CHEMICAL ENGINEERING TRANSACTIONS
VOL. 52, 2016

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Petar Sabev Varbanov, Peng-Yen Liew, Jun-Yow Yong, Jiří Jaromír Klemeš, Hon Loong Lam

ISBN 978-88-95608-42-6; **ISSN** 2283-9216
DOI: 10.3303/CET1652147

Economic Feasibility Study on the Wastewater Treatment Plant in Fuel Companies. A Cuban Study Case

Yailen Busto[a], Edesmin W. Palacios*[b], Liz M. Ríos[c], Javier Martín[c], Yamell Jiménez[c], Hortensia Pérez[d], Miriam Yera[e]

[a]Technological University of Israel, Francisco Pizarro street and Orellana Avenue E4-142, Quito, Ecuador
[b]Faculty of Odontology, Central University of Ecuador,University Citadel between Bolivia and Salgado street, Quito, Ecuador
[c]Central University of Las Villas, Camajuani street km 5 ½, Santa Clara, Villa Clara, Cuba
[d]Fuel Trading Company of Villa Clara. Road to Subfloor 76, 50300, Villa Clara, Cuba
[e]Iberoamerican University of Ecuador, 9 de Octubre and Santa Maria street, Quito, Ecuador
wsaudades@gmail.com

In the Cuban oil industry, wastewater from the process of reception and distribution of hydrocarbons, contain a wide range of contaminants with high chemical and biological oxygen demand (COD and BOD). However, the most significant pollutants of these effluents are the hydrocarbons, fats and oils due to its high toxicity and ability to spread in thin layers on the water surface which difficult the passage of sunlight, hurting life in such ecosystems.

Two technological alternatives were evaluated from technical, economic and environmental point of view. The first one, considered as short-term solution (rehabilitation of the existing system) and second one (building of a collection pool), considered investment in the medium to long term. Taking into account the equipment acquisition cost as well as the process flow requirements, the total investment cost for both alternatives was estimated. Furthermore, the main dynamic economic indicators: Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Period (PP) were evaluated to develop a comprehensive economic-financial study using the method of "Percentage of Delivered Equipment". In addition, a sensitivity analysis to evaluate the effect of increases or decreases in the price of the process equipment market over the economy of the proposal variant was analysed.

From the economic point of view, alternative 1 reported higher gross annual earnings ($ 2,139,553) compared to the second variant ($ 2,131,428). However, considering that the annual income of the company are substantial ($ 11,791,284 in 2013), the alternative 2 proposes a more effective solution from a technological point of view achieving greater life of the proposed technology and as better operation and maintenance. Moreover, this technological option guarantees a significant reduction on the environmental pollution risk.

1. Introduction

Approximate 88 % of global energy needs from the developing countries are mainly supplied from fossil fuel sources such as coal (28 %), oil (40 %) and natural gas (20 %) (Phneah et al., 2015). Due to the world is heavily dependence on fossil fuels, the planet had already experienced warming by 0.8 K over the past 100 y (Northon, 2015). Petroleum refining is an industrial activity with intensive use of energy, highly contributing with greenhouse gas (GHG) emissions (Caballero et al., 2014). The process of refining crude oil consumes large amounts of water. Consequently, significant volumes of wastewater are generated (Martinez-Huitle et al., 2014). Oilfield wastewater or “produced water (PW)” contains various organic and inorganic components that can pollute surface and underground water and soil (Ahmaduna et al., 2009). Pollution problems at the local, national and international levels are part of our daily life. It is a concern the way in which ecosystems of our planet as well as the surface layer of the crust have been degraded. Industrial activity has caused one of

