ARTICLE IN PRESS
CHNAES-00521; No of Pages 6
Acta Ecologica Sinica xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Acta Ecologica Sinica
journal homepage: www.elsevier.com/locate/chnaes

A novel perspective to bitumen refineries life cycle assessment and processes emissions

Saeed Morsali

Gazi University, Faculty of Applied Science, Department of Environmental Science, Ankara, Turkey

ARTICLE INFO

Article history:
Received 16 February 2017
Received in revised form 27 July 2017
Accepted 7 August 2017
Available online xxxx

Keywords:
Bitumen refinery LCA
Bitumen refineries emissions
Damage assessment of bitumen refineries
Environmental loads of bitumen LCA

ABSTRACT

This study provides an introduction and a novel view of the impacts of oil refineries industry on human health, ecosystem quality and resources. The scope and issues for dealing with these challenges are rather wide and complex because the Oil refineries are complex facilities. Several processes, such as distillation, vacuum distillation, or steam reforming are required to produce a large variety of oil products such as gasoline, light fuel oil or bitumen. The goals, perspectives and expectation for the environmental practice and control have changed dramatically over the last couple of decades. Hence the required approach has to be multidisciplinary, based on established scientific concepts and sound engineering principles. The environmental impacts of oil refineries are assessed using the technique of life cycle assessment (LCA). In this paper, only the material production phase of the bitumen LCA is considered. To improve the quality of the LCA, a regionalized life cycle inventory (LCI) database for the Oil refineries and commercial LCI databases are used to validate and model unit processes with an LCA software.

1. Introduction

The importance of quantifying the impact of products and services on the environment is growing due to the recent changes in patterns of climate, living, resources and ecosystem quality. Consumers and governments are increasingly demanding information about the sustainability of products and interest in comparing potential solutions based upon scientific data is necessary in order to do this. Petroleum refining is one of the largest industries in the oil producer's countries and a vital part of the international economy [1]. However, potential environmental hazards associated with refineries have caused increased concern for communities in close proximity to them [1]. This paper provides a new overview of the processes involved and potential environmental hazards associated with petroleum refineries in terms of three main impact categories; human health, resources and ecosystem quality. More than 660 refineries, in 116 countries, are currently in operation, producing >85 million barrels of refined products per day [2]. It is estimated that the current world use of bitumen is approximately 102 million tons per year. The primary use of bitumen is for paving and roofing applications, 85% of all the bitumen is used as the binder in various kind of asphalt pavements: pavements for roads, airports and parking lots, About 10% of the bitumen is used for roofing. The rest of the bitumen, approximately 5% of the total is used for the variety of purposes, each very small in volume. This sector is referred to as secondary uses [3].

Fig. 1 shows estimated yearly bitumen production worldwide by different area, it also represents bitumen applications by sector.

An LCA is a measure of the environmental impacts of a product, process or service during the course of its useful life. LCA studies indicate the synergistic products are favorable from an environmental perspective [4]. LCA is a growing popular method in different fields of research as it is being recognized that resource depletion and the emissions of different potentially harmful substances are often a result of the activities in different life cycle stages of a product's life. LCA is a versatile tool to investigate the environmental aspect of a product, a service, a process or an activity by identifying and quantifying related input and output flows utilized by the system and its delivered functional output in a life cycle perspective [5]. Ideally, it includes all the processes associated with a product from its cradle-raw material extraction to its grave-disposal [6]. LCA studies can help to assess and minimize the energy usage, resources consumption and emissions to the environment by providing a better understanding of the systems. LCAs can also suggest different alternatives for different phases or substances of a life cycle of the system if we have different design alternatives. Unfortunately, LCA has not yet been adopted by the industries. This could partly be explained by the lack of a technical tool that accurately represents all the aspects of the bitumen production sector, differences in production equipment, energy supplement, regional material extraction technology, transportation differences and etc.

There are several published studies for assessing the impacts of refineries. In the Venkatesh [7] "Uncertainty Analysis of Life Cycle Greenhouse Gas Emissions from Petroleum-Based Fuels and Impacts on Low Carbon Fuel Policies", the main method for determining emissions output comes from energy use and fixed energy emission values. The study emphasizes energy use above all else and uses a system boundary that is from well to wheel such that there is no breakdown between processes.

E-mail address: saeed.morsali@gazi.edu.tr.

http://dx.doi.org/10.1016/j.chnaes.2017.08.005
1872-2032/© 2017 Published by Elsevier B.V. on behalf of Ecological Society of China.

Please cite this article as: S. Morsali, A novel perspective to bitumen refineries life cycle assessment and processes emissions, Acta Ecologica Sinica (2017), http://dx.doi.org/10.1016/j.chnaes.2017.08.005

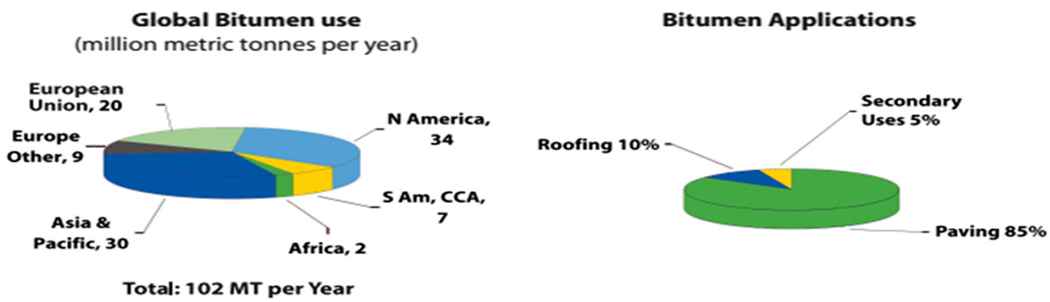

Fig. 1. Global bitumen use and application areas.

