International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:7, No:5, 2013

Analysis of Rubber Waste Utilization at Pandora Production Company Limited

S. Pechpoothong and M. Kopystecki

***Abstract*—**The eco-efficient use of "waste" makes sense from economic, social, and environmental perspectives. By efficiency diverting "waste" products back into useful and/or profitable inputs, industries and entire societies can reap the benefits of improved financial profit, decreased environmental degradation, and overall well-being of humanity.

In this project, several material flows at Pandora Production Company Limited were investigated. Principles of "industrial ecology" were applied to improve the management of waste rubbers that are used in the jewelry manufacturing process. In order to complete this project, a brief engineering analysis of each waste stream, and investigated eco-efficient principles for more efficient handling of the materials and wastes were conducted, and the results were used to propose implementation strategies.

***Keywords*—**Rubber, ecology, waste.

I. Introduction

THE jewelry manufacturer Pandora Production Company Limited uses rubber as well as silicon rubber from the supplier Castaldo® for mold casting. In average one rubber mold is used about 150-200 times before being useless and disposed. Under the current operating conditions, Pandora Production Company Limited is paying a service provider for transferring the scrap rubber and landfilling it. Recent data indicates that approximately 14 tons of waste rubber was produced during the last 6 months with disposal costs of 126,000 THB (EUR 3,150) or 21,000 THB (EUR 525) per month. We are assuming an average accumulation of scrap rubber of 2.3 tons per month.

With ecology efficiency concern, Pandora Production Company Limited has invested in a continued studying and researching for the better alternatives solution in managing rubber scrap. The company has absolutely unlike their own current landfill method of rubber scrap management. The following chapter will suggest different possibilities to reduce the environmental impacts of the rubber usage in the Pandora Production Plant. Herein we will explain the negative impacts of landfilling and discuss other approaches of handling the scrap rubber in more environment friendly and eco-efficient manners.

Sarisa Pechpooghong is with the Suan Sunandha Rajabhat University, Bankok, Thailand (Phone: +668-4126-1155; fax: +662-587-7826; e-mail: khunsarisa@yahoo.com).

Martin Kopystecki is an exchange student at Mahidol University, Nakorn Pathom, Thailand. (Phone +4917-6380-42075; e-mail: m.kopystecki@tu-harburg.de).

A. Objectives and Scope

The primary objectives that were used to guide the research process include:

1. Identify the life cycle flow of rubber waste.
2. Suggest the best feasible alternatives for improving the efficient management of rubber waste.

The scope of the research included the following specifications to keep the project within reasonable bounds:

1. For rubber processes: only current waste management in terms of current practices, location of disposal site, costs are considered.
2. The study area was the Pandora Production Company Limited.

II. Methodology

A. Data Acquisition

In order to obtain data, the manufacturing site has been visited for several times, one questionnaire was submitted to Pandora Production Company Limited, and relevant journal articles have been reviewed. This information was compiled in order to understand the characteristics of wastes, identify waste streams, and propose feasible solutions.

B. Analysis of Rubber Waste

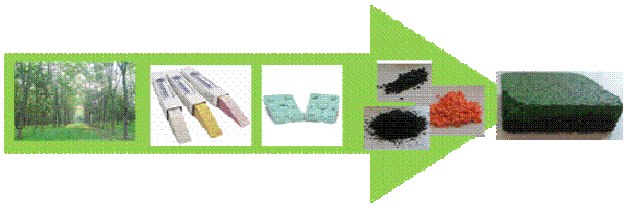

Fig. 1 Rubber for Pandora Production Company Limited - From the ground to the mold casting back to the ground

C. Literature Review

In a previous study, Adhikari [1] claims most of the waste rubber is disposed by landfilling which needs a very long time for natural degradation due to the cross linked structure of rubbers and their mixed-in additives like stabilizers. This is considered as a waste of valuable rubber which also causes environmental pollution. The two major approaches to dispose waste rubber without polluting the environment are the recycle and reuse of it as well as the reclaim of rubber raw materials.