Please cite this article as: Busto Y., Palacios E. W., Rios L. M., Martín J., Jiménez Y., Pérez H., Yera M., 2016, Economic feasibility study on the wastewater treatment plant in fuel companies. a cuban study case, Chemical Engineering Transactions, 52, 877-882 DOI:10.3303/CET1652147

the most serious problems of soil contamination, where the oil spill occupies one of the top spots (Orozco et al., 2004).
Hydrocarbons pollution is widely spread all over the world and our country is no exception. The oil and petrochemical industries are the medullar point in the production of hydrocarbons and derivatives. These products are designed to meet our energy requirements of fuels and lubricants for the industry and transportation sectors. Hydrocarbons spills constitute the major source of soils contamination as well as surface, ground water, flora and fauna pollution problems. Some hazard substances such as hydrocarbons have carcinogenic activity to the detriment of humans and animals. The presence of these chemicals in groundwater represents a huge threat for human consumption.
One of the most common problems, and that frequently accompanies other soil contamination is related to industrial hydrocarbons leakage. This problem extends, in no small measure, to auxiliary tanks and local distribution of hydrocarbons. Fuel leaks may occur during the production, handling, storage and transport of the process. From these industrial leaks, the most dangerous one are those that are hidden, being only discovered when the wells and/or rivers contamination occurs. His previous detection is therefore difficult and expensive. A retrospective analysis has shown how the most common causes are occasional and long-term leaks, in places of container or pumping tanks (Castro, 2007). As regards the significant matter of environmental concern, many countries have implemented more stringent regulatory standards for discharging “produced waters”. On the other hand, because large volumes of these contaminated waters are being generated, many countries with oilfields, which are also generally water-stressed countries, are increasingly focusing on efforts to find efficient and cost-effective treatment methods to remove pollutants as a way to supplement their limited fresh water resources (Martinez-Huitle et al., 2014).
The marketing and distribution activity of fuels in the country constitute a key element of the economic development due to innumerable productive and service areas require this raw material for its operation, primarily in the energy order. The Fuel Trading Company of Villa Clara (ECC VC) is responsible for receiving and distributing the amount of oil requested by the province. This company belongs to the Union of Cuba-Petroleum from the Ministry of Energy and Mines.
This company is one of the companies on business improvement of the province that has advanced in recent years with regard to improving their business management schemes. This has been the result of several management systems implementation, such as quality (ISO 9001:2008), safety and health (NC 18001:2005), environmental management (ISO 14001:2004) among others. All the above systems have been certified except environmental management, due to the persistence of environmental issues that cause significant environmental impacts. The poor performance of the wastewater treatment system has led to non-compliance with some of the parameters of the standard wastewater disposal (NC: 27/2012, 2012).
This situation could cause the imposition of environmental taxes and harsher penalties due to actions of regulatory bodies of the Ministry of Science, Technology and Environment, the Public Health as well as the National Institute of Hydraulic Resources.
To the above joins, that wastewater oil industry contains a wide range of contaminants with high chemical and biological oxygen demand (COD and BOD). However, undoubtedly, are hydrocarbons, fats and oils, the most significant of those polluting effluents. On the other hand, these substances are extremely toxic to the ecosystems life due to his property of spread of in thin layers on the water surface preventing the passage of light, which harms life in such systems (Kraus, 2013).
In the ECC VC, liquid and solid wastes are produced during operations and soils are contaminated with hydrocarbons due to spillage or leakage point. As part of the environmental policy of the country is a priority the proper treatment of waste fluids before being available to the receiving bodies. Currently, it constitutes an unmet need because the ineffective operation of the existing waste treatment systems disables efficient management and sustainable management of watersheds and the environment in general. The main objective of this study is to assess a rehabilitation project of the existing liquid waste treatment of the ECC VC from techno-economic and environmental points of view.

2. Material and methods

2.1 Site description

The wastewater treatment plant of the Fuel Trading Company of Villa Clara is located in the central region of the country specifically in the productive area. The main goal of the system is to treat and reduce the concentration levels of pollutants before being discharged to the receiving body in order to fulfil with Cuban regulations. The current system is able to recover the hydrocarbon and the effluent or treated water poured to a valley next to the installation. The wastewater treatment plant with a processing capacity of 722 m^3/y established for a constant volume of production of the ECC VC, should be able to efficiently remove the hydrocarbons contained in the oily water and reuse the recovered oil (0.52 t/y) and may bring economic benefits in their marketing when it is mixed with used oil. This system comprises an API separator, a Slop tank and a collecting lagoon (Figure 1).

