Study for reducing the logistics environmental impact drainage of liquid hydrocarbon pipeline

Gilberto Mourão
Centro Paula Souza– Fatec
gilberto.mourao@fatec.sp.gov.br

Getulio K Akabane
Ceetps
getulio@akabane.adm.br

Hamílton Pozo
Universidade Anhembi-Morumbi
hprbrazil@hotmail.com

Julia Rosa Borges Muniz Barreto
Ceetps
jumunizb@gmail.com

Vicente Miguel Sinkunas Junior
Ceetps
vicente.sinkunas@cpspos.sp.gov.br

Abstract
This research aims to reduce the environmental impact by eliminating occasional spills on logistics pipeline transportation of liquid hydrocarbons. Additionally, the company and its principles of operational excellence, avoids costs of product and reprocessing, which generates a significant annual savings.

Keywords: Environmental Impact, Liquid Hydrocarbon, Green Logistics

Introduction

The goal of this research is to reduce environmental impacts by eliminating spills from the logistics of inland pipeline transportation of liquid hydrocarbons. For this reason, this case study focused on activities dealing with drainage pipes in a section usually called a sump tank and, more specifically the drain valve, which is an integral part of the pipeline transportation system of this industry. This paper also has the objective of contributing to internal, strategic improvements in the operating conditions and safety of the company's pipeline and reducing the operating costs of the transport process. Transportation has always responded to human desires, and, therefore, some level of environmental impact resulting from transportation is inevitable. The concept of sustainability involves economic, socio-political, and environmental considerations. Sustainable transport, according to Black (1996), can be seen as meeting the "transportation needs of current and satisfactory mobility without compromising the ability of future generations to meet these needs." From an environmental policy perspective, supply-chain management offers opportunities for a more efficient, less polluting, less demanding, and more sustainable system of moving and storing resources.

Pipeline transportation first appeared with the supply of water to ancient villages. After its discovery, petroleum, a natural substance of great importance in the world economy, also came to be transported in pipelines, in its raw form, between extraction and processing stations.

A pipeline failure can lead to several negative outcomes, and some of these problems can constitute a serious environmental threat to people and assets close to the crash site. Several accidents that have released toxic or flammable substances have caused many consequences to populations near existing ducts (Viana 2011).

This case study focused on one step in the liquid hydrocarbon operations of a Brazilian petrochemical plant, which is part of an important stage of the product's logistics and transportation. The operations of a hydrocarbon petrochemical plant were chosen mainly due to the ongoing impact of a widespread focus on sustainability or green logistics.

This study examined the main costs of waste involved in liquid hydrocarbon drainage for the petrochemical industry, to justify and make feasible the project in terms of environmental and financial aspects of processes. The project was implemented where the product is pumped to the storage tank—eliminating leakage, showing a positive return on investment, and reducing operating costs.

Literature review

To answer the research questions and achieve this research's goal, sustainability concepts need to be understood as applied in this case study on leaks in the drainage pipe transporting processed liquid hydrocarbon. Therefore, this section addresses concepts of green logistics and the impact of pipeline models on oil spills and cleaner production.

Research on sustainable distribution has largely focused on improving the delivery of goods along the supply chain from manufacturer to end customer by developing a fundamental understanding of various operations in the chain's links, especially in urban centers (European Commission 2006). According to The Center for Sustainable Transportation (2002), a sustainable transport system is one that allows basic access to meet the needs of individuals and societies safely, in a manner consistent with human and ecosystem health and with equity within and between generations. It is affordable, operates efficiently, offers a choice of transport modes, and supports a vibrant economy. It further limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to a sustainable yield, reuses and recycles its components, and minimizes the use of land and the production of noise. It also involves meeting the needs of today without reducing the ability of future generations to meet their needs. Sustainability has three components: the environment, society, and economy, linked as shown in Figure 1.