According to the direct reuse of waste rubber, Adhikari divides the applications in two major fields. The first field is the use of crumb rubber in civil engineering applications like playground surface, athletic turf, parking lots, bank

stabilizations or fills under road surface. The largest market is rubberized asphalt which offers many advantages like greater elasticity which leads to less prone to cracking and aging. The second major field is the use of cryogenically ground rubber in the production of hoses, belts, tires, wire, cable, and in lot of other products. [1]

According to the reclaiming of waste rubber Eldho Abraham [2] states in his research work titled "Recent Advances in the Recycling of Rubber Waste", many reasons why waste rubber should be reclaimed or recovered include:

- Recovered rubber can cost half that of natural or synthetic rubber,
- Recovered rubber has some properties that are better than those of virgin rubber,
- Producing rubber from reclaim requires less energy in the total production process than does virgin material,
- It is an excellent way to dispose of unwanted rubber products, which is often difficult,
- It conserves non-renewable petroleum products, which are used to produce synthetic rubbers,
- Recycling activities can generate work in developing countries,
- Many useful products are derived from reused tyres and other rubber products,
- If tires are incinerated to reclaim embodied energy then they can yield substantial quantities of useful power. In Australia, some cement factories use waste tires as a fuel source,
- Reclaiming of scrap rubber is, therefore, the most desirable approach

The main reasons for their use are price and improved processing of rubber compounds.

Yi Fang [3] identifies common application for waste rubber which is recycling it as fuel or incinerating it directly. Lee and Azzam [4] introduced with their patent an environmental friendly process for recycling rubber waste materials to generate valuable fuels or chemical feedstock in a closed oxidation process which is free of hazardous emissions.

Ecological impacts resulting from the production of fresh rubber have been analyzed by Jawjit et al. [5] in their recent study with the title "Greenhouse Gas Emissions from Rubber Industry in Thailand". The results show that if emissions from land conversion are included (logging forest and converting to rubber plantations) the annual greenhouse gas emissions from rubber plantations are about 6.4 ton CO2-eq/ton fresh latex/year. If excluded, which can be assumed in SEA since most of the plantations are about 60-80 years old, the emissions are about 0.2 ton CO2-eq/ton fresh latex/year of which 60% (117 kg CO2-eq/ton fresh latex/year) from the production of raw materials, and 40% (82 kg CO2-eq/ton fresh latex/year) from the plantations. Nowadays there exist no greenhouse gas emission standards for rubber production.

D. Approaches for the Reduction of Environmental Impacts of Rubber Usage Pandora Production Company Limited

One tool to increase the level of sustainability in a production is "waste prevention". Reducing the mold size or using one mold more often than in the present situation (which is 150 to 200 times) would lead to a decrease of rubber consumption as well as the amount of waste rubber. Both ideas are hard to realize since they are dependent on other manufacturing issues like mold cutting techniques or products offer of the supplier Castaldo®. To increase the ecological efficiency of the mold casting production the tools "clean technology" (CT) and "industrial ecology" (IE) are applied in the following approaches. We want to illustrate that there are more eco-efficient alternatives for waste rubber disposal then the actual one Pandora Production Company Limited is using which is landfilling. The three major recycling approaches are directly reusing (IE) the waste rubber (just physical treatment like milling); reclaiming then reusing it; and recycling it for energy production (CT). All these recycling approaches are in contrast to landfilling value adding and so preferable Fig. 2 gives an overview of all these approaches and highlights our favorite one.

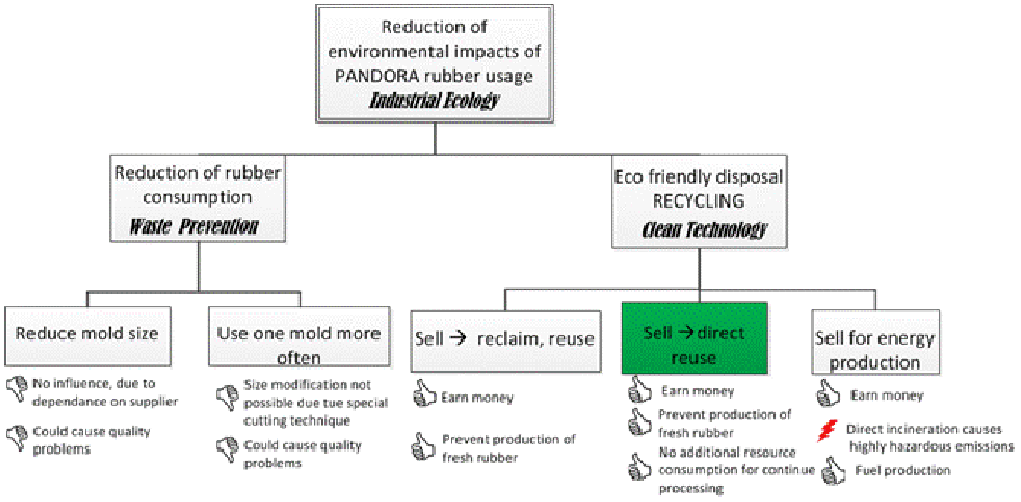

Fig. 2 Approaches to reduce environmental impacts of Pandora Production Company Limited's rubber usage