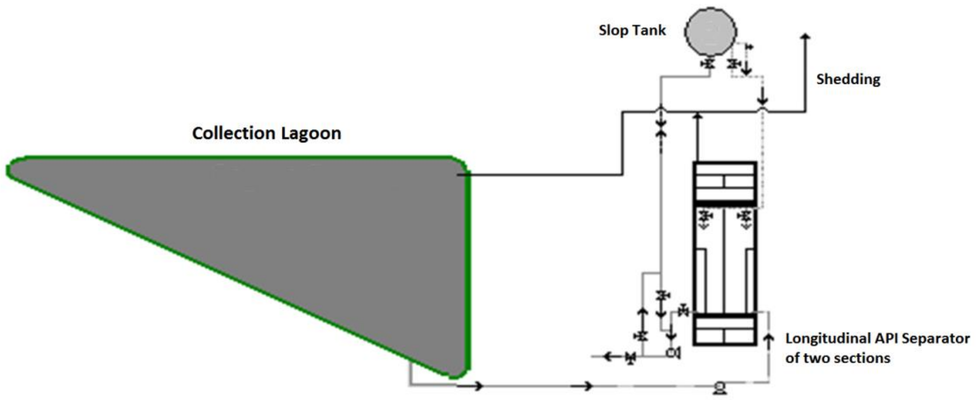

Figure 1: Flux diagram of the wastewater treatment system of Fuel Trading Company of Villa Clara (ECC VC)

2.2 Type font and type size

The treatment system of wastewater of the Fuel Trading Company of Villa Clara (ECC VC) involves a triangular collector lagoon with dimensions 20 m × 20 m × 30 m and 1.5 m deep, which goes all the liquid waste from cleaning and drainage of fuel storage tanks and scrub plant of fuel transporting vehicles. Subsequently, using a pump system (pump 1), of the collecting lagoon is sucked the petroleum that is floating on the surface to the API longitudinal separator of two sections, of dimensions 2.7 m long × 1.75 m wide and 2.7 m tall. The input channel of the separator allows equalization of water, eliminating turbulence and allowing the flow regime is in the separation channels, as laminar as possible and achieves greater efficiency in the separation process. To facilitate this process, will ensure a constant liquid level of 2,000 mm for those particles of free hydrocarbons can join and upload more quickly to the surface. Subsequently, the hydrocarbon collected in the separator channels is pumped (pump 2) to a vertical ESSO Slop tank (53.44 m^3) which aims to separate water from hydrocarbon by decantation. The decanted water in Slop tank is pour back into the longitudinal separator as rectification process. Finally, the treated water exits the bottom part of the separator and is discharged to the environment (Figure 1).

2.3 Techno-economic and environmental assessment

Technological assessment of the wastewater treatment system was developed considering the results obtained from previous studies, deficiencies found in the process and availability of the market. Two technologies were evaluated from the technical, economic and environmental points of view. The first technological alternative considered as short-term solution (rehabilitation of the existing system) and second one (building of the collection pool), identified as a medium or long term investment.

The economic assessment was addressed to determine static economic indicators such as Total Capital Investment (TCI), Total Production Cost (TPC) and Annual Gross Profit (AGP) as well as dynamic economic indicators such as Net Present value (NPV), Payback period (PP) and Internal Rate of Return (IRR). Total investment costs were based on the estimation of acquiring cost of equipment and accessories used for the operation of the wastewater treatment plant of ECC VC. For calculations, the specific year in which each of equipment was installed and included in the system was taking into account. To determine the investment cost of the pumps, flow requirements of the process and equipment selection according to catalogue were included. Estimating the Total Investment Cost for both rehabilitation of the wastewater treatment plant that is currently installed (alternative 1), as if to for the construction of the collection pool (alternative 2) was performed using the method of “Percentage of Delivered Equipment " reported by Peters et al. (1991).