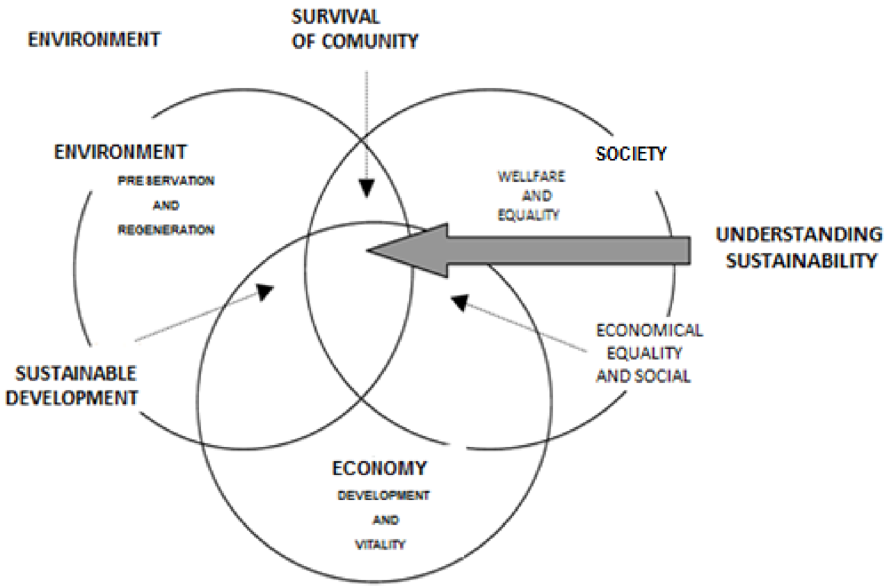

Figure 1 – Sustainable components

Source: Adapted from The Center for Sustainable Transportation (2002)

The description of each component is given in Table 2 along with their factors that meet human needs.

Table 1 – Components and description of sustainable transportation

Component	Description	Factors
Environment	The areas surrounding human beings and other life forms that support them and limit their activity	Affects present welfare and determines most of the legacy we leave to our descendants
Society	Complex human interactions and how they are organized	Determines the present quality of life and tends to be an important legacy for future generations
Economy	Resources available and how they are organized	Influences us through environmental and social factors

Source: Adapted from The Center for Sustainable Transportation (2002)

Green logistics in pipeline transportation

Globalization puts constant pressure on companies to improve their performance on environmental issues. In order to achieve improvements in environmental performance, companies must integrate their environmental management strategies, while maintaining the quality of production, reaching operating cost goals, and operating world-class processes. These goals apply to their supply chain, which includes all stages of the operational life cycle and to services performed by partner companies. Environmental sustainability, according to Silva and Fleury (2000), is "meeting the needs of the present without compromising the ability of future generations to meet their needs."

The term "logistics" was initially used for the task of organizing the supply of weapons, equipment, and food to distant military units (Gozzi and Petraglia 2003). Throughout history, wars have been won and lost through the power of logistics, for example, when World War II logistics played a key role in the invasion of Europe by Allied Forces. While the armed forces have long since understood the important role of logistics, business organizations have only recently recognized the vital impact that logistics management can have on achieving competitive advantage. Consequently, the value of logistics in corporate strategy generates a number of questions related to how companies in the same supply chain are organized to face new challenges (Silva and Fleury 2000). Besides being a contemporary management tool, logistics is also an important economic activity.

With the growing demand for "green" products, logistics systems that offer these products to consumers also need to be "green" (Wu et al. 1994). Green logistics should not be confused with reverse logistics (Lourenco et al. 2002). The reduction of energy and pollution associated with a better organization of transport and the use of less packaging material can be considered part of a green logistics agenda. In contrast, as Lourenco et al. (2002) point out, "If there are no goods or materials moving backwards," the activity is probably not a result of reverse logistics.

For petrochemical companies, the concept of sustainability is most appropriately used in evaluating their business strategies. The goal of sustainability is not only focused on reducing negative impacts on the natural environment through operations but also on investing in business practices that promote policies that broaden the scope of progress toward sustainable development. In industry, the operations of petrochemical companies are analyzed according to their impact on the surrounding environment, during any given period.

In order to distinguish between sustainability, as described above, and environmentally friendly operations, the latter are referred to as "green operations." Green operations are not necessarily sustainable in the long term, but they consciously minimize the negative environmental impact of operational processes. Petrochemical company operations deal with the energy consumption required for the operation of their facilities and emissions and waste processes. Meanwhile, the sustainability of products must deal with their liquid hydrocarbon products, such as naphtha and fossil fuels.

In this context, green logistics is defined as the effort to find ways to reduce the burden of external logistics associated with climate change, air pollution, noise, vibrations, and accidents—in order to achieve a sustainable balance between economic, environmental, and social factors. Therefore, all efforts are ultimately directed towards green logistics, and these help ensure sustainability (Ittmann 2011).

