Life cycle analysis and recycling of tires

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Abstract

*To achieve sustainable development of the environment, we have to consider the product lifecycle and its signature. One of the most important materials is the wasted tires. It is known that Egypt is hosting at least about 7 Million cars, if the average waste of the car is 1.5 tires a year, then we have at least 10 Million tires every year, wasted. So, before we consider an element or a product, we have to carry out a lifecycle assessment. To conduct the study, we used the SimaPro version 7.1 LCAsoftware" System for Integrated Environmental Assessment of Products", after collecting the waste tires there are different ways to treat them depending upon the end. Tires are now considered a resource instead of being waste because of their different applications and high value relative to the recovery cost.In analyzing the economics, the tire profit equation can be used***P= F+ R-C-T-D***= O + $1.84-$0.50-0-$0.08= $1.26 per tire. Thus the annual gross profit from the operation is $1.26 x 4.5 million tires= $5.7 million per year.Dividing the gross profit into the $38 million capital cost of the plant yieldsPayback Period= ($38million /$5.7million)=6.7years. The suggested main reusing and recycling of scrap tires are: produce reclaimed rubber , cement kilns, replace virgin martial, (children s playground) surface and tracks, soil amendment for sports turf , road construction and civil engineering purposes for construction.*

In conclusion , the current study proved that the implementation of energy and waste management systems assists in environment protection and achieved a number of direct cost saving , the most important environment impacts can be determined and quantified .

1-**Introduction**

Today in Egypt, there are 30 M tires and 2 M are recycled every year,Hough carbon emissions occur. It is therefore required to carry out assessment of the lifecycle of waste tires to identify which stages are most important sources of emissions .It is important to note that in comparative (LCA) studies, it is not the products themselves that form the basis for the comparison, but the function provided by these products. The tire played a significant role in our life and also in the component in the vehicle.

1.1 Relationship between poverty and environment

Zaman et al (2015) studied the relationship between poverty, population growth and environment. During a period of 1975 to 2009. The results show that rapid population and air pollution has a significant contributor to poverty. However, the results nullify the conventional view that poverty is a major cause of environmental degradation (or air pollution), while the result supports the hypothesis that population have a deleterious impact on increasing poverty. The results further conclude that there is a stable long-run relationship between populations. The results of causality test show that there is a unidirectional causal flow from population to carbon dioxide emission.

Tabassum (2004) examines the relationship between economic growth and income inequality both at aggregate and regional level using more comparable data set for 69 developing countries over the period 1965-2003. The study identifies credit market imperfection in low-income developing countries as the likely reason for a strong negative relationship between income inequality and economic growth. While in short run the relationship between growth and income inequality is positive but over time more income inequalities reduce economic growth. Moreover, Acharyya (2009) examines two most important benefits and costs of foreign direct investment in the Indian context - GDP growth and the environment degradation during 1980 to 2003. The findings show there is statistically significant long run positive relation, but marginal, impact of FDI inflow on GDP growth. While the long run, growth impact of FDI inflow on CO2 emissions is quite large. The finding has some far-reaching implications for the global environment as well, with India having emerged as the fourth highest in the global ranking of CO2 emissions by turn of this century. On the other hand in context of Government polices if targeted towards low income people, basic primary and agricultural education, this would promote the basic income level of poor people by employment and thus lowers the income inequality and poverty ascertaining positive impact and relation as well in income inequality and poverty (Taylor, et al 2012).

In 1991, concerns over the inappropriate use of LCAs to make broad marketing claims made by product manufacturers resulted in a statement issued by eleven State Attorneys General in the USA denouncing the use of LCA results to promote products until uniform methods for conducting such assessments are developed and a consensus reached on how this type of environmental comparison can be advertised non-deceptively. This action, along with pressure from other environmental organizations to standardize LCA methodology, led to the development of the LCA standards in the International Standards Organization (ISO) 14000 series (1997 through 2002).

1.2 Producing reclaimed rubber

Vladimir et al. (1991) reported that Reclamation of scrap tires is a process of dehumanisation of crumb rubber for the manufacturing process of scrap tires**.**The rubber is vulcanized by using sulfur providers and different other methods for improving the dynamic properties of tiers and prevent the tires from cracks. However, the use of sculpture makes the tireless heat resistant. The reclamation process the tires are shredded to a crumb rubber of suitable size, and then steel and fiber are removed by magnetic separator and fiber separator after rubber the separation of steel and fiberThe rubber is more groud to offender size and then mixed with different reclaiming agent depend upon their function and reaction with the process reclamation of Grand rubber is done by different

2. Materials and Methods

Technicality of tire industry Tire industry is one of the heavy chemical industries which need significant investments. This is to the rapid technical developments which lead to the use of automatic mechanical and electronic machinery for producing tires and sometimes remote control systems. In spite of the fact that manpower has its great effect on the product quality and productivity but the vast developments in tire machinery and equipment has a significant effect in decreasing labor numbers needed for the modern tire industry.

