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Análisis crítico de los impactos ambientales generados por la agroindustria panelera en la provincia de Pastaza - Amazonía ecuatoriana

Critical analysis of the environmental impacts generated by the sugarcane agroindustry in Pastaza Province, Ecuadorian amazon

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Palabras claves: Agroindustria panelera, Procesos, Impacto ambiental, Matriz de Leopold, Gestión ambiental.

Resumen

Introducción. El cultivo de caña de azúcar y su transformación son factores importantes que dinamiza la economía rural en la provincia de Pastaza. La tecnología rudimentaria y los mecanismos productivos paneleros conllevan a generar impactos ambientales que deben ser evaluados, identificados y corregidos. **Objetivo.** Analizar los impactos ambientales generados por la agroindustria panelera en la Provincia de Pastaza, Amazonía Ecuatoriana, específico en la central panelera Teniente Hugo Ortiz. **Metodología.** Se aplicó la matriz de causa-efecto de Leopold como herramienta metodológica, para la identificación de las actividades del proceso productivo y se evaluó su impacto en los componentes ambientales. **Resultados.** Se determinó 41 impactos evaluados, los aspectos positivos representan el 14,63%, mientras que los negativos alcanzan el 85,37%. Las etapas de corte de caña, molienda y limpieza de instalaciones presentan el mayor impacto negativo (20%). En términos de Unidades de Impacto Ambiental (UIA), se evaluaron 2190, de las cuales el 10,50% son positivas y el 89,50% son negativas. Los procesos de corte (25,51%), molienda (25,51%) y limpieza de instalaciones (19,90%) generan las mayores UIA negativas. **Conclusión**. Se concluye que la falta de una política clara de gestión ambiental y el desconocimiento de métodos de tratamiento de residuos contribuyentes a la generación de contaminación ambiental en los diferentes procesos productivos. Se recomienda cambiar de tecnología y tratar los efluentes para mejorar los ingresos económicos y la calidad de vida de la población circundante. **Área de la ciencia:** ciencias agropecuarias, medioambiente.

Keywords: Sugarcane agroindustry, Processes, environmental impact, Leopold's matrix, environmental management.

Abstract

Introduction: Sugarcane cultivation and processing are crucial factors that drive the rural economy in Pastaza Province. Rudimentary technology and panela production methods lead to environmental impacts that must be evaluated, identified, and corrected. Objective: To analyze the environmental impacts generated by the panela agroindustry in Pastaza Province, Ecuadorian Amazon, specifically in the Teniente Hugo Ortiz panela mill. Methodology: The Leopold cause-effect matrix was applied as a methodological tool to identify the activities of the production process and evaluate their impact on environmental components. Results: Forty-one impacts were evaluated, with positive aspects representing 14.63%, while negative aspects reach 85.37%. The sugarcane cutting, milling, and facility cleaning stages have the highest negative impact (20%). In terms of Environmental Impact Units (UIA), 2190 were evaluated, of which 10.50% are positive and 89.50% are negative. The cutting (25.51%), milling (25.51%), and facility cleaning (19.90%) processes generate the highest negative UIAs. Conclusion: It is concluded that the lack of a clear environmental management policy and the lack of knowledge of waste treatment methods contribute to the generation of environmental pollution in the different production processes. It is recommended to change technology and treat effluents to improve economic income and the quality of life of the surrounding population.

Introduction

Global sugarcane production reaches 1.9 billion tons annually on an area of 27 million hectares, with the highest concentration in America (50.7%), followed by Asia (40.9%), Africa (5.9%) and Oceania (2.5%) (Lagos-Burbano & Castro-Rincón, 2019). It is grown in tropical and subtropical regions, and is vital for both food and bioenergy production due to its high biomass production per area (González et al., 2024), and is harvested mechanically, and also manually (Aguilar-Pardo et al., 2016). In 2012, sugarcane was produced in more than 100 countries (Silalertruksa & Gheewala, 2018), and its cultivation has a significant impact on ecosystems, mainly through deforestation and burning during harvest (Semie et al., 2019).

