Environmental impact assessment of paints production in Egypt

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Abstract

Painting materials are being used worldwide for decoration, equipment and machinery refinishing among many other applications. The total value of the global paint market amounted to approximately 160.54 USD billion in 2017 and is expected to reach 209.36 USD billion by 2022. The local paint market in Egypt reached 764 USD million sales in 2016. The local expansion in both the industrial and real estate construction sectors is associated with increasing demand of painting materials. This raises the concerns of paint production impacts on the environment.

The aim of this study was to assess the environmental impacts of one of the most locally used painting materials "White alkyd enamel paint". This was done in order to identify the hot spots of local paint production process, and need for future studies. Life cycle assessment (LCA) was employed as a tool for assessing the environmental impacts.

LCA results indicated that white alkyd enamel production impacts on resources, ecosystem quality and Human health by 45.8%, 31.8% and 22.5%, respectively. Top impacted category is fossil fuels depletion which accounts for 44.8% of the total environmental impacts. The production of Alkyd resin is the main contributor to the different environmental impact categories. Overall environmental impacts of this industry can be reduced by implementing proper energy management practices that reduce energy consumption during Alkyd resin manufacturing.

Furthermore, no previous LCA studies were conducted concerning the environmental impact assessment of paint production process at local level. It is recommend to conduct further studies in this area taking into consideration other types of painting materials. Also comparing between the impacts of different painting colors can be studied.

Keywords: Environmental impacts, Life cycle assessment, Alkyd Enamel paints, Egypt

1. Introduction

The total value of the global paint market amounted to approximately 160.54 USD billion in 2017 and is expected to reach 209.36 USD billion by 2022 [1]. Paints are being used worldwide for a number of applications like decoration, car refinish, steel structure, .etcthere are different types of paints based on their application and function either protective or decorative[2]. The fact that there are few objects which do not require coating is an indication of the enormous importance of coating technology. According to the Euro monitor International analyst production levels in the Egyptian domestic paint with coating sales reached USD 764 Million in 2016 the decorative paints segment holds the largest market share (74%), followed by wood coatings (10%) and industrial protective paints (9%)[3].

The most important task for coatings, in economic terms, is surface protection. Thus coatings help to retain value and enhance properties usage of almost all products, therefore they are of huge economic significance. However, coating paints should be manufactured in accordance to the environmental standards throughoutall their process steps from cradle to grave, starting from raw material production passing by processing to application till disposal whenever possible. Without coatings, a drastically decrease in product live might happened [3].

The current study aimed to assess the environmental impacts of paint production process in Egypt. This was done in order to recognize the hot spots of this industry, recommend improvement options and need of future studies in this area.

2. Life cycle assessment

In order to assess the environmental impacts of paint production process Life cycle assessment (LCA) technique was employed following the framework of the International Standard for Life cycle assessment (ISO14044 : 2006) [4] which includes (a) Identifying the goal and scope of study, (b) Data collection and inventory analysis, (c) Conducting the impact assessment and (d) Data and results interpretation.

2.1. Goal, scope and system boundaries

Presented in Fig. 1. Layout and system boundary of paint production process.

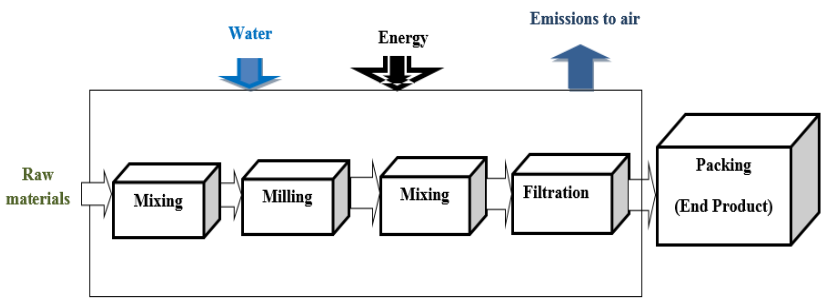

Fig. 1. Layout and system boundary of paint production process

2.2. LCA inventory, data collection and uncertainty

Input/output data was collected from a local case study plant for paint production located at Alexandria governorate, Egypt during 2018 and is presented in Table (1). Background data was compiled using the available data in the Eco-vent data base.