2.1 Recycling Techniques In the materialRecycling process, the tires are shredded and the rubber and steel fractions are separated. The remaining rubber is granulated before use in modified bitumen for asphalt and as an infill the rubber fraction is incinerated in a cement kiln and the steel fraction is recycled. By recycling, several processes such as production of synthetic rubber are avoided. In the co-incineration process, whole or shredded tires are fed into the cement kiln and Incinerated this not only provides a source of energy, but iron from the steel component of tires also contributes to the process. By co-incineration, energy production from other fuels and extraction of iron ore are avoided.A change from co-incineration to recycling implies an increased demand for other fuels and iron ore in the co-incineration route, whereas the emissions occurring from Incineration of tires is avoided.

2.2 LCA is a holistic methodology that allows the investigation of environmental impacts and resource use caused by each of the processes that are part of the two tire treatment options. LCA takes into account the substitution of other materials (bitumen, polymer) that would be used in rubber asphalt and as an infill if the tires were not recycled, or the energy sources that would be used in cement kiln if tires were not used as a fuel.The environmental impacts identified in an LCA are assessed by calculating the results for a broad range of impact categories. The results are always expressed as *potential* impacts since the *actual* impact from, for example, emissions of CO_2, can only be quantified exactly if and when it actually happens. In this study, the environmental impact categories covered are:Global warming potential expressed in kg CO_2-equivalents. Greenhouse gases such as carbon dioxide and methane can cause climate change. Acidification potential expressed as g SO_2-equivalents. Acids and compounds that can be converted to acids emitted to the atmosphere can cause regional damage to ecosystems as a result of acid rain.Toxicity potential (carcinogenic risk) expressed as mg arsenic equivalents. Chemical substances can cause cancer in humans and animals. Toxicity potential (acute human toxicity: PM101) expressed as g PM10- equivalents. Small dust particles can cause respiratory diseases. Photochemical ozone creation potential expressed as g ethylene equivalents.Solvents and other volatile organic compounds react with nitrous oxides and form smog which is detrimental to human health as well as ecosystems. Furthermore, two indicators are used to describe the use of resources:The impact within each category is calculated for both recycling and co-incineration using information on the inputs and outputs of each process included in the analyzed system. All impacts are expressed per ton of tires.

2.3 Life cycle impact assessment

(i) Soft Wareto facilitate the study, we used the SimaPro version 7.1 LCA software developed by PRé Consultants. The SimaPro software name comes from the full title “System for Integrated Environmental Assessment of Products”,SimaPro features user interface that allows the environmental inventory of any Product or process to be modeled by specifying inputs (resources, fuels, electricity) and outputs (emissions to air, water, and soil, etc.). Each component of every phase of product's life can be modeled separately and then combined to form a complete model of the entire life cycle. These components, such as raw materials production or disposal routes, can either be developed as new data sets by the user or existing pre-packaged databases that contain detailed environmental inventory data for thousands of products and Processes across the world can be used. These databases (BUWAL, IDEMAT, Franklin USA, etc.) are developed by environmental professionals and are peer reviewed to assure confident data sets describing any potential environmental impact of a process, but each data set is usually geographically specific and may differ if the process is being modeled in a different country.

(ii)Cost-benefit economic analysisin analyzing the economics of tire utilization, it is helpful to consider each situation where cost data are available in terms of the profit per tire. Entrepreneurs will launch a tire processing facility only if the potential profit per tire is high enough. The profit per tire may be computed from the equation shown below:

P= F+ R-C-T-D

Where : **P** is the profit per tire,**F** is the tipping fee collected per tire,**R** is the revenue received per processed tire,**C** is the processing cost per tire for operating the facility,**T** is the transportation cost to bring in tires and **D** is the disposal cost for waste products.