The agroindustry derived from sugarcane cultivation includes the production of non-centrifugal cane sugar (NCS), a traditional minimally processed sweetener recognized by the FAO (Velásquez et al., 2019). NCS is a solid, unrefined product with a unique flavor and aroma, obtained by mechanical extraction of cane juices and subsequent evaporation of water until reaching 88-94 ºBrix (Alarcón et al., 2020). Its composition mainly includes sucrose (65-85%), reducing sugars (7-15%) and water (3-10%) (García et al., 2017), in addition to phenolic compounds with antioxidant activity (Zhu et al., 2020). This sweetener is mainly used in Asia, Africa, Latin America and the Caribbean, valued for its characteristic flavor and nutritional value (Velásquez et al., 2019).

Of the 25 panela producing countries in the world, India is the main producer, and Colombia is the second, who participate with 60.8% of the world production and 14.2% respectively (Tobón, 2018). Other producing countries in Latin America include Brazil, Mexico, Ecuador and Guatemala, among others (Murcia, 2012).

In Ecuador, the main sugarcane producing areas are the provinces of Guayas, Manabí, Cañar, Los Ríos, Imbabura, Azuay, Bolívar and Loja. The Guayas River Basin is the area with the highest production, with 92% of the area, with 72,000 ha, distributed with 60% (43,200 ha) belonging to sugarcane producers and 40% (28,800 ha) to sugar mills (Peñarrieta & Sánchez, 2015). In the province of Pastaza, sugarcane production is 862.05 ha, which are destined for the production of NCS (González et al., 2019).

In Pastaza, there are 10 technologically improved factories for the production of panela, which have received technical assistance since 1987 to improve production and quality (González, 2013). However, there are currently small traditional mills that use rudimentary technologies. The panela and sugar production activity generates byproducts that can be polluting if not managed properly, such as wastewater that carries organic and inorganic loads as a result of cleaning the plant and materials, which can be polluting to bodies of water if not properly treated. The must or vinasse are viscous products with 4 to 10 ºBrix, which at high temperatures and concentrations are very corrosive, and the cachaza, which are residues from the sugar industry (Lagos-Burbano & Castro-Rincón, 2019).

When assessing environmental problems, normal and significant environmental aspects can be identified and distinguished, the latter being those that cause the greatest environmental impact. Products and services that can cause changes in the environment must be identified. The main environmental aspects that must be identified to determine the possible environmental effects and how high the priorities are (Vélez et al., 2021). Environmental impact assessment is an environmental protection tool that, with the support of an institutional framework that meets the needs of various countries, facilitates the decision-making process at the level of policies, plans, programs and projects according to new factors and variables to be considered in the global analysis (De la Masa, 2007).

In Ecuador's sugarcane mills, the lack of a specific environmental management policy has led to an increase in environmental impacts. These mills, whether artisanal or agro-industrial, must comply with current environmental regulations. The Constitution of the Republic of Ecuador of 2008 recognizes the environment as an individual and collective right and duty. Therefore, it is essential to apply measures to maintain environmental quality and correct existing damage. In this context, an environmental assessment using the Leopold matrix is proposed, with the aim of identifying the impacts generated by agro-industrial activity and recommending sustainable technological alternatives that support socio-environmental development.

Methodology

A. *Description of the environment under study*

Currently, the Association of Sugarcane Growers of the province of Pastaza has a renovated infrastructure in the sugarcane mill in the parish of Teniente Hugo Ortiz, but they continue to use the same system and technology similar to the traditional one. The civil works infrastructure of the plant was completely renovated. The plant is located in a central location in the parish, where most of the members and sugarcane producers are concentrated. This sugarcane mill offers services to internal and external clients of the association, which was legally established in 2000. The plant produces granulated and block sugarcane.

There are three plant workers and four assistants on each work shift. The panela factory is located at kilometer 18 of the Puyo-Tena highway, which belongs to the Teniente Hugo Ortiz parish. The building has electric power and receives rainwater from the roof of the buildings in a cistern. The plant does not have a sewer system, so it has a septic tank to collect wastewater and not from the processing area, which is discharged into the environment without treatment.

B. *Methodological application of Leopold's cause-effect matrix*

The methodology used is a key factor in predicting whether panela production will have an impact (positive or negative) on the environmental factors of the process operations. The analysis and project activities are organized in a matrix in chronological order. The environmental factors included in the matrix correspond to natural and anthropogenic components (Coria, 2008).

