOR	1		2398.13
PH AND TEMPERATURE METER FLOOR CONTACT	1		618.47
EC METER	1		334.47
CHOPPER (M:EN 12B) + MOTOR + ACCESORIES	1	2500-11500 KG/H	3005.32
			6356.38

1 USD = S/. 3.76

By making an improvement in the process, the quality of the compost will better influence the fertility of the soil on which it will be applied; This is how a better impact will be achieved in the recovery of low-fertile soils and obtain better final products.

IV. CONCLUSION

A study was carried out on the current problems of organic solid waste management in Peru and in the selected mining unit; which allowed establishing the basis to carry out the feasibility analysis for the use of organic waste.

Organic solid waste has a high degree of energy utilization, achieving biogas through an anaerobic digestion process.

The project to implement a biogas plant analyzed is feasible, according to the following values: Proposal 1 requires a total investment of S/. 54,738 and generates an annual profitability of S/. 5,192. Therefore, the investment recovery time is 10.3 years. Proposal 2 requires a total investment of S/. 41,738 and generates an annual return of S/. 4,914. Therefore, the investment recovery time is 8.5 years. Both proposals can be implemented by the mining unit given that their investment costs are minimal.

The generation of biogas can be used as an environmental control that will generate positive environmental impact in the mining unit. It can also be used as a social responsibility project to benefit the communities near the mining complex; or it can simply be used for the energy use of biogas.

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