CLEANER PRODUCTION POTENTIAL EVALUATION. CASE STUDY MINE OF CARBONATED SILTS IN CAYO MOA BAY, CUBA

EVALUACIÓN DEL POTENCIAL DE PRODUCCIÓN MÁS LIMPIA. ESTUDIO DE CASO MINA DE LECHOS CARBONATADOS EN LA BAHÍA DE CAYO MOA, CUBA

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SUMMARY

The purpose of this study was to do a Rapid Plant Assessment (RPA) in order to identify Cleaner Production options in extracting carbonated silts at Cayo Moa bay. To fulfill this purpose, the executing mining processes were identified and characterized, and the Cleaner Production potentials were defined in semi-quantitatively way. The extraction process is not optimal; because the excavator used does not have the necessary automation for using the deposit rationally. This causes irregularities in the mining front influencing the dynamics of the sediments, energy distribution means and negatively impacts on fauna and vegetation areas surrounding the dredging.

KEYWORDS: Seabed mining, sustainable development in mining, cleaner production potential, Cayo Moa bay.

RESUMEN

El presente trabajo tuvo como objetivo hacer una evaluación rápida en planta, con el fin de identificar opciones de Producción Más Limpia en el proceso de extracción de cienos carbonatados en la bahía de Cayo Moa. Para su cumplimiento se identificaron y caracterizaron los procesos mineros que se ejecutan y se definieron de forma semi-cuantitativa los potenciales de Producción Más Limpia. El proceso de extracción no es óptimo porque la excavadora usada no tiene la automatización necesaria para usar el depósito racionalmente. Esto causa irregularidades en el frente minero que influyen en la dinámica de los sedimentos, los medios de distribución de energía e impactan negativamente en las áreas de fauna y vegetación que rodean el dragado.

PALABRAS CLAVES: Minería en el mar, desarrollo sostenible en la minería, Producción Más Limpia, bahía de Cayo Moa.

INTRODUCTION

Nickel mining is one of the fundamental axes of Cuban economy, providing one of the relevant raw materials for the economic and industrial development of the country. This sector currently represents a large part of the Gross Domestic Product with income of up to 600 million dollars in 2017.

With these important economic contributions, a greater technological push on the industry, which has not always been focused on the sustainability of the mining industry, is perceived. Over 60 years of mining in Moa, negative environmental impacts have generated a significant impairment degree, what makes it as one of the most polluted regions (Cervantes et al 2011).

Due to these elements and the government's interest in a sustainable development of the territory, the most appropriate strategies have been established within the mining sector and using this technology since last year, focused on cleaner production.

Despite these efforts, there are still activities causing extensive damage to the ecosystems and this is the case of dredging carbonated silts in Cayo Moa bay (Cervantes et al. 2011 and Cervantes et al. 2017).

From the bottoms of Cayo Moa bay are extracted daily about 1200 tons of carbonated slimes. These sediments have a high $CaCo_3$ (70-80%) composition, which makes them ideal for the process of neutralization of the acid residuals that are generated in the mining industry. This activity is developed by dredging and

generates a group of negative impacts to the environment between what stand out the changes in the geomorphology of the bottom, the chemical composition of the water and the destruction of the benthic organisms.
Taking into account these problems, the study is aimed to evaluate the potential of cleaner production in carbonated silts mine in Cayo Moa bay.

Case study

Carbonated silts deposit is part of the mining at Pedro Soto Alba nickel plant, where calcium carbonate is used as raw material for neutralizing acids contained in liquors to be processed for the final obtaining of sulfides of Ni + Co. This site is located in Cayo Moa Bay, off the city coast of the same name (Figure 1).