In this context, pipeline transportation proves important because it can provide both economic and environmental benefits (Coleti 2013). In the proposed model, fixed costs are higher because improvements include construction and maintenance; however, these are offset by lower variable costs, with lower demand for labor in operations (Viana 2011).

According to Santos et al. (2009), pipelines are a clean alternative form of transportation not subject to traffic congestion and a relatively inexpensive means of transportation for liquid hydrocarbons and safer derivatives worldwide. Nevertheless, operating pipelines represents significant risks to the environment. Several accidents, in Brazil and around the world, involving the release of toxic or flammable substances have had a serious environmental impact on flora and fauna, as well as deaths and damage to the health of populations in the vicinity of pipelines. This has led the countries involved to increase environmental requirements relating to the operation and maintenance of pipelines transporting hydrocarbons.

Impact on the environment and workers' health arising from leaks of liquid hydrocarbons in the petrochemical industry

The petrochemical industry, at all stages of its production process, has the potential to have an impact on the environment and the health of people in surrounding areas—in particular, their workers, depending on specific risks in their workplace (Augusto 1991). Because hydrocarbons are a complex mixture of organic compounds—predominantly hydrocarbons and smaller percentages of sulfur, nitrogen, oxygen, and metals such as vanadium, nickel, sodium, calcium, copper, and uranium—they can be used in numerous syntheses (Vieira et al. 2004).

Refineries and petrochemicals derived from human activities are a major potential pollutant since they produce large amounts of liquid discharges and release many harmful gases into the atmosphere, resulting in difficult waste treatment and disposal processes. Due to these facts, petrochemical industries are often large contributors to degrading environments: they have the potential to affect the air, water, soil, and consequently all the biotic environments in their surroundings (Mariano 2001).

Environmental damage results from the installation and operation of petrochemical refineries, which provide both raw materials and their derivatives through refining. These have an impact due to the wide variety of processes and operations used in the extraction of fractions. Many of the compounds used and generated in refineries come out of the processing units in the form of air emissions and solid waste effluent. Atmospheric emissions include fugitive emissions of volatile compounds present in crude oil and its fractions contained in processing units and generated by burning fuels during production. Typically generated pollutants include volatile hydrocarbons, carbon monoxide, sulfur oxides, nitrogen oxides, particulate matter, ammonia, hydrogen sulfide, metals, acids, and exhausted toxic organic compounds (FADE Environmental Impact Report 2006, cited in Do Monte Gurgel et al. 2009).

Human exposure can be occupational or environmental, as these compounds are released through leaks, fugitive emissions, improper disposal of waste, or accidents. Among the related health impacts introduced into the landscape by petrochemical refining are increased risk of cancer and development of neurological and psychological disorders, as well as diseases of the skin, liver, and cardiovascular and respiratory systems, among others. These affect community environments, where the local population lives at risk—vulnerable to exposure to chemical pollutants (Augusto 1991).

Regarding accidents in petrochemical plants, these can occur in engineering and maintenance processes, with both typical industrial accidents and larger chemical accidents often generated by explosions, leaks, improper waste disposal, and transportation of hazardous materials (Sevá Filho 2010; Souza and Freitas 2002).

According to Do Monte Gurgel et al. (2009), the wastewater produced during the operation phases involving hydrocarbons and their derivatives can affect workers' health through cancer and the problems previously described caused by hydrocarbons. Toxic substances include benzene (e.g., benzene poisoning, hematological changes, signs of neurological abnormalities, and chromosomal abnormalities), toluene (e.g., skin and upper airway irritation, anemia, central nervous system (CNS) depression, psychiatric disorders, and neurological diseases), and xylene (e.g., skin and mucous membranes irritation, eye and liver damage, anemia, and CNS problems). With regard to the environment, the effects on living things include: reducing the amount of sunlight available; reduction in the rate of photosynthesis; death of certain organisms (e.g., plankton); adherence of oil on the bodies of animals (e.g., mammals, fish, birds, and crustaceans), which causes damage to their health or death; and narcosis in aquatic animals. In addition, wastewater leads to the production of bad odors; pollution of surface water by entrainment or infiltration of debris into water bodies; release of toxic gases; air pollution; and toxic chemicals in the soil (e.g., impacts on biota and damage to human health and other living organisms).

Da Silva et al. (2013) presented the results of their analysis of sustainable development and occupational health in the context of environmental impact studies of petrochemical plants in Brazil. These indicate the need for inclusion of basic health indicators for workers, at the minimum, to be included in the licensing process of these industries.