The diagnosis of the environmental impacts generated in the artisanal production of panela was carried out using the methodology of Ordoñez-Díaz & Rueda-Quiñónez (2017), who indicate in their study that the cause-effect matrix called the Leopold matrix is a two-dimensional checklist tool: one shows the individual characteristics of a project (activities and impact elements), while the second identifies the environmental categories that may be affected by the project (table 1-2).

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Table 1

Leopold matrix rating scale by environmental component

ENVIRONMENTAL COMPONENT RATING		
	ENVIRONMENTAL COMPONENT	weight
1	Soils	10
2	Surface water	10
3	Seasonal flooding	10
4	Sedimentation	10
5	Mangroves	10
6	Natural vegetation	5
7	Terrestrial fauna	4
8	Aquatic fauna	10
9	Food Chains (ecological relationships)	10
10	Agriculture (land use)	10
11	Employment (Social component)	10
12	Improving quality of life (social component)	10

Fountain: Monar et al. (2017)

Determining factors and those established in the regulations (ISO 14001: 2015) to determine the importance of the impacts (Vélez et al., 2021):

- Use of water, energy, chemicals and raw materials.
- Product storage location.
- Place of water discharge.
- Air emissions.
- Place of dumping on the ground.
- Hazardous materials.
- Unusual situations

The environmental impact assessment method consists of several phases, which are summarized below: identification of panela production activities, determination of the impact of each activity, determination of the scope of the impact, forecasting, evaluation of the environmental impact, research and evaluation of various alternatives in relation to their management and mitigation and the evaluation criteria described in Table 2 (González & Zúñiga, 2023).

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Table 2

Leopold Matrix Rating Scale for Environmental Magnitude

MAGNITUDE AND IMPORTANCE RATING SCALE				
	Magnitude	Importance		
Intensity	affectation	Duration	Influence	Ratings
	Low	Temporary	Punctual	1
Limited	Average	Average	Punctual	2
	High	Permanent	Punctual	3
	Low	Temporary	Local	4
Reduced	Average	Average	Local	5
	High	Permanent	Local	6
	Low	Temporary	Regional	7
Evident	Average	Average	Regional	8
	High	Permanent	Regional	9
Considerable	Very high	Permanent	National	10

Note: Negative impacts:magnitude (-) and importance (+);**Positive impacts:**magnitude (+) and importance (+).**Fountain:**Monar et al. (2017) and Ordoñez-Díaz & Rueda-Quiñónez (2017)

Results

C. Production processes

In the panela sector in Ecuador and in Pastaza, a lack of scientific and technical knowledge was noted. Panela production is considered to be artisanal and not industrial production, mainly because panela is produced in small factories known as trapiches (Valle et al., 2021). Due to the type of traditional technology used in panela production, it is necessary to carry out a general diagnosis of the environmental impacts and management of panela waste.

The plant has a facility where they mainly produce panela in blocks and granules for the consumption of the partners and part of it is sent to the market. Sugar cane is known as perennial and has two harvests per year in the province of Pastaza-Ecuadorian Amazon. For each harvest, the plant works for two months each cycle and 14 hours a day on a full-time basis.

Processes:

- Sugarcane cutting depends on maturity (18–22°Brix), variety, climatic conditions and altitude level (Mosquera et al., 2007).
- Readiness is a fundamental factor for the performance and quality of panela.
- Juice extraction through a grinding process (50 – 60%).