3. Results and Discussion

The study aimed to assess the environmental impacts of locally produced white Enamel paint in Egypt in order to identify hot spots of the process and recommend improvement options. A cradle to gate approach was selected for the study, starting from raw materials extraction till the end of the paint production stage.

Regarding the life cycle inventory the following was considered: a) different inputs from raw materials including: Alkyd resin, Titanium dioxide, Dolomite , Cobalt, Calcium, Zirconium, White spirit, Bentonite (Clay), Polycarboxylate as a dispersing agent, b) energy used for mixing, milling and packing, c) no water input was added as the process does not require any water addition. As for the outputs: the end product (White alkyd enamelpaint) and generated air emissions in form of particulate matter and Hydrocarbons. The generated solid wastes are in form of empty bags and drums which are being reused so they were excluded from the study (Table 1). A cut off criteria of 1.5% was used in this study.

Table 1. Input / Output data for Life cycle assessment of 1000 kg Alkyd Enamel paint production

Item	Unit	Amount
Input		
Raw materials		
Alkyd resin	kg	520
Titanium dioxide	kg	200
Dolomite	kg	140
Cobalt	kg	3.6
Calcium	kg	4.8
Zirconium	kg	17
White spirit	kg	100
Bentonite (Clay)	kg	5
Dispersing agent :		
- Polycarboxylate	kg	5
Energy		
Electricity for mixing, milling and packing	Whr	25
Output		
End Product (Paint)	kg	1000
Emissions to air		
Suspended dust/Particulate matter	ppm	213.5
HC	ppm	166

LCA was evaluated based on the impact assessment methodology Eco-Indicator 99. The following impact categories were considered: global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), carcinogens potential (CP), ecotoxicity potential (ETP), respiratory inorganic formation potential (RIFP), respiratory organic formation potential (ROFP), radiation potential (RP), ozone layer depletion (OLD), mineral depletion (MD), land use (LU) and fossil fuel depletion (FFD).

4. Life cycle analysis results

Analysis results show that top impacted category from white enamel production is resources (45.8%), followed by ecosystem quality and Human health, 31.8% and 22.5%, respectively. The production of Alkyd resinis the main contributor to the environmental impacts of enamel paint production as presented in the ecological impact network of white enamel production (Fig 2). Table (2) and Fig. (2 – 3) show the impact assessment of 1 ton production of white enamel paint on the environment. Fossil fuels depletion is the highest impacted category followed by land use and respiratory inorganic formation potential. Climate change impacts represent 3.5% of the total impacts. It was found that the production of alkyd resin and Titanium dioxide, the main raw materials used in the production process, are the main contributors to the different impacted categories.

Table 2. Environmental Impacts per category of white enamel Alkyd paint production

Impact category	Total (%)
Fossil fuels	44.8
Land use	29.1
Respiratory inorganics	14.6
Carcinogens	4.4
Climate change	3.5
Acidification/ Eutrophication	1.4
Ecotoxicity	1.3
Minerals	0.9
Respiratory organics	0.1
Radiation	-
Ozone layer	-