Minimization and reuse of waste through methods of cleaner production

Cleaner production (CP) means a strategic focus on reducing environmental impacts throughout the product life cycle and, therefore, considers techniques to conserve energy and raw materials, eliminate toxic materials in processes, and reduce the quantity and toxicity of all emissions and wastes. It can be achieved by technological improvements and changes in attitude (Medeiros et al. 2007).

Therefore, CP is a set of actions aimed at the prevention of waste generation and wastage and even the reuse of waste from production processes. These can be applied at various stages of transformation processes and already be provided for when planning products and processes to encourage the proper disposal and return of waste. Figure 2 shows the levels of performance of CP, with the items of highest priority in the top left, that is, to avoid the generation of waste and emissions (Level 1). Waste that cannot be avoided should preferably be reintegrated into the production processes of the firm (Level 2). In the absence of this level, recycling measures outside the firm (Level 3) can be used. This study highlights the minimization of waste at the source (Level 1) and the modification of processes and subsequent housekeeping, as well as proposing the reuse of waste (Level 3)—in this case, also the finished product—through its reincorporation into processes (i.e., return to the distribution system).

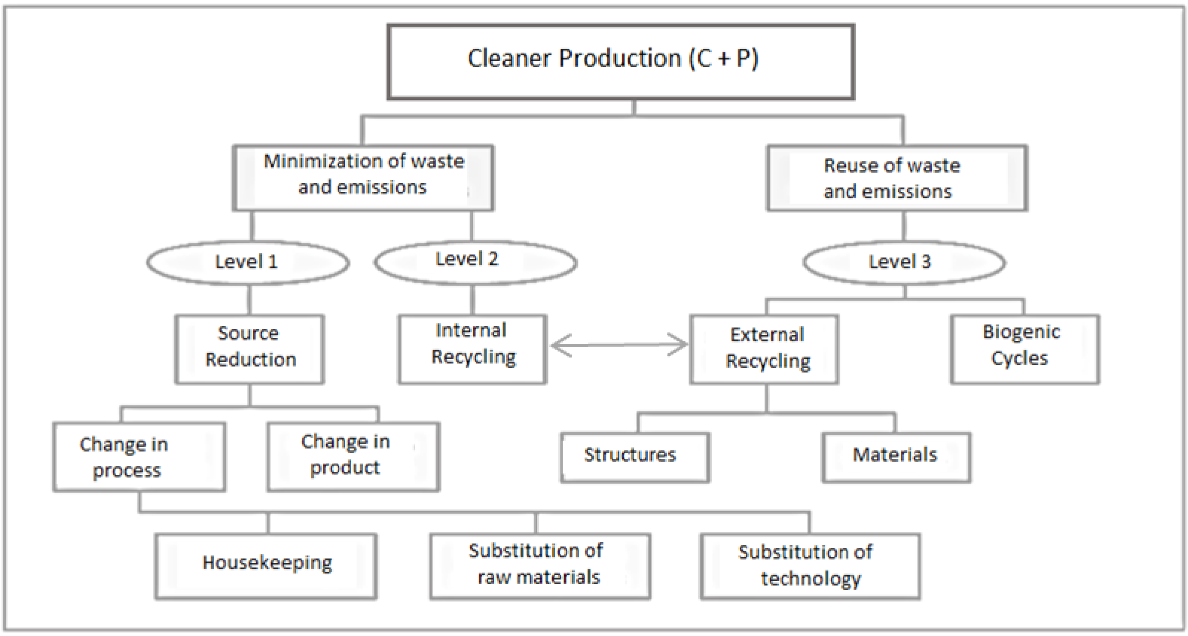

Figure 2 – Levels of actions in cleaner production
Source: Oliveira and Alves (2007) adapted by authors

Housekeeping is, as proposed by Berkel (2000), one of the five most common practices in preventing waste generation:

- Modification of the product—changes the composition, type of packaging, and shelf life of products
- Replacement of feedstock—uses raw materials and inputs cleaner and longer life
- Changes in technology—improves process automation, process optimization, process redesign, and replacement equipment
- Housekeeping—changes operational procedures and management to eliminate waste and emissions, such as spill prevention and training of employees

- Recycling in place—recycles internally, improving waste and polluting processes that were generating wastage

Methodology

The method used was a case study in a petrochemical industry in the state of São Paulo. The choice of carrying out a case study was justified by the fact that the overall objective of the research involved operational issues that needed to be investigated over time, rather than being seen as isolated events or incidents. Furthermore, a case study is the most recommended strategy when examining contemporary events and when doing research that cannot handle all the relevant behaviors to be studied or ignore the context in which they occurred (Yin 2005).