In the sections of this chapter where data are available, the various options for processing tires into fuel are analyzed in terms of this tire profit equation. Clearly, to motivate entrepreneurs, there must be a positive profit per tire for any feasible utilization method. If the equation yields a negative value (a loss) then the private sector will not use such a utilization method, and the tires will stay where they are. Not only must there be a profit, but it must be high enough to give a good return on the invested capital to build a plant or buy equipment. A rough method of analyzing the return is to calculate the simple payback period using the equation shown below.

3. Result and Discussion

3.1Life cycle impact assessment The used method in the current study as an indicator for climate change, eco-toxicity, carcinogens and respiratory inorganic impacts was "Eco-indicator 99(E) V2.06/Europe EI 99 E/E" .it in clouds impact categories which cover the most important environmental issues. the eleven impact categories taken into consideration as compiled by the Eco- indicator 99 methodology were :global warming potential(GWP) represented by climate change, Acidification potential (AP),Eutrophication Potential (EP) , Carcinogens Potential (CP), Eco-toxicity Potential (ETP), Respiratory Inorganic Formation Potential (RIFP),Respiratory organic Formation Potential (ROFP), Radiation Potential (RP), Ozone Layer Depletion (OLD), Minerals Depletion (MD0, Land Use(LU)and Fossil Fuels Depletion (FFD).this impact categories are grouped in three group: impact on human health , impact on ecosystem quality and impact on resources . As for fossil fuels depletion the used methodology was 'Cumulative Energy Demand (CED)". The evaluation of the impact categories were expressed I mega points (mpt) to evaluate the impact of a product or process, more points mean worst environmental burden (Goedkoop et al., 2008).After collecting the waste tires there are different ways to treat them depending upon the end Tires are now considered a resource instead of waste because of their different applications and high value relative to the recovery cost.Recycling of scrap tires (waste);

3.2 The suggested main reusing and recycling of scrap tires are:

i. To produce reclaimed rubber
ii. As TDF in cement kilns
iii. To replace virgin martial
iv. For (children s playground) surface and tracks
v. As soil amendment for sports turf
vi. In road construction
vii. For civil engineering purposes for construction