3. Results

3.1 Characteristics and deficiencies of the wastewater treatment system of ECC VC

As a result of previous studies and monitoring of wastewater, the treatment system is capable of achieving removal rates that ensure a residual according to the NC 27:2012, if it operates satisfactorily and with the proper maintenance. However, currently the system is not working efficiently and residuals are sent to the receiving body without effective treatment (Águila, 2008). The major deficiencies were identified as follows:

- Due to frequent filling and emptying of storage tanks, drainage thereof is performed sporadically. Added to this is the poor condition of the pipes and part of the pipes used in the treatment system, which means that in practice, all this waste reaches the separator.
- The lagoon receives the volume of wastewater and storm water generated in the tank. However, the lagoon-separator system does not work due to nonfunctioning of pumping required, so that the supernatant hydrocarbon, content in the lagoon is not recovered.
- The separator is dirty, being corroded, there is evidence of impairment constructive, passes between the chambers, and valves mostly, are out of service.
- The residual of the maintenance shop (scrubbing floor) area has a grease trap system are discharged into the grease trap and thence to the storm water drainage network to the lake, so do not receive adequate treatment.

3.2 Feasible alternatives to revitalize the wastewater treatment system

Two technological alternatives were evaluated from the technical, economic and environmental point of view. The first one, considered as short-term solution (rehabilitation of the existing system) and second one (building of a collection pool), considered investment in the medium to long term.
For both alternatives, the first action to be executed in the project is the restoration and improvement of system API separator - Slop tank. To do this it is necessary to develop the following technical tasks:
• Clean and remove the sludge present in the API separator,
• Reinstall the existing pump system using positive displacement pumps and rehabilitate existing valves,
• Remove the interconnection between compartments and seal the leaks,
• Removing hydrocarbon purge to the separator, emptying the tank if necessary,
• Relocate the Slop tank drain to the inlet of the separator and
• Install sampling of level at Slop tank to determine the interface of oil-water separation.
As a second action to carry out as part of Alternative 1, the following technical tasks should be implemented:
• Empty and remove the lagoon sludge,
• Restoring the waterproofing layer of clay,
• Rehabilitate the slope of the lagoon, as well as the existing record and finally,
• Rehabilitate the extraction system of superficial hydrocarbon of the pond, with pump 1, using skimmer with a flexible hose.
Similarly, the second action to be performed in alternative 2 must include, in addition to the above, the following technical tasks:
• Perform earthwork and excavation and
• Construct the rectangular pool with size 30 m × 10 m × 3.67 m and 350 m^3 of capacity (EIPP, 2009).
As a comparative analysis, the Alternative 1 involves an easy and simple commissioning and operation of the system. Moreover, it is not requiring significant earthworks and construction, as well as increased labour, reporting less acquisition costs from the economic point of view. However, as main drawback, the current alternative, not completely guarantee the protection of the environment, because can occur infiltration. Moreover, from technological point of view, does not facilitate the cleaning and maintenance procedure. From comparison, option 2 propose a more effective solution from a technological point of view, achieving greater life of the proposed technology and better operation and maintenance of the same, which guarantees, from the point of view environmental, reducing potential risks of environmental pollution. Despite their remarkable advantages, it is necessary stand out that these variants imply higher investment costs compared to alternative 1; however, its implementation is feasible if we analyse the cost-benefit relationship (Dimitri, 2014).

3.3 Economic assessment for both remedial alternatives

The acquisition cost of the process equipments as well as reference sources used for both proposed alternatives, are reflected in Table 1. From calculations it was obtained that Total Investment Cost for alternative 1 (US$ 88,643) was due primarily to the Total Direct Costs (US$ 73,645), of which the 48.8 % was correlated to the cost of equipment purchased. On the other hand, for alternative 2 showed a substantial increase of the total investment cost (US$ 169,730) due to the increase of total acquiring cost of the equipment mainly by concept of construction materials cost (US$ 14,515), earthwork (US$ 6,217) and buildings (US$ 9,326).
An integrated economic analysis of the proposed technology with the Fuel Trading Company of Villa Clara (ECC VC) was carried out for both alternatives of rehabilitation of the wastewater treatment system. For this integration, the values of Total Capital spending (US$ 10,530,800) and Total Annual sales (US$ 12,031,900) reported in 2015 by the CUPET Trading Company were included (data reported by personnel of the plant).
In order to develop a comprehensive economic-financial study, the main dynamic economic indicators (NPV, IRR, and PP) were evaluated for both alternatives. Static and dynamic indicators of the two integrated alternatives are shown in Table 2.