In the first step, a literature search was done in order to identify theoretical approaches to possible environmental impacts of the operation and maintenance of the pipeline model of transportation and good practices related to green logistics. For this reason, a case study that would enable us to identify ways of reducing the impacts highlighted in the literature survey was conducted. Case studies, which are characterized by the profound and exhaustive study of one or a few items, allow researchers to gain both broad and detailed knowledge of the items, an almost impossible task when other research designs are considered (Gil 1989). The operationalization of the case study followed the protocol outlined in Table 2.

Table 2 – Case study protocol

Overall goal of the case study	To identify how to reduce the environmental impact of leakage of hydrocarbons through the logistics of pipeline transportation
Data collection: document analysis	Operating manuals for the maintenance and drainage of a liquid hydrocarbon line
Data collection: direct observation	Visits and studies that followed the draining operations of the line and observations of patterns of liquid hydrocarbon leakage
Analyzed aspects	Worker safety in operations, volume of leakage, drainage maintenance process, and tests of solutions for casting
Data collection instrument	Aspects to be analyzed operationalized through semi-structured research and observation
Timeliness of data	Data concerning draining operations collected
Data analysis	Data collected analyzed to identify viable options to reduce the impact of the leaks studied

Source: Authors (2014)

Analyses and results

The company used standards for drainage of lines without pumps as a reference for the maintenance of ducts and their equipment and accessories. In this case study, the maintenance process required the drainage of the liquid hydrocarbon line to exchange the control valve connected to the drain valve. To implement these services, it is mandatory to use personal protective equipment: gloves of leather or a suitable plastic material, safety shoes or boots, a PVC safety helmet and goggles, and a filter mask for organic vapors.

Furthermore, attention needs to be paid to the fact that hydrocarbons and alcohols can cause irritation. To prevent these chemicals from coming into contact with skin during activities, workers must use uniform with long sleeves, avoiding the exposure of body parts without proper protection.

Usually aligned through valves, the line drains into a sump tank, which is a collector box that receives waste from draining lines and is the environment for later reprocessing. In our case study, the drain valve is located on the sump, which has a direct pathway to the sump tank. As a contingency measure, the workers use a vacuum truck for situations that may occur during a sudden increase in the volume of hydrocarbons or other unexpected events. The workers close the valve on the manifold of the hydrocarbon tank. They open the drain valve when allocating the contents remaining in the sump tank. They wait until there is zero flow through the duct.

With the removal of the drain valve, it is clear that, as shown in Figure 3, the shutoff valve does not completely halt the flow of liquid hydrocarbon through the line, allowing partial passage of the product. This passage is recurrent in the product lines, especially for those substances whose aggressiveness affects the sealing qualities of the valve seat materials. These products require a higher rate of exchange and repair of equipment, tools, and accessories.