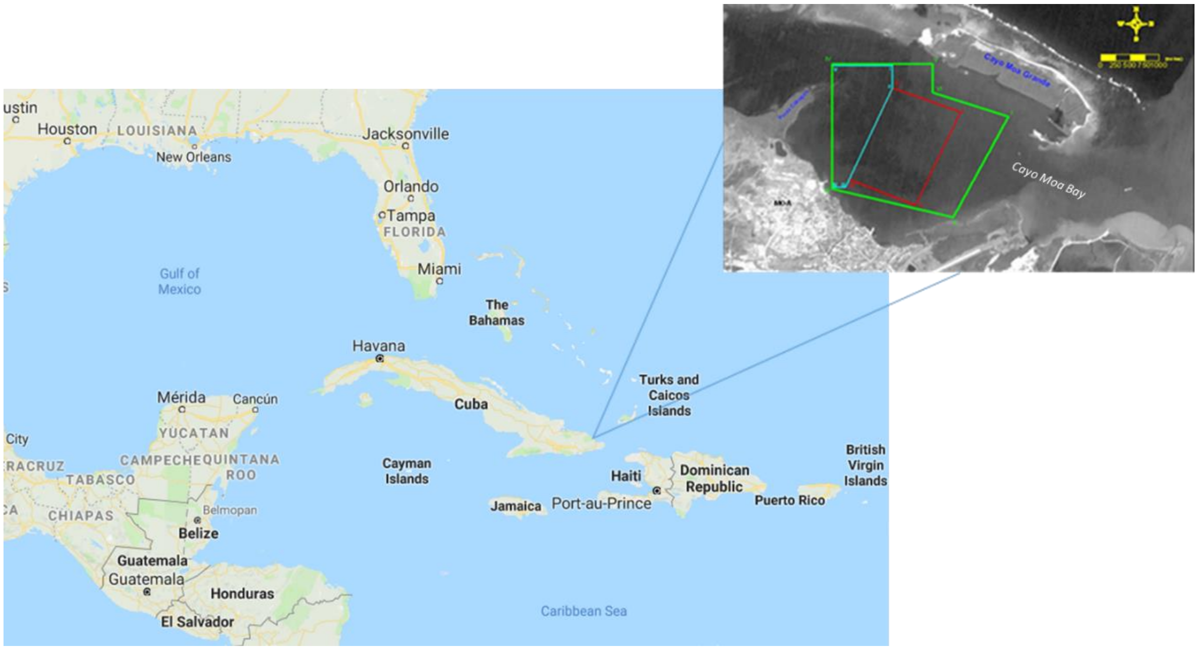

Figure 1. Area of carbonated silts mine within Cayo Moa bay, Cuba.

Exploitation system and mining-technical conditions for mineral extraction

The current exploitation system is carried out by dredging, using a mechanical dredger (bucket), formed by an excavator located on a barge with a 2.5 m^3 spoon. The process is based on a series of mining-technical conditions, which were projected by the company in charge of the deposit, these are:

- ✓ Minimum dredging depth: 2 m
- ✓ The extraction is carried out to the level where the basic parameters required in the technical task are met.
- ✓ The minimum useful power: 1 m.
- ✓ The sterile cover power is insignificant and it is contemplated in the dilution.
- ✓ Intercalations are allowed both in depth and superficially.
- ✓ Exploitation is carried out in opposite direction to the current, for avoiding accumulation of very fine grading that are harmful to the process.

- ✓ Positioning of the mining equipment is carried out with global positioning system (GPS), with accuracy of less than 2 m error.
- ✓ The dredge intended for extraction is provided with the anchoring means that allow the most accurate extraction.

The equipment consumes an average of 50 l / hour of diesel and works under a regime of six to eight hours per day (figure 2).

Figure 2. Excavator used for dredging carbonated silts.

These conditions proposed and implemented by the company do not include any element that promotes good environmental performance of it.

However, from the economic point of view it is a profitable activity. According to Martínez (2009), the production cost of one ton of silt is 22.17 USD. According to the current production rates, the neutralization plant consumes 610 t / day of carbonate sediments, which represents a total of 222,040 t / year.

According to these indicators, the company spends around 4 936 150.00 USD on this mining activity (Hernández, 2017).

The extraction process is not complex and it is done after placing the platform on the block to be exploited. After platform is located, the sediment is extracted and it is deposited in a barge located on the side of the platform. It has a storage capacity of 400 t (figure 3).

Figure 3. Barge for transporting and depositing the mineral, coupled to the extraction platform.

After filling the barge, it is transported to the beneficiation plant located in the port of Moa. The labor regime is continuous, every day of the year.
Dredging is characterized by being an aggressive activity for the marine and coastal environment. According to Hernández (2017), in mining silts the main impacts caused are:

- ✓ Energy changes and distribution of marine sedimentary
- ✓ Mixing and re-suspension of sediments in the path of dredge (figure 4)
- ✓ Resettlement of the removed sediment and possible danger for benthic animals.
- ✓ Alteration of chemical composition of the bottom water (bottom waters can retain sediment in solution-leached with high concentration of heavy metals).
- ✓ Diminished light penetration by turbidity plume.