Table 1: Equipment investment costs of the wastewater treatment plant

Equipments	Alternative 1 (US$)	Alternative 2 (US$)	References
Horizontal separator API	16,640	16,640	(Matches, 2012)
Positive displacement pumps	7,600	7,600	(Matches, 2012)
Slop tank vertical ESSO	5,074	5,074	(CUPET, 2015)
Stabilization Lagoon	1,055	-	(IMC, 2015)
2 Valves of Ø8”	1,000	1,000	(Peters et al., 1991)
Collection Pool	-	24,917	(IMC, 2015)

*Table 2: Economic assessment of both integrated alternatives using static and dynamic economic indicators**

Economic Indicators	Integrated Alternative 1	Integrated Alternative 2
Annual sales (US$)	11,791,284	11,791,284
Annual Total Production Cost -TPC (US$/y) ***	9,647,510	9,651,774
Annual depreciation (US$/y) **	4,221	8,082
Annual Gross Profit - AGP (US$)	2,139,553	2,131,428
Return on investment, aver. - ROI (%/y)	869	452
Payback period - PP (y)	0.1	0.2
Net Present Value - NPV (US$)	11,990,732	11,888,043
Internal Rate of Return - IRR (%)	2,177	1,135

* Considering the economic data reported by the Company Distributor CUPET (2015).
**Considering an annual depreciation factor of 0.05 (20 year life of the plant).
***Considering the price of recovered hydrocarbon of wastewater and reused for oil blends 7.23 US$/HL (Information provided by the ECC VC, 2015).

Considering the results obtained in the economic evaluation, could be selected alternative 1 as the best alternative to be implemented in the Company, because a greater Annual Gross Profit for the first alternative (US$ 2,139,553) was observed compared to the second (US$ 2,131,428). Also, the internal rate of return is about twice the value obtained for the second alternative. However, considering that the annual income of the company are substantial (US$ 11,791,284 in 2015), the alternative 2 proposes a more effective solution from a technological point of view, achieving greater life of the proposal technology and better operation and maintenance; which guarantees, from the environmental point of view, reducing potential risks of environmental pollution. Moreover, taking into account their economic viability as the Pay Period remains at a value extremely low (less than 1 year) the alternative 2 represents the most feasible option to implement in the Fuel Trading Company of Villa Clara.

Until now, it has been shown that alternative 2 represents the best option from techno-economic and environmental terms. However, a sensitivity study was developed in order to assess how sensitive could have the techno-economic analysis of this alternative to possible (future) changes/variations of the parameters considered in this study. As the acquisition cost of positive displacement pumps fluctuates on the market; it was necessary to conduct a sensitivity analysis to assess the effect of increases or decreases on the economics of the proposed variant. The Figure 2 represents the NPV profiles for the selected alternative considering changes in the price of pumps.

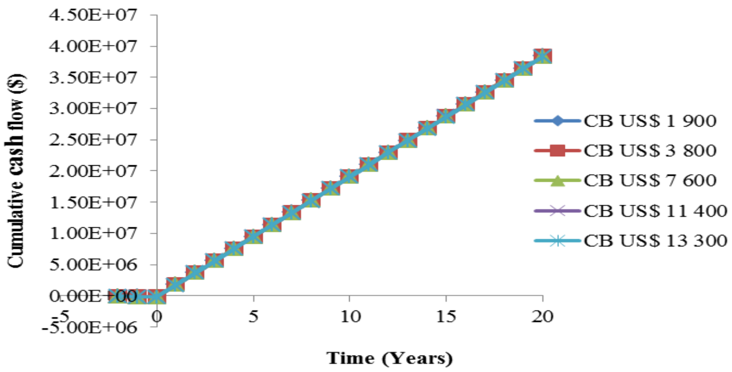

Figure 2: NPV profiles for alternative 2 considering changes in the price of the pumps

From the results obtained, it can be state that even if the proposed technology is evaluated with the higher prices of the pumps (worst economic scenario), the project can be considered feasible. This phenomenon can be attributed to the fact that the Annual Sales of the Company is extremely high compared to prices on the pumps.