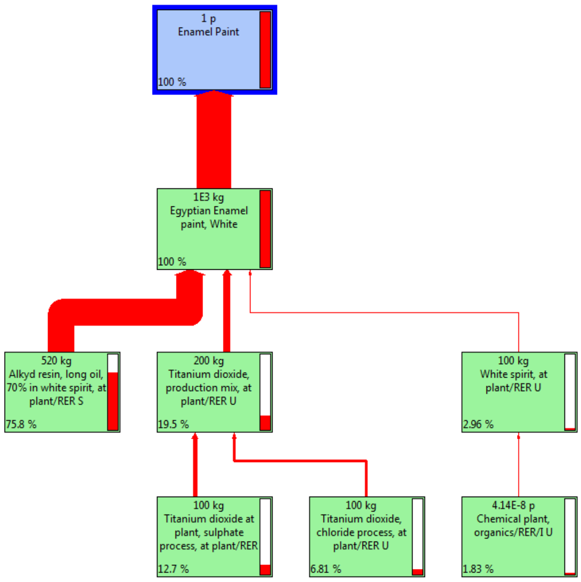

Fig.2. Ecological impact network of Alkyd Enamel paint process

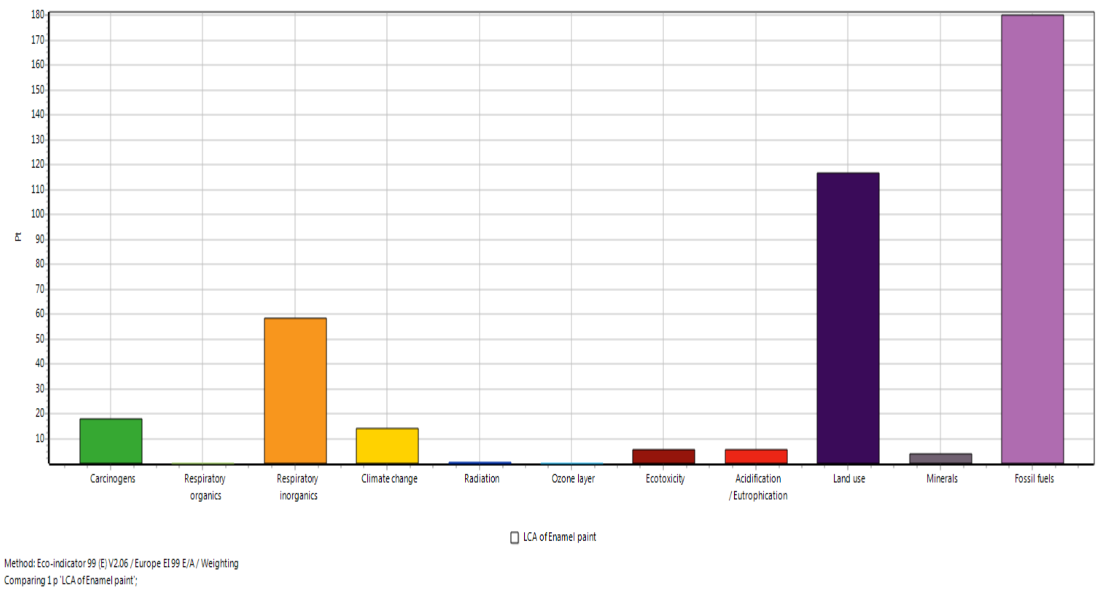

Fig.3. Impact assessment of white enamel Alkyd paint production on the environment (Weighting)

The top impacted category is fossil fuels depletion which accounts for 44.8% of the total environmental impacts due to generated emissions from Alkyd resin manufacturing process (Table 2 and 3). This manufacturing process is an energy consuming process[5]. Alkyd resins are synthetic polyester resins produced by esterifying polyhydric alcohols with polybasic carboxylic acids where at least one of the alcohols must be trihydric or higher. They are always modified with natural fatty acids or oils and/or synthetic fatty acids**.** Furthermore, Alkyd resin is manufactured through a Poly condensation reaction carried out in a reactor where raw materials are being heated in boiler ranged from 190 ^{o}C to 270 ^{o}C with the existence of almost 5% of hydrocarbon solvent. Water of the reaction is then transferred to condenser where water separated from the azeotropic mixture, and solvent returned back to the reactor. Reactants are separated from residuals through filtration system. Heating source may be electric or an oil, gas or coal furnace [3] .