III. Analysis

A. Negative Impacts of Landfilling

Polymeric materials don't decompose easily. That's why the disposal of waste rubber is a serious environmental problem. With the decreasing amount of available sites and due to the corresponding increasing costs this way of waste rubber disposal is no longer practicable and has no sustainable future …By landfilling the waste rubber no value is added to the waste material. Because of the implicit cost of transporting the material to the landfill site; preparing maintaining the landfill to satisfy environmental requirements there are further cost caused [2]

To get specific attributes like stability, color etc. different additives were mixed together into rubber during compounding. When disposing the waste rubber for landfilling small molecular weight additives leach from bulk to the surface and from surface to the environment, which are not eco-friendly and may kill useful bacteria in the soil. In this way landfill can causes serious environmental problem [1].

B. Waste Rubber Recycle

1. Reclaiming and Reuse

Reclaimed rubber, as the advanced form of rubber recycling, is the most scientific, rational and popular approaches to the rubber recycle business. "Reclaiming of scrap rubber products is the conversion of a three dimensionally interlinked, insoluble and infusible strong thermoset polymer to a two dimensional, soft, plastic, tackier, low modulus, processable, and vulcanizable essentially thermoplastic product simulating many of the properties of a virgin rubber. Recovery and recycle of rubber from used and scrap rubber products can, therefore, save some precious petroleum resources as well as solve scrap/waste rubber disposal problems" [1].

Although reclaimed rubber is a product of discarded rubber articles it has gained much importance as additive in various rubber article formulations. It is true that mechanical properties like tensile strength, modulus, resilience, tear resistances etc. are all reduced [6] with the increasing amounts of reclaim rubber in fresh rubber formulation. But at the same time the reclaim rubber gives many advantages if incorporated in fresh rubber.

By the middle of 1980s less than 1% of the worldwide polymer consumption was in the form of reclaim whereas at beginning of 20th century it was about 50%. It is expected that in the 21st century most of the scrap rubber will be recycled in form of reclaim because of the day to day increase in environmental awareness [1].

2. Direct Reuse

Rubber can be broken down or milled and formed into an entirely new product, such as playground surfacing. This is the most desirable kind of recycling since it doesn't require any more resources for continues processing. The rubber is just cut in smaller pieces and reused directly. That's a main reason that this alternative has been searched is searching to get the waste rubber of Pandora disposed.

3. Recycling Energy as Fuel

Incinerating waste rubber produces energy used for manufacturing processes, electricity or other purposes. This direct burning causes highly hazardous emissions. That's why this kind of recycling should be avoided and will not be taken under concern as a recommendation for Pandora Production Company Limited.

But environmentally friendly processes exist for recycling rubber waste materials (mainly waste tires) to generate valuable fuels or chemical feedstocks in a closed oxidation process which is free of hazardous emissions [4] [7].

IV. Application of Recycled/Reclaimed Rubbers

A. Ground Rubber in Civil Engineering Applications

The market for ground rubber also referred to as sized-reduced rubber or crumb rubber has been growing over the past several years. In the ground rubber market there are two classes of particle sizes: "ground" rubber (10 mesh and smaller) and "coarse" rubber (larger than 10 mesh, with a maximum size of one-half inch) [8].

Large amounts of crumb rubber are used for civil engineering projects [9], such as playground surface, parking lots, bank stabilization, fill under road surface and asphalt modifier. The largest market for reclaimed rubber is rubberized asphalt which offers many advantages. Roads paved with rubberized asphalt have greater elasticity and are less prone to cracking and aging. Because of this, maintenance and replacement costs are reduced [10]. Rubberized asphalt roads are also safer because they offer more skid resistance, which allows drivers to come to a stop more quickly. In addition, this material also helps buffer road noise, reducing it by 5 decibels.

