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Recycle or Dispose Off? Lifecycle Environmental Sustainability Assessment of Paint Recycling Process

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Abstract People are sometimes confronted with the need to decide whether a product should be recycled or disposed off. The purpose of this project was to assess whether it is more environmentally sustainable to recycle paint than to dispose it off in a landfill or not. Lifecycle assessment method was used to analyze potential environmental costs and benefits associated with paint recycling. Data used for the analyses were collected from a recycled paint manufacturing company, literature, and a database. The lifecycle impact analyses of the paint recycling process were based on monthly production of a recycled latex paint brand. Results of the analyses revealed that the process have a monthly 122760.8kg CO_2-eq global warming potential (GWP), 1481.6 max kg O_2-eq eutrophication potential (EP), and 106.8kg C_2H_4-eq photochemical ozone creation potential (POCP). The LCA results showed an environmental benefit of eliminating 31,237.29kg CO_2-eq GWP, 0.02kg CFC-11eq Ozone depletion potential (ODP), 5943.58kg C_2H_4 eq POCP and 197.83 max kg O_2 eq EP by recycling latex paint rather than disposing it off in the landfill and producing equal amount of latex paint to replace it . Results also revealed that recycling of paint containers and plastics reduces the GWP by 25.34%, ODP by 29.79%, POCP by 15.39%, and EP by 12.47%. Paint recycling is therefore not only economically wise but it is also ecologically sustainable.

Keywords Environmental Impacts, Environmental Cost, Environmental Benefit, Latex Paint, Life Cycle Assessment

1. Introduction

Water dilutable (latex) paints are widely used all over the world as a backdrop to the campaign against solvent emissions. They are used for surface protection, beautification and rejuvenation. Latex paints are applied in residential and commercial indoor environments. They are also used in the painting of car bodies[1].

About 30 million litres of paint is sold in Alberta, Canada every year. 5-10% of these paints and over 1 million empty paint containers are disposed off annually in Alberta[2]. Similarly, over 16 million gallons of latex paint (WLP) is also disposed off in USA every year[3]. However, increasing awareness of the potential environmental and health risks posed by residual paints necessitated regulation of waste paint disposal. Some of these paints contain combustible materials, volatile organic compounds, lead, mercury, and other heavy metals[4 -7]. Consequently, municipalities are required to collect residual paints from households for proper waste management. For example, waste paint constitutes around 21.7% of the total hazardous waste (HZW) collected by municipalities in Ontario province every year. Waste latent paint alone constitutes 12% of the total HZW[8]. The good news about these waste paints is that many have potentials for reuse, recycling and recovery[9, 10]. Recyclability of waste paints is an indication that their human and environmental risks could be eliminated or minimized by recycling. The largeness of the amount of latex paint disposed annually indicated its high economic potential[11]. As a result of these potentials, a number of organizations are now involved in latex paint recycling. However, recycling of materials also has socio-economic and environmental implications. This necessitates an assessment of the net benefit (or cost) of recycling resources at the end of their useful lives[12]. This case study involved a number of forward looking individuals that sought and experimented how these old paints could be reprocessed, repackaged and reused for various applications. These individuals have been reprocessing and repackaging old paints for about ten years and they wanted to know the environmental worth of their paint recycling effort. They also want to know whether it is more environmentally sustainable to recycle latex paint than disposing it off in a landfill or not.

2. Methodology

Lifecycle Analysis (LCA) method was used for this study because it is a comprehensive and proven analytical tool for

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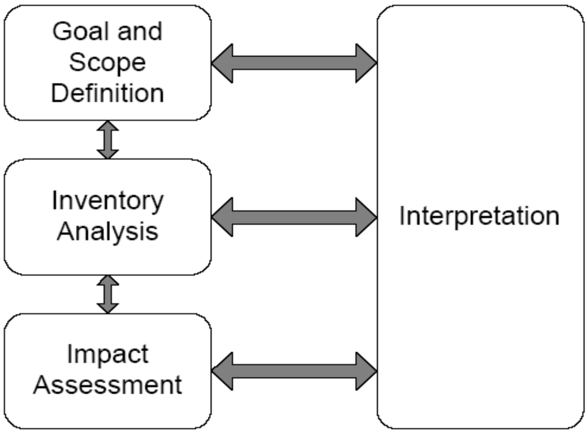
evaluating potential environmental burdens resulting from resource consumption and emissions by a product or process. It also enables us to assess product/process environmental impacts and to evaluate improvement opportunities that could be implemented to address areas of concerns[13-19]. The method consists of four iterative steps (Figure 1): goal and scope definition, inventory analysis, impact assessment, and interpretation.