These elements show that mining is only justifiable from the economical point of view and it does not carry out a clean production (as a system). The divorce between the economic and environmental results of this activity shows the need for analyzing cleaner production (CP) potentials in the mine.

MATERIALS AND METHODS

In this research, the cleaner production assessment methodology developed by the United Nations Industrial Development Organization (UNIDO) was used to define the potential of cleaner production in carbonated silts mining. First, CP team was designated and the process steps were listed. Secondly, steps were analyzed by preparing flow charts and reviewing waste causes. Thirdly, CP opportunities were developed and then the CP.

For generating CP opportunities of results, Eco-inspector2.1 software was used, which is formed in a semi-quantitative way and in accordance with the information it integrates. It is used in the methodology to develop CP opportunities stage of results and defines the economic and environmental potentials of CP in the evaluated processes (FHBB, 2002; Little, 2002), (figure 4)

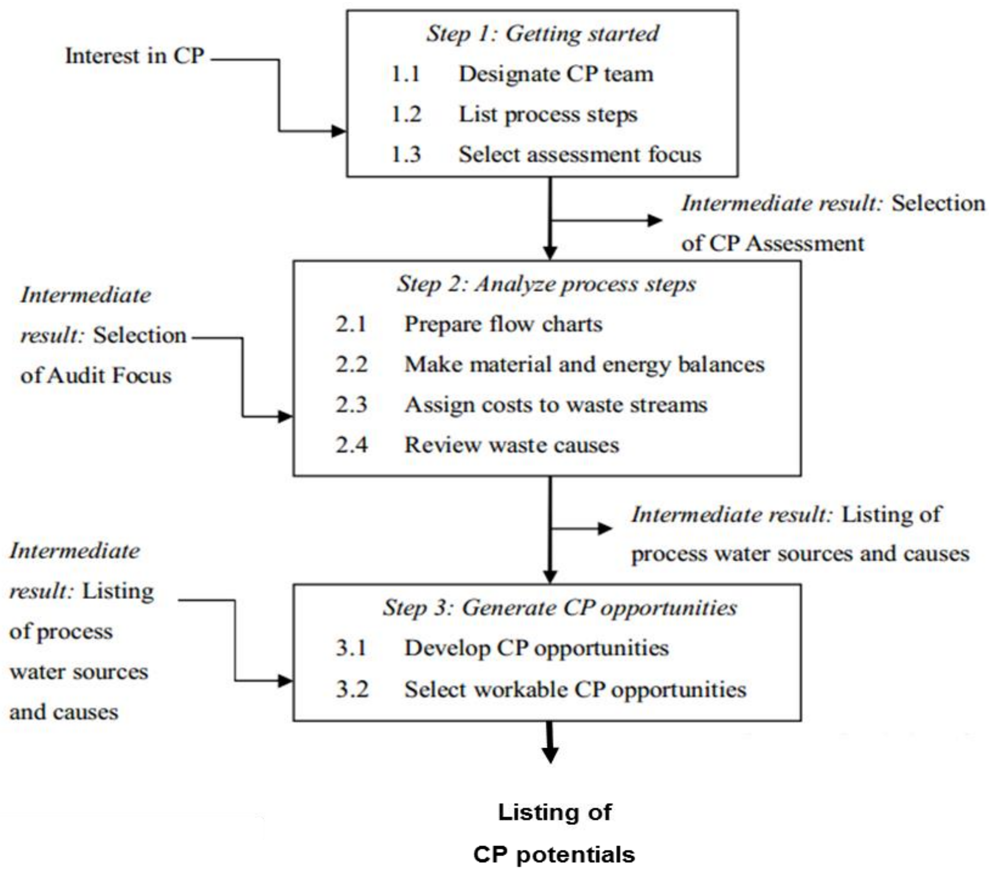

Figure 4. Cleaner production assessment methodology (Source: UNIDO, 2014).

RESULTS AND DISCUSSION

Identification of resource consumption and waste generation patterns in the industry

To measure the potential of CP in mine, a characterization of the mining processes was carried out. Technological scheme of the process, the technical mining conditions and current exploitation system were taken into account.

When analyzing the significant environmental aspects existing in mine and the impacts they cause to the environment, it was determined as processes to be evaluated: the operation of extracting ore and transporting into the beneficiation plant.