1. Floor Surfaces

"Using Recycled rubber for flooring is attractive and durable. It has long been a staple in commercial and educational buildings. Recently, new designs and colors have made it popular with residential architects and designers as well. A 30-year life cycle is typical for a recycled rubber floor. Rubber floors do not need to be sealed or waxed because their durable surface is nonporous. Since strong cleaning products and waxes are not needed for rubber floors indoor air quality improves" [11].

2. Outdoor Surfaces

"Ground rubber is increasingly used for trails, athletic turf, mulch, and playground surfaces. Ground rubber is sometimes used around playground equipment, or it is made into pre-cast tiles and mats that are installed around the equipment. This rubber surface cushion falls and makes the playground safer. Likewise, ground rubber adds a shock-absorbing component to athletic fields and running tracks. Ground rubber is also cost-effective, clean, durable and less likely to compact than traditional materials. Rubber mulch can also be applied around landscaping. It requires less maintenance since it doesn't break down like traditional wood-chip mulch. It can be installed over existing substrates safely, like gravel" [5].

B. Uses of Cryogenically Ground Rubber

Cryogenically ground rubber is used in the production of hoses, belts, tires, wire, cable, and in lot of other products [1].

V. Saving the Environment by Recycling

Every use of direct/reclaimed rubber serves as a replacement for fresh. The production of every kilogram of fresh rubber is linked with greenhouse gas emissions.

More than 70% of the global rubber plantations are located in South East Asia (SEA). PANDORA's supplier Castaldo® is also purchasing latex sap of rubber trees grown on plantations in the rain forests of South East Asia. If emissions from land conversion are included (logging forest and converting to rubber plantations) the annual greenhouse gas emissions from rubber plantations are about 6.4ton CO_2-eq/ton fresh latex/year. If excluded, which can be assumed in SEA since most of the plantations are about 60-80 years old, the emissions are about 0.2ton CO_2-eq/ton fresh latex/year of which 60% (117 kg CO_2-eq/ton fresh latex/year) from the production of raw materials, and 40% (82kg CO_2-eq/ton fresh latex/year) from the plantations [5]. However, it should be noted that this assumption could be underestimated to some extent (e.g. see for instance [12]). Nowadays there exist no greenhouse gas emission standards for rubber production.

VI. Conclusion and Recommendation

In this chapter we want to give recommendations for Pandora for future research and potentially viable solutions for the actual Rubber/Silicone waste

As illustrated above there are other more environmental friendly approaches for waste rubber disposal then landfilling which is the actual solution of Pandora Production Company Limited. The most environmentally friendly recycling concept is to use the waste rubber directly for new products because this is, in contrast to landfilling, value adding usage with the lowest resource consumption for continuous processing (e.g. milling). In addition there are also financial saving benefits. In the actual situation, PANDORA PRODUCTION COMPANY LIMITED has to pay their service provider for picking up the waste rubber and landfilling it. Forwarding the waste rubber to a recycling company would not only save these costs (which are around 126,000 THB or 3,150 EUR for 14 tons rubber in the last 6 months) but also create profit by selling.

To make a further step towards sustainability, to increase positive marketing as a "green" company, and to decrease financial costs associated with waste disposal, we recommend Pandora Production Company Limited to collaborate with a recycling company which is making a direct use of the waste rubber. To this end, one possible service partner who is located close to the production plant of Pandora Production Company Limited (60-90 min. by car) "Rubber Recycle Company Limited" is cutting the waste rubber and converting it to outdoor surfaces like athletic turfs or playground surfaces as well as indoor surfaces like rubber under layer for fitness center floors.

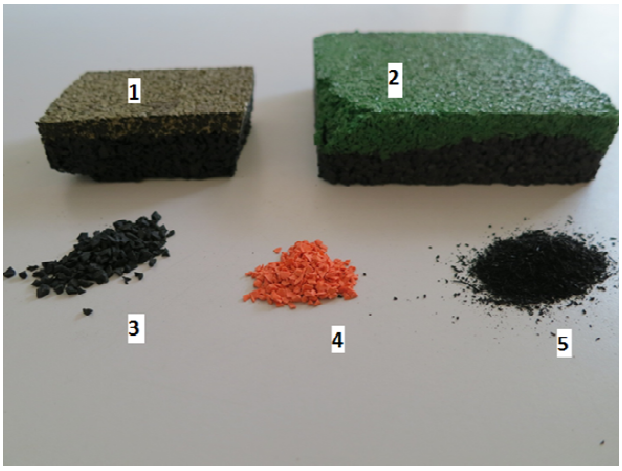

Fig. 3 Products of a rubber recycling company
1. Tile consisting of one homogeneous waste rubber layer, painted on the surface (purpose for indoor use) 2. Tile made of two different waste rubber layers-the bottom layer was consisting of waste rubber while the top one consists of fresh rubber (purpose for outdoor use) 3. Waste rubber from synthetic rubber after grinding process (purpose for the bottom layer of indoor tiles) 4. Fresh rubber after grinding process 5. Waste of natural rubber after grinding process