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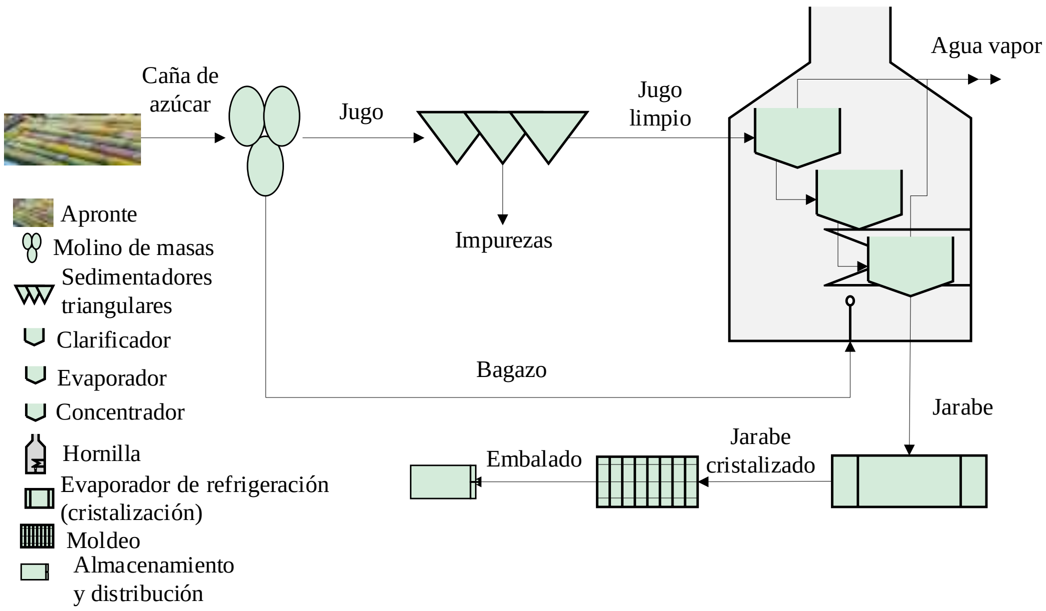
- Cleaning removal of non-nutritional impurities by physical means (decantation and flotation) in conical bottom pre-cleaners (Osorio, 2007).
- Clarification: elimination of suspended solids (bagasse, leaves, soil), colloidal substances and some colorants present in the juice, by adding natural flocculants and sedimentation at 60 - 70ºC (black cachaça) and 75 - 85 °C (white cachaça) (Mosquera et al., 2007).
- Evaporation of water and concentration of juice in order to obtain the syrup, where thermal energy is obtained in the oven; the sugar concentration increases from 22 ± 2 °Brix to 60 ± 10 ° Brix (96°C). Finally, the concentration stage evaporates the water to a concentration of 92 ± 4 °Brix to obtain panela in blocks (Velásquez et al., 2019).
- The syrup is crystallized by mechanical agitation at temperatures between 115 and 120 °C and molded into the solid form (Velásquez et al., 2019).
- Molding is a process of vigorous manual agitation in 304 stainless steel trays for 4-5 minutes (Mosquera et al., 2007).
- Packed 20 – 24 kg, the dry and cold panela is removed from the molds and packaged in plastic bags for transportation and storage.

Figure 1

Panel production diagram or NCS



D. Components of the panela processing plant

Equipment and machinery

- Dough mill with 220 V, 4 Hp electric motor.

- 6 stainless steel tubs of 280 L
- 2 triangular sedimentation tanks
- Bagasse and firewood burning stove
- 3 plastic containers 20 L
- 3 iron shovels
- 2 carts
- 156 plastic bags capacity 45 kg
- 1000 polyethylene bags for granulated panela packaging

Raw materials used

- Sugarcane
- Calcium hydroxide
- Natural coagulant balzo
- Vegetable oil.

Energy consumption

18.4 KW/h per day

Water consumption

200 L/day

E. *Agro-industrial waste management*

Waste disposal

The waste products that are discharged into the atmosphere are solid and liquid. Among the solid products is bagasse, a by-product of juice extraction. It is known that for each ton of sugar cane that enters the system, only 50-60% is used in the best of cases and the rest is bagasse; particulate material such as ash and soot that are produced in the stove or combustion chamber. Among the liquid waste products are black and white filter cake, and water as a product of washing the vats and utensils that are involved in the panela manufacturing process.

Emissions

The emissions generated mainly come from the stoves, such as: carbon dioxide CO_2, nitrogen oxides N_2O, water vapor, soot, ash, etc., and in the condensation and evaporation process they are water vapor.

Solid waste

Solid waste includes bagasse as a by-product of extraction in the sugar cane milling process, soil, sand, pebbles and plant tissue residues in the sedimentation and pre-cleaning processes of the judos, ash as a product of the combustion of wood and bagasse fed into the furnaces of the sugar cane mill.