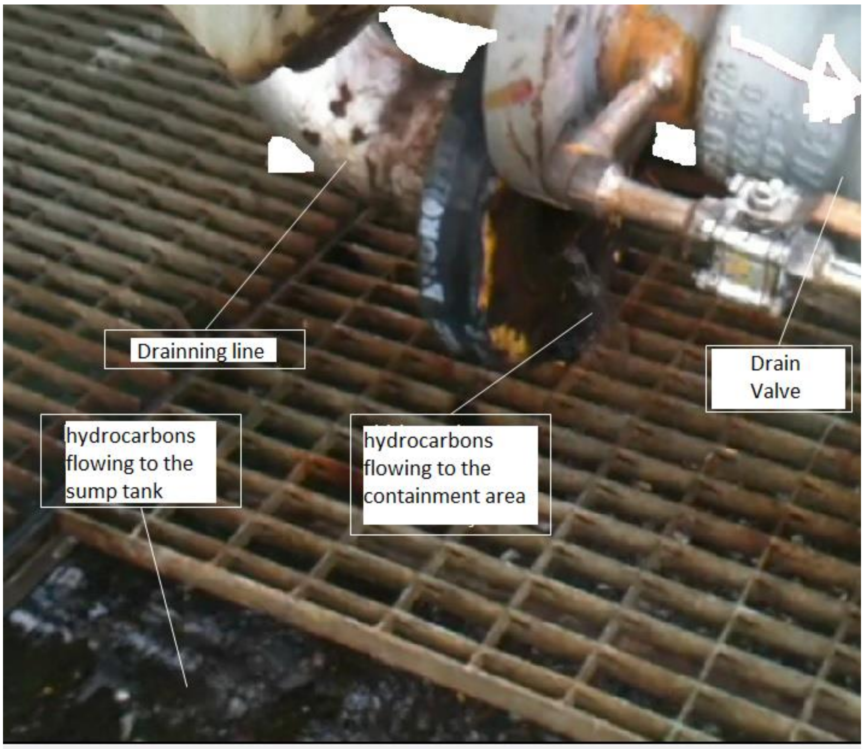

Figure 3 – Pipeline draining valve
Source: Authors

The calculated volume of contained liquid hydrocarbon in line and during transfer to the sump tank is 155 ml per second. After removal, assembly, and testing, the volume is 837 L of hydrocarbon. Table 3 provides details of major losses and the costs involved for each item.

Table 3 – Cost estimate

	Volume (liters)	**Qty. of similar operations per year**	**Value/unit (US$/unit)**	**Subtotal (US$)**
Product drained to the sump tank	837	283	0.58	137,385.18
Reprocessing cost	837	283	0.23	54,480.33
Total				**191,865.51**

Source: Authors

Aiming to mitigate the potential environmental risks of operations of petroleum and petrochemical industries, the company recognizes the need to employ the best technology and best practices using best available techniques (BAT)/industrial emissions directives (BAT 2010) to, among other things, implement measures to limit and reduce emissions and discharges of gases and hydrocarbon vapors. It is also considers waste and the need to maximize the reuse of products.

In this case study, we used equipment composed of a positive displacement hose pump flange to capture and transfer the hydrocarbon drained into the tank, using a pump with a volume suitable for this product. Table 4 details the value of the equipment required and the annual cost reduction generated by the proposed action.

Table 4 – Savings calculation

	US$
Cost of equipment to pump liquid hydrocarbon	20,000.00
Annual savings	171,865.51

Source: Authors

The results show that re-using the pump to drain the waste liquid, beyond providing an annual savings of over US$170,000, completely eliminated leaks, reducing any environmental damage. This implies the proposed action is economically viable as an operation based on sustainable environmental practices.

Conclusion

A healthy environment is essential in efficient transport because of its ability to promote economic growth and opportunities, which is essential for effective and lasting environmental management markets. The drainage of liquid hydrocarbon produces gases and vapors that can cause potential environmental hazards and waste products that can be eliminated without large technological investments. This technology can be reused later, helping to develop best practices for CP and green logistics, including the following aspects of the product life cycle: production, storage, transport, use, maintenance, disposal, resource and energy saving, hazardous materials handling, and recycling and reuse.

With the implementation of the proposed procedure for pumping drained hydrocarbon, a new standard of operational waste was established that reinforces the need for management of control drainage. This contributes to the reduction of toxicity and concentrations of gases and noxious fumes, risks of undesirable changes, and effects on the ecosystem near the premises, especially those aspects related to adverse effects on the professionals who deal with, and are exposed to, the drained product’s effects.

In addition, the company can respect its principles of operational excellence, avoiding production and reprocessing costs and generating annual savings of over US$170,000. Moreover, the pumping of liquid hydrocarbon directly affects operational quality, reducing their impact on the environment, workers’ health, and the organizational climate. This aligns with the strategy of sustainability and respects the interests of stakeholders in the industry.

Bibliography

Augusto, L. G. S., ed. 2009. *Saúde do Trabalhador no Desenvolvimento Humano Local: Ensaios em Pernambuco*. Editora Universitária UFPE, Recife.

Augusto, L. G. S. 1991. *Estudo das Alterações Morfológicas (Medula Ossea) em Portadores de Neutropenia Secundária à Exposição ao Benzeno* (dissertation). Universidade de Campinas, Campinas.

Berkel, R. V. 2000. *Cleaner Production for Process Industries: Overview of the Cleaner Production Concept and Relation with Other Environmental Management Strategies.* Curtin University of Technology, Perth, Australia. Available at http://infohouse.p2ric.org/ref/13/12031.pdf (accessed 25 August, 2014).