4. Conclusions

The proposed project for the rehabilitation of the wastewater treatment system will report significant environmental benefits to the entity due to the minimization of the pollutant load. Moreover, as a result of a proper system operation, the recovered hydrocarbon could be mixed with the used oils, constituting commercial value for the company. This research demonstrated that alternative 2 is the most feasible for the rehabilitation of the wastewater treatment system of the ECC VC from techno-economic and environmental points of view.

References

Águila R.V., 2008, Wastewater treatment system in the ECC Villa Clara, Company Engineering and Petroleum Projects, 3: 1-7 (in Spanish).

Ahmaduna F.R., Pendashteh A., Chuah L., Awang D.R.; Siavash S., Zainal Z., 2009, Review of Technologies for Oil and Gas Produced Water Treatment, Journal of Hazardous Materials, 170, 530-551.

Caballero E.F., Hoyos L.J., Kafarov V.V., Barajas C., 2014, Exergy analysis applied to separation processes in a FCC plant using computational models, Chemical Engineering Transactions, 39, 79-84, DOI:10.3303/CET1439014

Castro G., 2007, Final design and monitoring report against oil spills, Valparaíso, Chile, 1-148 (in Spanish).

CUPET (Union Cuba-Oil), 2015, Oil Industry in Cuba (in Spanish), <www.cupet.cu/es/>, accessed 02.05.2015.

Dimitri, M. (2014) Correlating the chemical engineering plant cost index with macro-economic indicators, Chemical Engineering Research and Design, 92, 285-294.

EIPP (Company of Engineering and Petroleum Projects), 2009, Handling and storage of fuel oil 650, Havana, Cuba (in Spanish).

IMC (Industry of Building Materials), 2015, Sales prices for building materials, Industry of Building Materials, Villa Clara, Cuba (in Spanish).

Kraus R.S., 2013, Encyclopedia of Health and Safety at Work, Chemical, Oil and gas, petroleum refining process <www.ilo.org/safework/info/publications/WCMS_113329/lang--en/index.htm> accessed 05.02.2016.

Martinez-Huitle C.A., Chanca de Moura D., Ribeiro Da Silva D., 2014, Artmipplicability of electrochemical oxidation process to the treatment of petrochemical effluents, Chemical Engineering Transactions, 41, 373-378, DOI:10.3303/CET1441063.

Matches, 2012, Conceptual process and cost engineering services to the chemical, energy, manufacturing and metallurgical industries <www.matche.com>, accessed 20.01.2015.

NC: 27/2012, 2012, Wastewater discharges to ground water and sewerage, Specifications, Cuban Standard, Havana, Cuba (in Spanish).

Northon K., 2015, 2014 Warmest Year in Modern Record, <earthsky.org/earth/2014-warmest-year-on-record>, accessed 28/09/2015.

Orozco C., Pérez A., González M.N., Rodríguez F., Alfayate J.M., 2004, Environmental pollution: a view from the Chemical, 1st Edition, Thompson, Madrid, España (in Spanish).

Peters M.S., Timmerahus R.E., West R.E., 1991, Plant Design and Economics for Chemical Engineers, 5th edition, McGraw-Hill <www.learningace.com/textbooks/1397-plant-design-and-economics-for-chemical-engineers-5-th-edition> accessed 10.07.2014.

Phneah S.L., Hassim M.H., Ng D.K.S., Goh W.S., 2015, Review on sustainability assessment of integrated biorefineries based on environmental, health and safety perspectives, Chemical Engineering Transactions, 45, 1399-1404, DOI:10.3303/CET1545234.