F. *Qualitative and quantitative assessment of impacts*

Identification of qualitative impacts in the different panela manufacturing processes.

Cutting the cane. -The sugarcane growers of the Lieutenant Hugo Ortiz parish only harvest sugarcane that is at optimal maturity. Maturity is identified based on the physical phenological characteristics of the sugarcane plant. This process generates a negative impact on the environment due to the alteration of the edaphological composition or structure of the soil, modifying the microatmospheric conditions, because all the leaves and buds are left where they were cut, limiting edaphotranspiration, puddles, very slow decomposition of organic matter, uncontrolled decomposition to obtain by-products and a decrease in the conversion of CO_2 to O_2.

Preparation process. – This process does not generate environmental pollution, since it involves the collection of the cut sugarcane and its transportation to the mill and its storage, which takes approximately 24 hours and a maximum of 48 hours from the cutting process to the extraction process (Table 3).

Process of grinding or extracting juices. - generates environmental disturbances due to different factors: the operation of the mill generates high noise levels in the area, as the electric motor does not generate polluting gases, but bagasse is generated as a by-product of the extraction, which is stored for 15-20 days to dry and is later used in the furnaces.

*Pre-cleaning and clarifying processes of juices.*Organic waste resulting from pre-cleaning and clarification is frequently dumped into open air or nearby water sources, becoming potential sources of contamination and altering the surrounding ecosystems.

Evaporation and concentration process of juices. - They produce environmental pollution by heated water vapor, in these stages 84% of water evaporates and 16% is honey, generating large amounts of heat energy that is dissipated in the environment, reaching 40% of losses, in itself altering the microclimates of the environment.

Beating, cooling, molding and storage processes.- The churning and cooling area produces contamination to the environment due to overheating of the surrounding medium, and can become a major source of contamination by honey residues. The honeys are transferred to wooden moulds in which solidification is carried out and therefore the final product is obtained. In this process, contamination from wood and plastic residues is generated.

Impacts generated by plant cleaning and the materials used in the processes. - This activity involves the use of large volumes of water that are in turn contaminated by detergents and soaps, which are mixed with organic loads at each stage of processing. These are dumped in nearby open-air lands and contaminate bodies of water, altering terrestrial and aquatic ecosystems.

Table 3

Application of the Leopold matrix for the evaluation of environmental impacts in panela production

Environmental impacts / Activities	job creation	Alteration of atmospheric composition	Noise levels	Generation of by-products as waste	Spread of pollution sources	Alteration of water quality	Soil pollution	Modification of microclimates	Sum I. Positives	Sum I. Negatives	Total sum of impacts
Court	10 / 6	-10 / 8	-10 / 3	-10 / 8	-10 / 7	-10 / 7	-10 / 9	-10 / 8	1	7	8
Get ready	10 / 2	0 / 1	0 / 1	0 / 1	-10 / 2	0 / 1	0 / 1	0 / 1	1	1	2
Grinding	10 / 6	-10 / 4	-10 / 9	-10 / 8	-10 / 8	-10 / 7	-10 / 7	-10 / 7	1	7	8
Pre-cleaning and clarification of juices	0 / 5	-10 / 3	0 / 1	-10 / 4	-10 / 4	-10 / 3	-10 / 2	0 / 1	0	5	5
Evaporation, concentration and spotting	10 / 2	-10 / 9	-10 / 6	-10 / 7	0 / 1	-10 / 3	0 / 1	0 / 1	1	4	5
Molding, packaging and storage	10 / 5	-10 / 4	0 / 1	-10 / 5	-10 / 3	-10 / 2	0 / 1	0 / 1	1	4	5
Cleaning the facilities	10 / 2	-10 / 3	-10 / 4	-10 / 7	-10 / 4	-10 / 8	-10 / 6	-10 / 7	1	7	8
Sum of positive impacts	6	0	0	0	0	0	0	0	6		
Sum of negative impacts	0	6	4	6	6	6	4	3		35	
Total sum of impacts	6	6	4	6	6	6	4	3			41

This method was applied to categorize the environmental impacts caused by the processes in the manufacture of panela in the panela mills of the rural agroindustry of the Ecuadorian Amazon, denoting that the rows are the activities that generate the environmental impact, and the columns are the environmental aspects in which the impact occurs (Table 3).