Best Available Techniques (BAT). 2014. *Industrial Emissions Directive (IED)*. Available at http://www.epa.ie/licensing/info/bat/#.VCyTh3d0h34 (accessed 25 August, 2014).

Black, W. R. 1996. Sustainable transportation: A US perspective. *Journal of Transport Geography* **4**(3): 151–159.

Coleti, J. C. 2013. *Nova Logística de Etanol para o Abastecimento do Mercado Interno* (dissertation). Esalq-Log Universidade de São Paulo, Piracicaba, Brazil.

Da Silva, J. M. et al. 2013. Desenvolvimento sustentável e saúde do trabalhador nos estudos de impacto ambiental de refinarias no Brasil. *Saúde e Sociedade* **22**(3): 687–700.

Do Monte Gurgel, A. et al. 2009. Framework dos cenários de risco no contexto da implantação de uma refinaria de petróleo em Pernambuco. *Ciência & Saúde Coletiva* **14**(6): 2027–2038.

European Commission. 2006. *Urban Freight Transport and Logistics: An Overview of the European Research and Policy*. DG Energy and Transport Brochure. University of Leeds, West Yorkshire, England. Available at http://www.transport research.info/Upload/Documents/ 200608/ 20060831_ 105348_ 30339_Urban_freight.pdf (accessed 25 August, 2014)

Gil, A. C. 1989. *Métodos e Técnicas de Pesquisa Social*. Atlas, São Paulo.

Gozzi, S., J. Petragalia. 2003. *A Evolução da Logística no Setor Petroquímico em Busca da Vantagem Competitiva*.

Ittmann, H. W. 2011. *Green Supply Chains – A New Priority for Supply Chain Managers*.

Lourenço, H. R., J. P. Soto. 2002. *A Recoverable Production Planning Model* (working paper) Grup de Recerca en Logistica Empresarial, Barcelona.

Mariano, J. B. 2001. *Impactos Ambientais do Refino de Petróleo* (dissertation). Universidade Federal do Rio de Janeiro, Brazil.

Medeiros, D. D., F. A. Calabria, G. C. S. Silva, J. C. G. Silva Filho. 2007. Aplicação da Produção mais limpa em uma empresa como ferramenta de melhoria contínua. *Revista Produção* **17**(1): 109–128.

Oliveira, J. F.G., S. M. Alves. 2007. Adequação ambiental dos processos usinagem utilizando Produção mais Limpa como estratégia de gestão ambiental. *Revista Produção* **17**(1): 129–138.

Rogers, D. S., R. S. Tibben-Lembke. 2001. An examination of reverse logistics practices. *Journal of Business Logistics* **22**(2): 129–148.

Santos, J. C. D., A. Santos, A. R. Berto. 2009. Logística: Evolução e perspectiva. *Revista de Ciências Empresariais* **2**(4): 1–14.

Sevá Filho, A. O. 2010. Problemas intrínsecos e graves da expansão mineral, metalúrgica, petrolífera e hidroelétrica nas Amazônias. Zhouri, A., K. Laschefski, eds. *Desenvolvimento e Conflitos Ambientais*. UFMG, Belo Horizonte, 114–147.

Silva, C. R. L, P. F. Fleury. 2000. Avaliação da organização logística em empresas da cadeia de suprimento de alimentos: Industria e comércio. *Revista de Administração Contemporânea* **4**(1): 47–67.

Souza, C. A. V., C. M. Freitas. 2002. Perfil dos acidentes de trabalho em refinaria de petróleo. *Revista de Saúde Pública* **36**(5): 576–583.

The Center for Sustainable Transportation. 2002. *Definition and Vision of Sustainable Transportation, Mississauga, ON.* Available at http://cst.uwinnipeg.ca/documents/Definition_Vision_E.pdf (accessed 2 February, 2015)

Viana, V. C. 2011. *Desenvolvimento de Metodologia de Análise Quantitativa de Risco para Dutovias de Petróleo e Derivados* (dissertation). Recife.

Vieira, F. C. D. S. et al. 2004. *Toxicidade de Hidrocarbonetos Monoaromáticos do Petróleo sobre Metamysidopsis Elongata Atlântica (Crustácea: Mysidacea).*

Wu, H.-J., S. C. Dunn. 1995. Environmentally responsible logistics systems. *International Journal of Physical Distribution & Logistics Management*.

Yin, R. K. 2005. *Estudo de Caso: Planejamento e Métodos*. Bookman, Porto Alegre, Brazil.