The overall production process flow in the industry is as follow (figure 5).

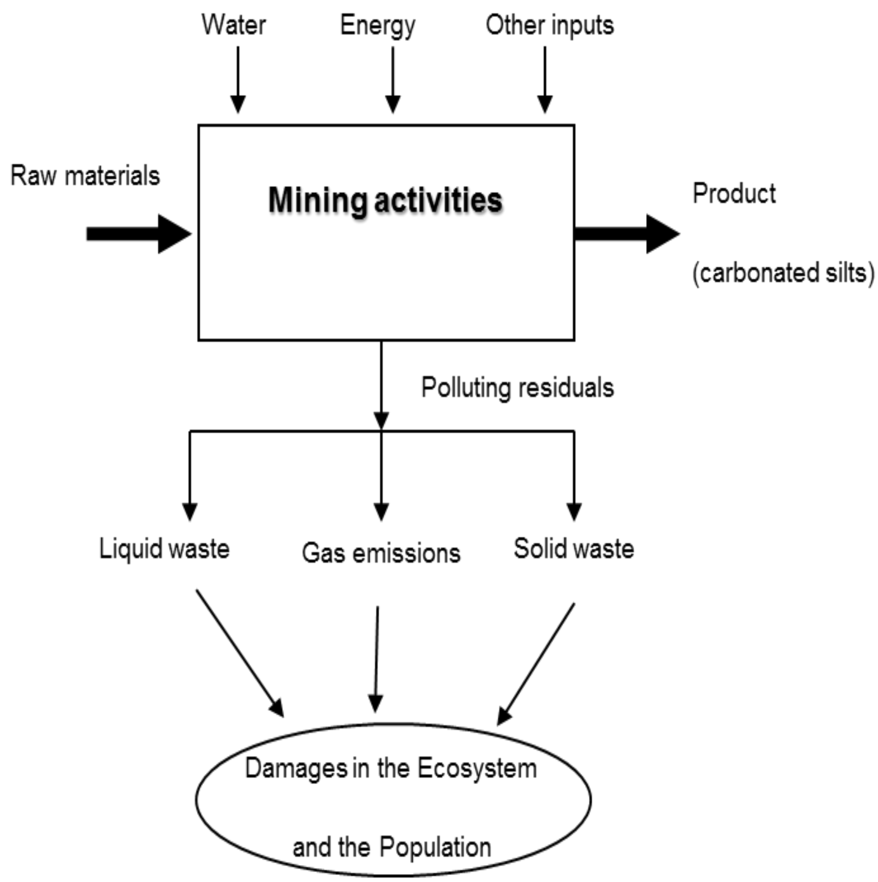

Figure 5. General flowchart of mining activity in the carbonated silts deposit.

The information collected in each process is grouped into three indicators, they are:

- ✓ Input materials in the process: eco-toxic materials, raw material, auxiliary and operating material, energy consumption and costs.
- ✓ Wastes produced in the process: solid waste, waste (including packaging material), special or hazardous waste, sewage, substances that cause problems in wastewater, airborne emissions and the cost of treatment of waste.
- ✓ Technology: state of the machinery, automation level, losses due to errors in production, maintenance and maintenance service cost.

To estimate the potential of CP in the extraction process (process # 1), no evidence of using eco-toxic materials were found.

According to the interviewed workers, when platform is painted, oils or fuel are changed; necessary measures are taken in order to protect the environment. Waste material resulting from maintenance and cleaning equipment: Rags containing hydrocarbons, filters impregnated with oil, paint residues, fluorescent tubes, etc., (1kg / day).

Using just few auxiliary materials in this process could be verified. The fuel consumption is around 400 l / day. Economically, the highest expenses in use and maintenance of mining equipment are reported.

Regarding the generated waste, it is estimated that solid products are not directly generated, however, it is representative the volume of water with high content of suspended solids draining when washing the extraction organ in water column and when depositing mineral in the barge.

Domestic waste generated in platform is collected in deposits for this purpose and it is classified as follow:

- ✓ Food: Includes all food waste not shredded or crushed; also paper and wood (approximately 2 kg / day).
- ✓ Plastics: disposable containers, bags, glasses and office plastic waste, as well as other types of garbage mixed with plastics (approximately 4 kg / day).
- ✓ Sewer waste: generated amount is not counted. This material deposit is exchanged as needed.