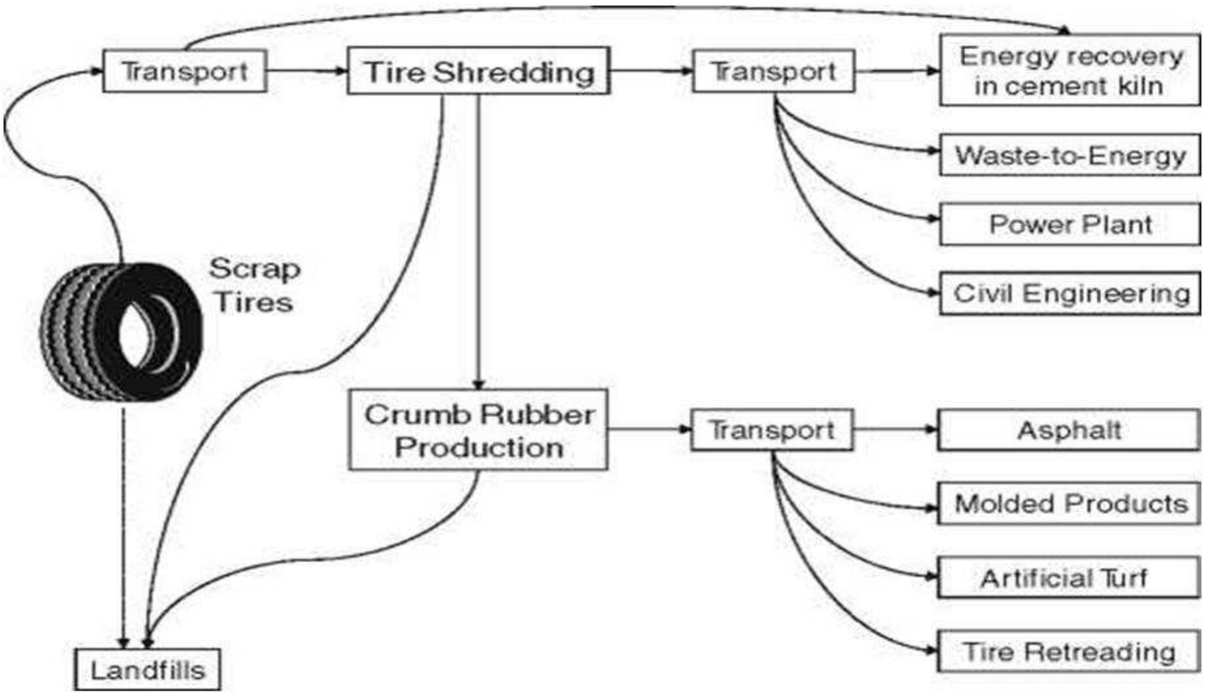

Figure (1) showe the alternatives end of life pathway for tires

3.3 Negative impact : Although the recycling and reusing of scrap tires have several or many benefits as mentioned before, it also has negative impact an attempt to summarize all negative impacts as follows:Open burning of tires produces many toxic gasses which are extremely harmful theenvironment and human health. The burning of tires releases benzene, lead, polycyclic aromatic hydrocarbons (PAH), dioxins and furans.

3.4 IN case of non-recycling, of scrap tires (waste)

(i) Alternatives of non-recycling : It can be summarized that if we do not adopt the recycling and reuse of scraped tires as mentioned before, several disadvantage and negative impacts on the environment as follows:

3.5 Negative impact Excessive burning of wastes can generate pollutants such as sulfur oxides (SOx) and nitrogen oxides (NOx), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), and dioxins/furans, which potentially could contribute to environmental problems, like acidification, human toxicity, and ecotoxicit That is why modern incinerators must be equipped with pollution controls Systems to minimize these harmful emissions. These pollution control technologies' are capable of removing up to 90% of NOx emissions and 99% of the toxic metals and acid gasses.Other-burning of waste tires in an open field results in the pollution of air, soil, surface water, and possibly groundwaterReginald B.H. Tan and HsienH.Excessive burning of wastes can generate pollutants such as sulfur oxides (SOx) and nitrogen oxides (NOx), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), and dioxins/furans. This pottentially contribute to environmental problems, such as acidification, human toxicity, and Eco toxicity Khoo reported that these pollution control technologies are capable of removing up to 90% of NOx emissions and 99% of the toxic metals and acid gases

3.6 Biological Treatment
(i) Biodegradable wastes. Many types of air pollution have significant negative health and environmental effects. Therefore, the reduced amounts of NOx, SOx, and toxic metals will place the country in a better position for achieving environmental protection and health
(ii) Life cycle assessment of tires, Environmental impact of manufacturing

LCA for the tire industry was based on the international organization for standardization Environmentalmanagement – Life Cycle Assessment-Principals and frameworks (ISO14040:2006) and international organization for standardization: environmental management – life cycle assessment – requirement and guidelines (ISO14044:2006).

3.7 Goal and scope definition: The present LCA analyzed the impact of tires manufacturing on the environment starting from obtaining the raw material till the end of the production process. Inagreement with Tobler (2000)LCA of textile process depended on water and energy management of the company, therefore focus was given to water consumption, energy utilization in tires production and generated waste from the industry as shown in figure (2)

Figure (2) : LCA system boundaries of the rubber industry

3.8 Inventory Analysis: LCA of the rubber industry started with systematic inventory of all resource consumption and emissions during the product's entire life cycle. All input and output data used in this study are presented as follows (1)

3.9 The input which taken into accounts were:

I. Chemicals that are used as raw martial the production process
II. Treated water used
III. energy sources

3.10 The outputs were

i. the end product of tires
ii. liquid waste
iii. solid wastes
iv. energy losses

3.11 Life cycle impact analysis

i. **Emissions to air**The raw emissions life cycle totals can be helpful though to begin determining which product is more environmentally friendly overall. Summing up each of the emissions in Table shows that a tire achieving the design target would produce 13 kg less CO_2, 48 g less CO, 10 g less N_2O, but 6 g more SO_2. These totals establish the tire as generally less harmful regarding these emissions, but as with comparing the use phase to the Production phase, the collected entire inventory must be considered to determine which product has a smaller environmental load most accurately.

ii. **Energy consumption :**The energy inputs for rubber curing presses have been recorded and analyzed by tire manufacturers, and the average Tire curing process requires about 1.1 kWh of energy for a tire weighing 10 kg, whichmeans roughly 0.11 kWh of energy is Needed to vulcanize 1 kg of rubber.At the early stages of Tire manufacturing, Michelin is using the same type of Press that is used to cure radial tires, so it is assumed in this analysis that the same energy will be required to cure 1 kg of Rubber in a tire as 1 kg of pneumatic tire rubber. The thickness of rubber in these two products varies slightly, but the curing temperature and time is close enough to assume the same energy requirements per kg of rubber. So, the required energy to cure the shear band in the Tire isroughly (6.35 kg)*(0.11 kWh/kg), which equals 0.7 k.