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Table 4

Cause-effect matrix expected values of the evaluation of environmental impacts in panela production

Environmental impacts / Activities	job creation	Alteration of atmospheric composition	Noise levels	Generation of by-products as waste	Spread of pollution sources	Alteration of water quality	Soil pollution	Modification of microclimates	Sum I. Positives	Sum I. Negatives	Total sum of impacts
Court	60	-80	-30	-80	-70	-70	-90	-80	60	500	560
Get ready	20	0	0	0	-20	0	0	0	20	20	40
Grinding	60	-40	-90	-80	-80	-70	-70	-70	60	500	560
Pre-cleaning and clarification of juices	0	-30	0	-40	-40	-30	-20	0	0	160	160
Evaporation, concentration and spotting	20	-90	-60	-70	0	-30	0	0	20	250	270
Molding, packaging and storage	50	-40	0	-50	-30	-20	0	0	50	140	190
Cleaning the facilities	20	-30	-40	-70	-40	-80	-60	-70	20	390	410
Sum of positive impacts	230	0	0	0	0	0	0	0	230		
Sum of negative impacts	0	310	220	390	280	300	240	220		1960	
Total sum of impacts	230	310	220	390	280	300	240	220			2190

Table 4 shows the result of multiplying environmental components by environmental magnitudes, generating expected values of environmental impacts on panela production in the Teniente Hugo Ortiz parish of the Pastaza province.

Table 5

Summary of the number and environmental impact units (EIU)

Processes or activities	Number of environmental impacts						Environmental impact units					
	Positive		Negative		General		Positive		Negative		General	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Court	1	16.7	7	20	8	19.5	60	26.1	500	25.5	560	25.6
Get ready	1	16.7	1	2.86	2	4.88	20	8.7	20	1.02	40	1.83
Grinding	1	16.7	7	20	8	19.5	60	26.1	500	25.5	560	25.6
Pre-cleaning and clarification of juices	0	0	5	14.3	5	12.2	0	0	160	8.16	160	7.31
Evaporation, concentration and spotting	1	16.7	4	11.4	5	12.2	20	8.7	250	12.8	270	12.3
Molding, packaging and storage	1	16.7	4	11.4	5	12.2	50	21.7	140	7.14	190	8.68
Cleaning the facilities	1	16.7	7	20	8	19.5	20	8.7	390	19.9	410	18.7
Total	6	100	35	100	41	100	230	100	1960	100	2190	100

In Table 5, the total results of the number of environmental impacts evaluated were reported as 41, of which the positive aspects are 6, equivalent to 14.63%, while the negative aspects are 35, equivalent to 85.37%. The positive aspects have the same value for all the process stages, being 16.67%, while the negative aspects are different in the panela manufacturing process stages, presenting the greatest environmental impact in the preparation, grinding and cleaning stages of the facilities with 20%.

The number of Environmental Impact Units (UIA) evaluated in the project or panela plant was 2190, of which 230 were positive (10.50%) and 1960 were negative (89.50%). The highest negative UIAs were found in the cutting (25.51%), grinding (25.51%) and cleaning of the facilities (19.90%) processes, as shown in Table 5.

Discussion

In the analysis of Table 5, which focuses on the sugarcane cutting process, there are coincidences with the findings of Ordoñez-Díaz & Rueda-Quiñónez (2017). These authors point out that this activity generates both positive and negative impacts. Among the positive aspects, the generation of employment stands out. However, negative impacts also occur, such as the alteration of atmospheric components.

This alteration is due to the decrease in the levels of oxygen produced and carbon dioxide captured by the plants through photosynthesis as a consequence of the cutting. It is important to note that this analysis is limited to the activities after the cutting of the sugarcane, excluding its cultivation. Therefore, the impacts associated with this previous stage, such as the alteration of the soil properties due to monoculture, changes in air quality and the reduction in water availability, will not be considered in this diagnosis.

The stoves emit particulate and volatile matter (soot and ash), vapours and greenhouse gases (carbon dioxide, etc.) that pollute the air, contribute to global warming and acid rain. Coal and ash particles damage water, soil, flora and fauna, and cause respiratory and eye diseases. Bagasse particles cause hypersensitivity pneumonitis, a group of respiratory diseases (Montilla et al., 2017). The generation of particulate matter is an important factor to consider as an environmental problem of this activity that directly affects the air; the use of firewood and sugarcane bagasse for combustion in artisanal stoves reduces air quality (González & Zúñiga, 2023).