Main environmental impacts associated with this process are:

- ✓ Air quality: Increased levels of CO_2 emission into the atmosphere from exhaust gases of the excavator and tug engines. Emission of 1044 kg of CO_2 into the atmosphere, coming from combustion engine, is calculated.
- ✓ Marine water quality: Increase of dissolved and suspended solids, which causes an increase in the turbidity of water in the extraction zones and surrounding areas during the operations of dredging and transporting mineral (Cervantes, *et al*. 2017).

- ✓ Marine background: Changes in morphology of seabed because of deposit exploitation. It brings about the increasing of dynamics in the erosion and sedimentation processes by migration of sediments from the peripheral zones towards the extraction areas and other depressed areas of the seabed (Cervantes, *et al*. 2017)
- ✓ Marine vegetation: Disappearance of natural structure and floristic biodiversity in the extraction areas (Cervantes, *et al*. 2017).
- ✓ Marine fauna: Habitat destruction of marine fauna in the extraction areas. Partial impacts to the habitat and migration of marine species fauna in the areas surrounding the extraction areas due to the increase in turbidity of waters and displacement at sea of the means of exploitation of the deposit (Cervantes, *et al*. 2017).
- ✓ Landscape aesthetics: Alteration of landscape aesthetics for dredging and transporting ore.
- ✓ Port infrastructure: Increased sediment carryover from extraction areas to the port channel and the dock.
- ✓ Economic infrastructure: Economic benefits to the country by using mineral in neutralization of the acid effluent from sulfur plant.
- ✓ Mineral resources: Depletion of useful mineral reserve extracted from the deposit.

Process # 2 (ore transport) It is less complex in terms of influencing environment. The ore is transported around 4 - 7 km distance from the extraction platform to the beneficiation plant.

During the evaluation it was possible to observe the use of eco-toxic materials is minimal (around 2 kg/day), and it includes: rags containing hydrocarbons, filters impregnated with oil, paint remains, fluorescent tubes, plastics, disposable containers, bags, glasses and office plastic waste, as well as other types of garbage mixed with plastics.

The fuel consumption is around 90 l / day. Economically, the higher expenses are associated with the ore-loading platform maintenance and the rental of tugboat to Moa Company. This process does not generate solid residuals.

The main environmental damages associated with this process are:

- ✓ Air quality: Increased CO_2 emission levels into the atmosphere from the exhaust gases of tugboat engine. For this reason, the emission of around 234.9 kg of CO_2 into the atmosphere, product of the combustion of the engine.
- ✓ Marine water quality: Increase in dissolved and suspended solids, which cause an increasing in the turbidity of water.
- ✓ Landscape aesthetics: Alteration of landscape aesthetics for transport operations ore.
- ✓ Economic Infrastructure: Economic benefits to the country due to the use of mineral in neutralizing effluents acid of sulfide plant.
- ✓ Mineral resources: Depletion of the useful mineral reserve, extracted from the deposit
- ✓ Marine fauna: Partial affectations to the habitat and the migration of species of the marine fauna due to the increase of the turbidity of the waters and the displacement in the sea of the means of exploitation of the deposit.

When analyzing CP potential, it is demonstrated that both processes have potential and allow optimization or improvement on efficiency and environmental performance (Figure 6).

	Process		CP potential environmental benefits (process)												CP potential economic benefits			Estimation of CP potential*			
			Input				Waste / wastewater / emissions				Technology				Costs						
			(Eco-) toxic problem materials	Raw, auxiliary, operating materials	Energy consumption	Solid waste	Special waste	Wastewater (flow, amount)	Wastewater components	Airborne emissions	Status of technology	Level of automation	Faulty batches, scrap	Maintenance, servicing, cleaning	Input materials, energy	Disposal, preparation	Maintenance, stoppages	environmental benefits	Points average of economic benefits (costs)	Environmental CP potential **	Economic CP potential **
P1	Mineral Extraction		1,5	1,5	1,5	1,5	1,5	1,5	1,5	3	3	3	3	1,5	3	-	3	2,0	3,0	xx	xxx
P2	Mineral Transport		1	1	2	1	1	1	1	2	1	2	1	1	1	-	2	1,3	1,5	x	xx
P9	Storage		No CP potential anticipated															0,0		-	
P10	Transport	Goods	Low CP potential available for further analysis															0,0		-	
		Employees	No CP potential anticipated															0,0		-	
E1	Process heat		No CP potential anticipated															0,0	0,0	-	-
E2	Compressed air		No CP potential anticipated															0,0	0,0	-	-
E3	Refrigeration systems		No CP potential anticipated															0,0	0,0	-	-
E4	Energy management		No CP potential anticipated															0,0	0,0	-	-
Safety, health, material handling			Low CP potential for more detailed analysis															1,0		x	