(Source: Eco-efficiency-action-project.com)

Figure 1. An illustration of LCA process

2.1. Goal and Scope Definition

The main purpose of this LCA study was to determine whether it is more environmentally sustainable to recycle latex paint than to dispose it off in a landfill. Other reasons for the project are:

- To evaluate the environmental burden associated with the monthly production of a recycled paint over their entire process lifecycle in order to identify the stage with the largest environmental impacts (hot spots)
- To identify impact category of greatest concern with the aim of finding ways of reducing the ecological footprint

2.2. Functional Unit and System Boundaries

The functional unit was defined as the mass of a monthly production of 12 colour recycled latex paint in two packages of 4, 10 and 18.9 litres. The company produces 60000 litres of recycled paint every month for sale to the clients. The monthly volume of recycled paint production is approximately 49,800kg by mass.

The system boundaries for the analysis are shown in Figure 2. The entire lifecycle was composed of the following stages:

- Old paint transfer from municipalities to the company's recycling facility in Calgary
- Sorting and inspection of the paints to oil based paints, reusable latex paint, and unreusable latex paint
- Emptying of reusable latex paints into one of the 12 totes based on the paint colour
- Compression and transportation of metallic and plastic containers for recycling
- High speed mixing of each full tot of latex paint
- Filtration of the paints to remove particles and to comply with industry standard
- Storage tank mixing of the paints
- Packaging of the processed paints into 4, 10 and 18.9 litres containers
- Distribution of reprocessed latex paint to retailers
- Transportation of oil paints and unreusable latex paint for disposal in landfills

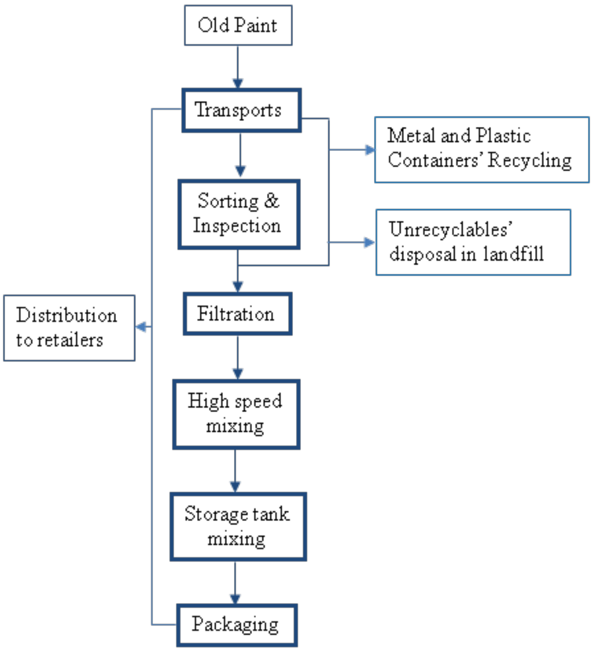


Figure 2. General flow scheme of paint recycling process

In addition to these main sequential processes, each stage of the process lifecycle included energy utilization. Allocation is not necessary in this case study because it is a single output process. In order to simplify the study, materials and emissions less than 0.01% of the functional unit were not included in the study. Production, maintenance and disposal of machinery and buildings as well as their environmental burdens were also excluded from the study. Non-material values, economic aspects, and human resources were also not considered.

Two dimensions of impact analyses were carried out: absolute impact analysis and comparative/relative impact analysis. The absolute impact analysis examined the potential environmental impacts of the recycled paint production on its own. The comparative analysis assessed the recycled paint production process in relation to avoided disposal and avoidance of the need to produce same amount of new virgin paint to replace the disposed old paint.

The comparative/relative impact analysis aspect of this study was based on the average composition, resource use and emissions from the various brands of residual latex paints used as input by the company.

Environmental impacts of packaging, distribution and disposal from the paint recycling process were excluded on the premise that new virgin paint production would require the same number and type of packaging. It was also reasoned that environmental impacts of distribution would be the same for the new virgin paints as well as for the recycled paint. This is because the company has the same client base. So, the impact would be the same if the company is to manufacture and/or distribute the same amount of new virgin paints that they are recycling. Furthermore, it was assumed that no other ingredient is added to the old paint materials in producing the recycled paint.

2.3. Lifecycle Inventory

Inventory data compilation was implemented by using database included in Simapro 7.2 software. Process specific data used for the analysis was collected from the paint recycling company. The primary data on material and energy use as well as solid waste emissions was collected from the company in 2011. Secondary data was obtained from literature and eco-invent database. Table 1 is a sample of inventory data for the paint recycling process. This conformed to the recommendation in [18].

2.4. Impact Assessment

Five categories of impact were considered for each dimension of the two impact analyses. The impact categories are global warming potential (GWP), ozone depletion potential (ODP), photochemical ozone creation potential (POCP), acidification potential (AP), and eutrophication potential (EP). All the inventory data that could be found on the available conversion tables and that are greater or equal to 100 mg were mapped into the affected impact categories. 100years time horizon conversion data were used for the characterization of inventory data for global warming and ozone depletion potentials. Conversion factors for average of three European countries were used for the POCP while maximum oxygen conversion data were used for eutrophication potential assessment.