Water bodies are contaminated by the inadequate storage of fossil fuels, lubricating oils, and poor disposal of solid waste from processes, meaning there is no waste management plan. This lack of knowledge is probably due to the fact that there is no environmental awareness training in rural communities or parishes where artisanal agroindustry is developed by government agencies.

In this research, negative impacts similar to those found by González & Zúñiga (2023) were observed. These authors point out that soil erosion is caused by the washing of equipment, the removal of filter cake and the discharge of wastewater from the process.

In this study, the results of the washing process are compared with those obtained by Ordoñez-Díaz & Rueda-Quiñónez (2017). These authors point out that this activity generates employment, since it requires personnel to perform specific tasks such as parking and distributing water, scrubbing and rinsing floors, walls, equipment and instruments.

However, the current cleaning method poses serious environmental problems. The use of large quantities of water, which is then contaminated with soap and organic waste rich in sucrose, is not treated properly. This contaminated water is then dumped directly into the environment without any precautions.

This inadequate waste management practice causes waste to evaporate naturally and run off into nearby bodies of water. This significantly alters the quality of water available to the community, generating a negative impact on their health and well-being.

These impacts are considered moderate due to the lack of adequate systems for managing water and waste in the panela factories. As a result, water and filter cake flow uncontrolled towards the lower areas of the land.

The positive impact of panela production activity is the generation of employment in the different processing areas, from cutting the sugar cane to packaging, storage and distribution of the product.

A. *Proposal for the treatment of effluents.*

Nowadays, the treatment of effluents is of vital importance, not only because of the demands of national and international regulations, but also because of ourselves and the environmental feeling and the climate change that we are experiencing. Untreated effluents become a polluting entity of the environment. It is known that any modification of the conditions, however small, will cause serious ecological damage, modifying the microclimates of terrestrial and aquatic ecosystems.

The water with residuals from the cleaning of materials, equipment, vats and the infrastructure of the plant was shown to be a significant source of contamination, and the water should be treated for discharge into the environment; the treatment would be: pre-primary (retention of large particles), primary (biological), secondary (chemical). And the solid effluents should be used in composting processes and in the production of feed for animals.

Utilization of residuals for added value.

Panela production generates waste in most of its stages. These residues, with a high content of organic matter, can be used as raw material in various biotechnological processes, as decontamination alternatives and in the composting process. In the latter, cellulosic, lignocellulosic and hemicellulose residues are used, together with certain volatile fatty acid components and non-structural carbohydrates, for their decomposition.

Furthermore, these residues can be used in the production of animal feed, since they are rich in fibre and non-structural carbohydrates. These feeds can be fortified with the inoculation of certain microorganisms to increase their protein content or mixed with other components in their matrix.

It is recommended that the panela plants in the sector change their technology and treat their effluents to improve the economic income and living standards of the surrounding population.

Optimization of water and energy use.

In order to optimize water and energy resources, panela plants must migrate from open to closed container technology, with the main component being that the heat generated in the evaporators and concentrators is recirculated for preheating of other processes and can finally be sent to the condensers to obtain clean water free of microorganisms, which will be used for different purposes such as human consumption and cleaning of the processing plant.

Conclusions

- The sugarcane mill does not have a clear environmental management policy, due to the lack of knowledge of the methods of treatment and management of process waste. From the results of the Leopold matrix of environmental impacts, emphasis is placed on those with the greatest negative impacts, such as: in the cutting processes (25.51%), grinding (25.51%) and cleaning of the facilities (19.90%), which generate environmental pollution at the different stages of the process.
- Using the Leopold matrix, those processes that generate positive impacts were determined, such as job creation, in the cutting processes (26.09%), milling (26.09%) and molding, packaging and storage (21.74%), these are impacts that help the socioeconomic development of the rural population of the Teniente Hugo Ortiz parish in the province of Pastaza.

Conflict of interest

The authors declare that there are no conflicts of interest in the submitted manuscript.

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