Additionally, the study comes from the United States and uses time series data that is from 1998 to 2008 respectively [8]. Another study that follows the same energy input rubric is the study by Wang [9] "Allocation of Energy Use in Petroleum Refineries to Petroleum Products" that analyzes energy usage. The Wang study uses the same model as the Venkatesh study but it classifies the emissions by process which is more clear, besides in this study the used data are from 1996 and 1999 within the geographical boundaries of the US which are sort of old data. These studies are only focused on the CO_2 emissions and are based solely on energy inputs, these studies neglect all other emissions. They offer a small glimpse of how different fuel types produce different emissions but are not inclusive of all processes within a refinery. These studies do not go into detail on petroleum processing, transportation process, raw material extraction and waste flow over the bitumen lifecycle. In this study, the analysis leads to product specific allocation factors for energy, airborne and waterborne pollutants. Furthermore working material consumption, additive requirements, production waste, and infrastructure, the most important emissions and processes are given by their impacts values.

2. Methods and inventory analysis

The purpose of this paper is to analyze petroleum refining and its impacts on the environment. Many factors contribute to the consumption patterns of bitumen including price, government legislation, infrastructure, technology among others. Production can be just as affected by those factors but also by others such as labor strife, dwindling petroleum reserves, worldwide market price, profitability, seasonal demand and much more [8].

2.1. LCA methodology

As mentioned LCA is a system for collating and determining the environmental loads of a product, service or a process through its full life cycle, from cradle to grave. In international standardization, ISO 14040 series promote LCA as a technique to better understand and address the possible environmental impacts associated with products (including services) [10]. ISO 14040 defines the principles and framework of LCA, and ISO 14044 gives more detailed requirements and guidelines [10].

SimaPro is the most widely used LCA software. It has unique features such as parameterized modeling and interactive results analysis. It uses many LCA methods as well as databases to modeling a product based on real experiments from Europe and USA. In this novel, we used a commercial version of SimaPro 7.1 to validate the results. Unlike the mentioned studies in this paper, all airborne, waterborne and emissions to the soil were listed based on the procedures. Database for emission factors for the Swiss and for the average Western European refinery are used. Airborne emissions comprise CO, CO_2, SO_2, NO_X, particulate matter, hydrocarbons (specified), acids and heavy metals (specified). Waterborne pollutants comprise hydrocarbons (specified), and inorganic substances (sulfates, phosphates and nitrate). Different production waste and their further treatment are distinguished. The environmental impacts modeled include energy consumption and greenhouse gas (GHG) emissions from oil refineries.

There are various LCA methodologies that can be applied. They have different impact categories they cover, moreover they use different methods to evaluation these impacts, various kind of indicators selection, and in their geographical focus. In this paper we used Eco-indicator 99 which includes 3 main impact categories;

Human health: under this category, we include the number and duration of diseases and life years lost due to premature death from environmental causes. The effects we include are climate change, ozone layer depletion. Carcinogenic effects, respiratory effects and ionizing (nuclear) radiation.

Ecosystem quality: under this category, we include the effect on species diversity, especially for vascular plants and lower organisms. The effects we include are Ecotoxicity, acidification, eutrophication and land-use.

Resources: under this category, we include the surplus energy needed in the future to extract lower quality mineral and fossil resources. The depletion of agricultural and bulk resources as sand and gravel is considered under land use.

2.2. System boundaries

The model describes the production of oil products for energetic and partly non-energetic uses and the production of thermal energy and electricity in Switzerland and Western Europe. The inventory tables for oil products include oil field exploration, crude oil production, long-distance transportation, oil refining, regional distribution and the use of oil products in domestic and industrial boilers, in power plants and in spark ignition engines (of trucks, personal cars, excavator, locomotives, and ships).

This study covers the bitumen production chain, starting from raw material extraction and ending with a bitumen product ready for delivery to a customer. The process is divided into four stages: crude oil extraction, transport, production, and storage. A schematic description of the system boundary is given in Fig. 2.

2.3. Inventory data

Inventory data for this study is taken from commercial Simapro 7.1 program database and the oil fuel chain, in particular, is divided into the following process steps:

- Oil field exploration: Include emissions caused by drilling activities, barite and bentonite consumption and the emissions of oily drilling fluids into the sea (emission data for North Sea exploration is used).
- Crude oil production: The variation in drilling efforts and energy consumption per barrel oil extracted from different regions is modeled.
- Long distance transportation: Distance is used according to the specific supply situation of Switzerland and Western Europe.
- Oil refining

Please cite this article as: S. Morsali, A novel perspective to bitumen refineries life cycle assessment and processes emissions, Acta Ecologica Sinica (2017), http://dx.doi.org/10.1016/j.chnaes.2017.08.005