3. Results and Discussion

This study was carried out to determine whether it is more environmentally sustainable to recycle latex paint than disposing it off in a landfill or not. Tables 3 and 4 showed the summary of lifecycle impact analyses of the inventory data collected for this task. Figure 3 showed the percentage contribution of each recycling process stage to individual impact category. Although there were LCA reports on paints, no report was found on LCA of latex paint recycling process that these results can be compared with[20, 21]. In addition, this study was not aim at process comparison. The following interpretation of the study results was based on ISO 14043.

3.1. Interpretation

The standard (ISO 14043) stipulated a three step process for LCA results interpretation: (i) identification of environmentally significant issues from the inventory data and from the lifecycle impact assessment results, (ii) evaluation of those significant issues, and (iii) drawing conclusion from the evaluated significant issues.

3.1.1. Identification Of Significant Issues

In determining environmentally significant issues, Carbon dioxide was found to be the most significant substance emitted. From the impact assessment table (table 2), it was discovered that global warming which causes climate change is the most significant environmental issue in the paint recycling process. The method and the data used for this study were evaluated and found to be consistent with the requirements of ISO 14040s.

3.1.2. Evaluation

Consistency and completeness of the LCA analysis steps taken were evaluated and they were found to be in conformity with the ISO 14043 standard. This was followed by evaluation of the contribution of each process stage to various impact categories. Figure 3 showed percentage contribution of each recycling process stage to various impact categories. One could see from table 3 that distribution stage of the process has an overwhelming influence on the total potential global warming impact of the process. Packaging is another stage of the recycling process that contributes most significantly to ozone depletion potential and photochemical ozone creation (i.e. photochemical smog) potential of the process.

3.1.3. Environmental Savings

To determine whether it is environmentally better to recycle than to dispose off residual latex paint in the landfill, the difference between total impact of landfilling the residual paint (EI_L) and the impact of the latex paint recycling process (EI_{RP}) was calculated. A lower value of EI_{RP} than EI_L showed that it is better to recycle than to landfill the paint. This calculation was done for each impact category. The results of the environmental costs and benefits calculation are in Table 3. The negative values indicate environmental benefits.

These results showed that recycling latex paint by the process brings significant savings in global warming and photochemical smog impacts. Moreover, the results also showed that recycling latex paint by the process leads to slight increase in eutrophication impact.

Table 1. Samples of Inventory data for the paint recycling process

Data category	Substances	Unit	Quantity
Air Emission	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	mg	62.422246
Air Emission	Ethane, dichloro-	mg	16.916128
Air Emission	Ethane, hexafluoro-, HFC-116	mg	105.33392
Air Emission	Ethanol	mg	457.85147
Air Emission	Ethene, chloro-	mg	2.755309
Air Emission	Ethyne	mg	97.778655
Air Emission	Methane, bromotrifluoro-, Halon 1301	mg	402.67409
Air Emission	Methane, dichloro-, HCC-30	mg	1.5286144
Air Emission	Methane, tetrachloro-, CFC-10	mg	4.2406896
Air Emission	Methane, tetrafluoro-, FC-14	mg	948.00532
Air Emission	Methane, trichlorofluoro-, CFC-11	mg	2.3633944
Air Emission	Methanol	mg	554.26237
Air Emission	Acetic acid	g	1.0406542
Air Emission	Benzene	g	39.607146
Air Emission	Benzene, ethyl-	g	2.2740594
Air Emission	Butane	g	78.048095
Air Emission	Butene	g	25.573004
Air Emission	Dinitrogen monoxide	g	335.09789
Air Emission	Ethane	g	23.853359
Air Emission	Ethene	g	775.88079
Air Emission	Formaldehyde	g	1.838449
Air Emission	Heptane	g	17.961586
Air Emission	Hexane	g	37.782941
Air Emission	Methane	kg	5.6203882
Air Emission	Nitrogen oxides	kg	32.189457
Air Emission	Sulfur oxides	kg	7.8781966
Raw materials	Baryte, in ground	kg	4.5590617
Raw materials	Bauxite, in ground	kg	9.690721
Raw materials	Clay, bentonite, in ground	kg	1.3143554
Raw materials	Clay, unspecified, in ground	kg	19.773079
Raw materials	Coal, 18 MJ per kg, in ground	kg	193.12426
Raw materials	Coal, brown, 8 MJ per kg, in ground	kg	107.61832
Raw materials	Gas, mine, off-gas, process, coal mining/kg	kg	1.4600093
Raw materials	Iron, in ground	kg	97.440142
Raw materials	Lead, in ground	kg	3.0827645
Raw materials	Marl, in ground	kg	105.16653
Raw materials	Sand, unspecified, in ground	kg	2.8753678
Raw materials	Sodium chloride, in ground	kg	41.46825
Raw materials	Wood, dry matter	kg	9.5688289