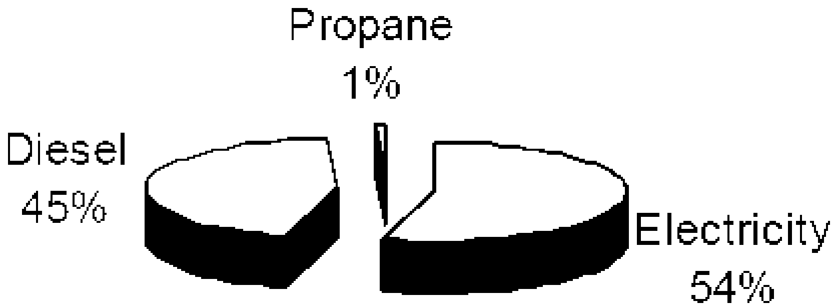

Figure 3: Ful sources of rubber tire recycling

By combining all of the stages from "cradle to grave," a picture of the overall environmental effects of the entire lifecycle can be assembled. This life cycle analysis presents theenvironmental impact of one tire or Tire beyond simply the energy required to manufacture either.

To facilitate the study, we used the SimaPro version 7.1 LCA software developed by PRé Consultants. SimaPro features a user interface that allows the environmental inventory of any product or process to be modeled by specifying inputs (resources, fuels, electricity) and outputs (emissions to air, water, andsold waste, etc.). Each component of every phase of aProduct's life can be modeled separately and then combined to form a complete model of the entire life cycle. These components, such as raw materials production or disposaloutes can either be developed as new data sets by the user or existing pre-packaged databases that contain detailed environmental inventory data for thousands of roducts and processes across the world can be used.

LCA result in figure show the impact of rubber manufacturing on different environmental categories. Fossil fuels depletion is the highest category affected by the manufacturing process, followed by human respiratory system due to inorganic substance used in the industry .potential impact was also noticed on climate change, acidification /eutrophication potential. Eco toxicity and smallest impacts were on cardings potential .no impacts were detected on radiation, ozone layer depletion, land use, minerals depletion or human respiratory system due to organic substances. The reasons for not detecting any impact on the previous categories is that the process of rubber manufacturing does not use any radiation elements not generated any substances that may affect the ozone layer , not uses large land areas in production . Furthermore, no organic substances are used in manufacturing process and the raw materials used in process are chemical compounds from petrochemicals, no minerals are use

3.12 End of life

Since the polyurethane can be separated from the rubber tread in a tire at the end of its life, this analysis assumed both materials will be disposed of separately, which simplifies the environmental assessment to a combination of rubber (whole tire tread) and polyurethane treated separately. The national average disposal route (i.e., landfill, tire derived fuel, civil engineering purposes, tire recycling) percentages for both materials were analyzed individually and then combined in the appropriate weight percentages for both a conventional and a tire. Considering the rubber first, the tread separated from a tire (done through a specified heating method) is assumed to have the sameMaterial properties and composition as rubber from a tire in order to group both rubber sources together for simplification. The tread from a tire has no wires and thus will produce no scrap metal upon grinding, but all other properties are assumed to be equal.

In analyzing the economics, the tire profit equation can be used. The buy-back rate of 8.3 cents per kilowatt-hour means that each tire consumed will generate revenue of $1.84 from the sale of electricity to the utility. For tires coming from the on-site tire pile, F = O, since there is no tipping fee and T = O, because there is no transportation cost. We estimate that C = $0.50, the processing cost per tire for operations, maintenance, labor, and materials. The estimate of the net disposal cost per tire of fly ash, gypsum from the scrubber, and bottom ash (taking into account the sales of byproducts) is D = $0.08. Substituting these values into the tire profit equation yields the following results:**P= F+ R-C-T-**

D= O + \$1.84-\$0.50-0-\$0.08= \$1.26 per tireThus the annual gross profit is \$1.26 x 4.5 million tires= \$5.7 million per year. Dividing the gross profit into the \$38 million capital cost of the plant yields Payback Period= \$38million/\$5.7 million = 6.7years.

Conclusion

In conclusion , the current study proved that the implementation of energy and waste management systems assists in environment protection and achieved a number of direct cost saving , the most important environment impacts can be determined and quantified . the established systems in this study can be implemented in different industries.

4. Research limitations and direction for further research

Further studies are require two investigateusage of energy from industrial wastes is renewable energy sources.

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