The second top impacted category was land use which accounts for 29.1% of the total environmental impacts (Table 3). This high impact can be attributed to the influence of oil used in the Long Alkyd resin manufacturing and illiminte ore used in the production of titanium dioxide (TiO_2). The used oil in the manufacturing process of alkyd resin as one of its inputs is being extracted from large amounts of vegetations crops such as cotton seeds or soybean [6]. As for titanium dioxide manufacturing, the main raw material used is illiminte ore which is extracted from mines. For each 1 ton production of titanium dioxide about two ton of raw material (ilmenite or ilmenite + slag) are being consumed meaning that 1 Ton of Alkyd enamel paint consumes 400 Kilogram of illiminte ore mines. Third major impacted category is respiratory inorganic formation potential accounting for 14.6% of the total impact. These impacts can be attributed to the generated air emissions from fossil fuel burning resulting in aerosols of sulphate and nitrates (Table 3). Also the use of fossil fuels in alkyd resin manufacturing generates air emissions. In the sulphate process for titanium dioxide manufacturing, Sulphuric Acid is being used to dissolve the feedstock resulting in ferrous sulphate monohydrated (MON), red gypsum and ferrous sulphateheptahydrated by products[7]

Table 3. Life cycle inventory of white Enamel Alkyd paint production process

Element	Unit	Amount	Impact indicator
Emissions to air			
Major elements			
CO_2	kg	2900.5	GWP
CH_4	kg	8.22	GWP
N_2O	kg	1.46	GWP
NOx	kg	7.82	RIFP, AP,EP
SO_2	kg	10.64	RIFP, AP,EP
Particulates, > 2.5 um, and < 10um	kg	1.2	RIFP
Minor elements			
Particulates, < 2.5 um	kg	0.54	RIFP
Ammonia	kg	0.96	RIFP, AP,EP
Sulphate	kg	0.94	RIFP, AP,EP
Cadmium	Kg	0.00014	ETP
Copper	kg	0.002	ETP
Nickel	kg	0.003	ETP
Zink	kg	0.003	ETP
Liquide discharge			
Arsenic	Kg	0.0017	CP
Emissions to Soil			
Zink	Kg	0.006	ETP
Cadmium	Kg	0.0009	CP
Resources Consumption			
Land use	m^2	1268	Land use
Energy	MJ	7943.9	FFD

Global warming potential (GWP), Acidification potential (AP), Eutrophication potential (EP), Carcinogens potential (CP), Ecotoxicity potential (ETP), Respiratory inorganic formation potential (RIFP), Respiratory organic formation potential (ROFP), Radiation potential (RP), Ozone layer depletion (OLD), Mineral depletion (MD), Land use (LU) and Fossil fuel depletion (FFD).

Regarding the carcinogenic potential, results in Table (2 - 3) and Fig (3) shows that this category is impacted by 4.4% of the total impact due to the Arsenic and cadmium emissions generated from the production of Alkyd resin. Climate change was impacted by 3.4% of the total impact due to the emission to air generated from the combustion process of energy generation (Table 2 and 3). Regarding Eutrophication, Ecotoxicity, Respiratory organics formation potentials and Minerals depletion, their combined impacts represented less than 4% of the total impact. These impacts were mainly attributed to the generated emissions during Alkyd resin manufacturing process. No impacts were detected on radiation or ozone layer potentials.

5. Improvement options and further needs for study

Furthermore, it was found that no previous LCA studies related to paint industry were conducted at local level. It is recommend to conduct further studies in this area taking into consideration other types of painting materials. Also comparing between the impacts of different painting colors can be studied. The drying time and application on the substrate for solvent based system as can be considered as well by incorporating the service life time of the substrate. This will have an effect on the different environmental impacts.

6. Conclusion

Paint production is expanding to meet the global demand. In order to determine the total environmental impact of Alkyd paint though its entire life cycle, a cradle to grave approach was conducted. The top environmental categories impacted by this production process are fossil fuels depletion, Land use, and Respiratory inorganics formation potential. Carcinogens potential, and Climate change were next in the impacted categories. Minor impacts were detected on acidification potential, Eutrophication, Ecotoxicity, Respiratory organics and Minerals depletion, their combined impacts represented less than 4% of the total impact. Alkyd resin manufacturing was the top source of impact on the different impacted categories due to the energy consumed in the different production processes and generated emissions from fuel combustion. Overall impacts can be reduced by applying proper energy management measurements in the pain industry.

No previous LCA studies addressing paint production were conducted at local level and very few one were done at global one. It is recommended to reduce the environmental impacts of paint production process worldwide by further studies in this area.

7. References

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