Table 2. Contribution of each process lifecycle stage to different impact category

Process Lifecycle Stages	Environmental Impact Categories			
	Global Warming (GWP) kg CO_2-eq	Ozone Depletion (ODP) kg CFC 11-eq	Photochemical Smog (POCP) kg C_2H_4 -eq	Eutrophication (EP) max kg O_2 -eq
Old paint transfer	13952.4	0.00504	1.0334	198.151
Sorting/ inspection	6402.7	0.00939	20.2009	52.46
High speed mixing	1220.9	0.00021	0.02711	7.90668
Filtration	732.5	0.00013	0.01627	4.74401
In-storage tank mixing	87.708	1.60E-05	0.00203	0.59324
Packag-ing	16444.5	0.02751	59.8931	141.647
Distri-bution	62772.9	0.02320	4.75451	907.159
Disposal	21147.2	0.01239	20.9182	168.956
Gross env. impacts of the process	122760.7	0.07789	106.846	1481.62

Table 3. Monthly environmental savings from the recycling process

Process Lifecycle Stages	Environmental Impact Categories			
	GWP kg CO_2-eq	ODP kg CFC 11-eq	POCP kg C_2H_4 -eq	EP max kg O_2 -eq
Env. impacts of the process (excluding packag'g & distrib'n)	22396.2	0.01479	21.2797	263.86
Monthly env. savings from metal & plastic recycling	-31,113.48	-0.0232	-16.44	-184.78
Monthly env. savings from latex paint recycling instead of disposal	-61.905	-5.02E-05	-2963.6	-6.5267
Monthly env. savings from latex paint recycling instead of producing virgin paint	-61.905	-5.02E-05	-2963.6	-6.5266
Total env. savings by avoiding landfill disposal, avoiding producing equivalent amount of virgin paint and carrying out container recycling	-31237.3	-0.02	-5,943.6	-197.83
Net monthly env. benefits of paint recycling	-8,841.1	-0.01	-5,922.3	66.02

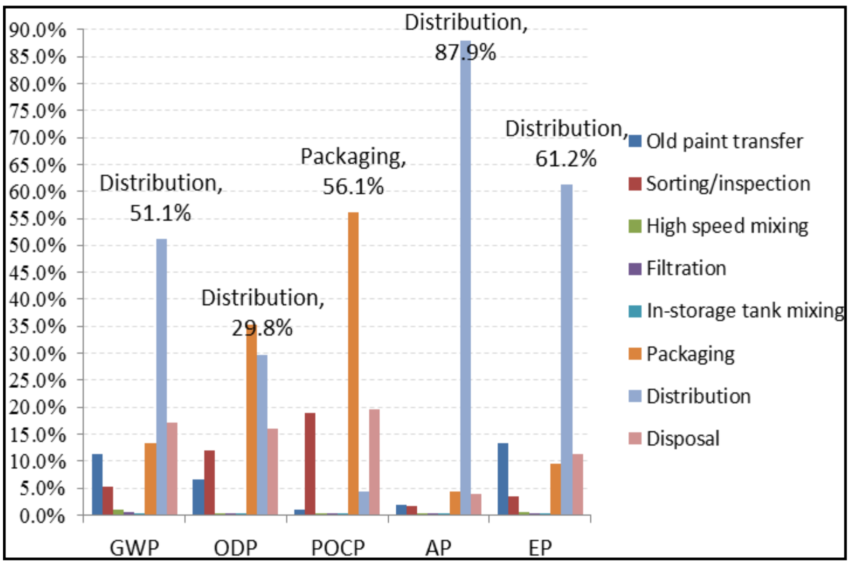


Figure 3. Percentage contribution of each process stage to individual environmental impact

4. Conclusions

Considering various stages of the process across the four impact categories shown in Table 2, there is no one single process stage that have the most significant impact across the board. Packaging, distribution and disposal process stages are the three stages that require more urgent attention. This conclusion was based on the significance of their impact potentials in most of the impact categories. Recommended improvements for this process are reuse of recycled paint packaging containers, exploration of possible alternative onsite use of old paint fraction that is disposed off in the landfill, and alternative transportation method for the distribution of the recycled paint. Results of this work showed that paint recycling process has appreciable global warming potential which could cause climate change. Furthermore, it showed that paint recycling is not only economically wise but it is also ecologically beneficial. Recycling old paint has lower ecological footprint than sending old paint to the landfill for disposal and producing the same amount of virgin paint in replacement.

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