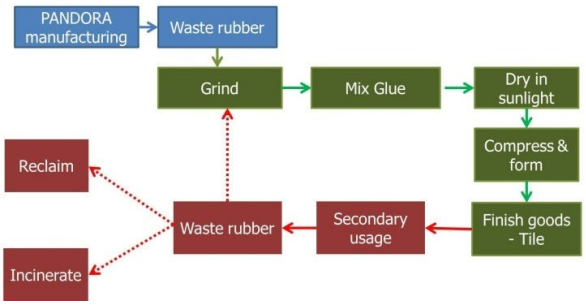

Fig. 4 the continued recycling processing of PANDORA's waste rubber

The recycle of waste rubber generated from the Pandora Production Company Limited manufacturing line can be done by Rubber Recycle Company Limited, a recycle company, cuts the waste rubber into small pieces, and then grind those small pieces. Afterwards the grinded waste rubber is mixed with special glue and compressed into the wished forms. At the end, the finished rubber forms need to be dried in the sunlight for a week. Final products are tiles or floor surface which can be used for either indoor or outdoor area. The tiles or floor surfaces are sold. After the rubber flooring is worn out and needs to be replaced, it can be probably brought again to the Rubber Recycle Company Limited for recycling. Otherwise the waste rubber can be reclaimed or incinerated. In this way there is a possibility for a multiple recycle of the same waste; this alternative creates a link among Pandora Production Company Limited, Rubber Recycle Company Limited and other households which can be considered as an "Industrial Ecology System". The result is a reduction of negative impacts to the environment by rubber usage of

Pandora Production Company Limited.

ACKNOWLEDGMENT

The project was together carried under International Masters Program in Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, Mahidol University. The study was completely done with an excellence support of resources from Pandora Production Company Limited and from Dr. Trakarn Prapapongsa, the project supervisor and lecturer at the Department of Civil and Environment Engineering, Mahidol University.

REFERENCES

[1] Adhikari, B., De, D., & Maiti, S. (2000). Reclamation and recycling of waste rubber. Progress in polymer science, vol.21, S. 9011-912.
[2] Eldho Abraham, B. M. (2011). Recent advances in the recycling of rubber waste. Kerale, India: Transworld Research Network.
[3] YI Fang, M. Z. (2000). The status of recycling of waste rubber. Materials & Design, S. 123-127.
[4] Lee, S., Azzam, F., & Kocher, B. (1996).Patentnr. 5,516,952. U.S.A
[5] Jawjit, W., Kroeze, C., & Rattanapan, S. (2010). Greenhouse gas emissions from rubber industry. Journal of cleaner production, 18, S. 403-411.
[6] Hong, S., Hwang, S., Choi, J., & Choi, H. (December 2006). Compatibility Effect of Reactive Copolymers on. Applied Polymer Scince vol.101, S. 1188-1193.
[7] Adkins, L. (1997). Patentnr. 5,618,852. U.S.A.
[8] Agency, U. E. (14. November 2012). www.epa.gov. Von http://www.epa.gov/osw/conserve/materials/tires/ground.htm abgerufen
[9] Dong, S., & Sapieha, S. (1991). ANTEC 91: In search of Excellence [49th Annual Technical Conference]. Montreal: Society of Plastics Engineers.
[10] Stutz, J., Donahue, S., Cotter, A., & Mintzer, E. (12. May 2003). Recycled Rubber Products in Landscaping Applications.Tellus Institute. Von http://www.epa.gov/wastes/conserve/tools/greenscapes/pubs/rubber.pdf abgerufen
[11] Fudge, C. (November 2006). The Green Benefits of Recycled Rubber. Buildings Magazine.
[12] Danielsen, F. B. (2009). Biofuel plantations on forested lands. Double Jeopardy for Biodiversity and Climate Conservation Biology, 23(2).