*	Estimation of CP potential	x	low CP potential	Points average "environmental benefits" or "economic benefits"	0,0	to	1,3
		xx	moderate CP potential	Points average "environmental benefits" or "economic benefits"	1,3	to	2,7
		xxx	high CP potential	Points average "environmental benefits" or "economic benefits"	2,7	to	4,0

** The value of "Process points average" corresponds to the environmental CP potential, the value of "points average of environmental benefits" corresponds to the "Economic potential".
The calculation of the points average covers all positions with a value. Positions without CP

Eco Inspector 2.1

potential (FHBB) 2003

(value = "-") are not taken into account.

Figure 6. The graphic shows the summary results of carbonated silts dredging.

In the case of process # 1, it shows a high coefficient from the economic point of view and average coefficient of environmental benefits. This reveals that with profound improvements in each of the stages it comprises, it can become a more rational extractive complex.

Considering the aspects evaluated, the improvement should be focused on the most rational use of the deposit and the reduction of environmental impacts that it causes to the environment.

These arguments imply changes in the exploitation system, which should be oriented to the automation of the process or using a suction dredger that allows complete use of the block and less loss of sediment during mining. These elements will allow in return, greater productive performance and fewer impacts on the bay's environment (Figure 7).

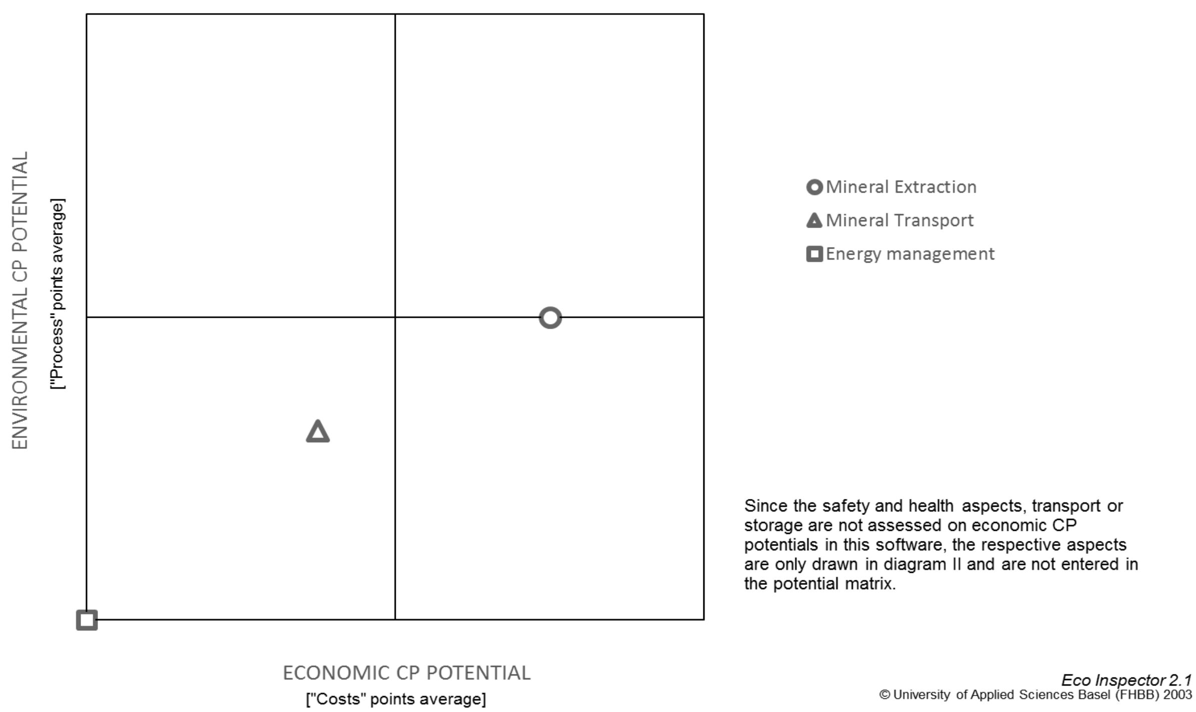

Figure 7. Matrix of potential for Cleaner Production in dredging carbonated silts.

In the case of ore transport (process # 2), since it is less complex from an environmental and productive point of view, it exposes low and medium potentials, respectively. In the case of environmental implications, the improvement alternatives would be focused on maintaining and improving the management system and the optimization of each of the proposed actions (figure 9).

From the economic point of view, improvements must be aimed at lowering expenses for maintenance and equipment performance. This will have a significant economic impact on the entire system.

CONCLUSIONS

The dredging of carbonated silts constitutes a necessary economic activity for the Cuban nickel industry; however, its environmental performance is directly affecting Cayo Moa bay. In spite of the efforts for a rational extraction, during the rapid evaluation at the plant, cleaner production potentials are reflected in the extraction and mineral transport processes.

As part of the evaluation, it was found that the extraction process is not optimal; because the excavator used does not have the necessary automation for using the deposit rationally. This causes irregularities in the mining front influencing the dynamics of the sediments, energy distribution means and negatively impacts on fauna and vegetation areas surrounding the dredging.

On the other hand, greater expenses caused by this activity are associated with maintenance and repairing equipment, which could decrease as exploitation system indicators are optimized.

Regarding the mineral transport, it does not constitute a determining element in the system. Although an adequate policy for an efficient management of the equipment and technological improvements in exploitation process, will influence positively on cleaner productions management in this process.

A rapid assessment carried out at the mine provided the necessary elements to proceed to a deep analysis of the dredging process of carbonated silts. Cleaner Production potentials result of this analysis, will allow the company searching for sustainability.

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BIBLIOGRAPHIC REFERENCES

CERVANTES GUERRA, Y., ALMAGUER CARMENATES, Y., PIERRA CONDE, A., OROZCO MELGAR, G., & GURSKY, H. J. (2011). Metales traza en sedimentos de la Bahía de Cayo Moa (Cuba): Una evaluación de la contaminación. *Minería y Geología, 27*(4), 1-19. Recuperado de: http://revista.ismm.edu.cu/index.php/revistamg/article/view/282/pdf

CERVANTES, Y., RODRÍGUEZ, A., PIERRA, A., ALMAGUER, Y., & GURSKY, H. (2017). Cambios en la geomorfología y el medio ambiente litoral asociados al dragado de los fondos marinos en Moa, Cuba. *Minería & Geología* 33 (1): 114 – 127. Recuperado de: http://revista.ismm.edu.cu/index.php/revistamg/article/view/art8_No1_2017/760

FHBB. (2002). Institut für Umwelttechnik. EcoInspector – schnelle und zuverlässige CP-Potential-Analyse. Retrieved March 20, 2018 at: https://manualzz.com/doc/4721458/ecoinspector-%E2%80%93-schnelle-und-zuverl%C3%A4ssige-cp-potential-ana

HERNÁNDEZ, C. (2017). *Caracterización del proceso de extracción de cieno carbonatado en la bahía de Cayo Moa*. Trabajo de diploma. Instituto Superior Minero Metalúrgico de Moa. Moa. 58 p. Recuperado de: ninive.ismm.edu.cu/bitstream/handle/123456789/2065/Hern%C3%A1nezp%C3%A9rez.pdf?sequence=1

LITTLE, A. (2002). Studie zur Konzeption eines Programms für die Steigerung der Materialeffizienz in mittelständischen Unternehmen. Retrieved March 20, 2018 at: https://www.innovation-beratung-foerderung.de/INNO/Redaktion/DE/Downloads/Unterlagen_go-inno/goeffizient_studie_zum_impulsprogramm_materialeffizienz.pdf?__blob=publicationFile&v=7

MARTÍNEZ ROJAS, R. (2009). *Caracterización de las propiedades físico mecánicas del cieno carbonatado para el perfeccionamiento de su hidrotransporte por tuberías*. Tesis de maestría. Instituto Superior Minero Metalúrgico de Moa. Moa.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO)(2014). Retrieved February 1, 2014 at http://www.unido.org/en/resources/publications/energy-and-environment/industrialenergyefficiency/cp-toolkit-english.html