" To stride into the future before it arrives!"

Waste Tire Disposal Methods

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It was identified that waste tire disposal can become a huge problem in the rubber industry in time to come.We, at the TWC are trying to help the industry by introducing the available technologies related to waste tire disposal, so that the industry can adopt whichever is approprite.

As a rule of thumb, the scrap tire generation in industrialized countries is approximately one passenger car tire equivalent (PTE, 20 lbs., 9 kg) per population and year. The most obvious hazard associated with the uncontrolled disposal and accumulation of large amounts of tires outdoors is the potential for large fires that are extremely detrimental to the environment. It is commonly believed that recycling has gained momentum, especially in the case of rubber recycling. The technology to turn a potentially hazardous waste product (i.e., scrap tires) into a valuable resource is now available .The scrap tire processing industry is growing rapidly, as the number of discarded tires increases, landfill capacity diminishes and environmental pressures mount.

Potential Uses

Waste tires can be ground and used:

- In asphalt for paving streets and highways
- As a low weight, high volume fill for septic systems
- As playground cover
- As drainage and fill materials in highway applications

Waste Tires can be shredded and used as:

- Mulch in flower beds
- Landfill liners and daily covers

Whole waste tires can be used:

- In retaining walls
- As artificial reefs and breakwaters

Rank	Processing Method	Examples
1	Use PRODUCT for its originally intended purpose as long as possible.	Design rubber compound and tire geometry for maximum durability. Keep tire properly inflated at all times to ensure maximum service life. Reuse partly world tires. Regroove or retread tire casings.
2	Use MATERIAL for its originally intended purpose.	Grind scrap tires into crumb rubber, separate steel and fiber. Sell rubber as raw material.
3	Use whole scrap tires for energy recovery.	Burn whole scrap tires as fuel supplement in cement kilns.
4	Use mechanically processed tires for energy recovery.	Tire chips added to coal as fuel supplement in power plants, paper mills, cement kilns, etc.
5	Alter the chemical structure of scrap tires and use the products for energy recovery.	Pyrolysis, Supercritical Extraction.
6	Storage for possible recovery at a later time.	Monofilling.
7	Disposal without any current or future use.	Landfilling.

Table 3: **Scrap tire disposal methods, ranked by environmental preference.**

Rubber Recycling

A concise definition of recycling would be *the re-use of a material for its originally intended purpose, e.g. old aluminum cans are used to make new ones.* In the case of scrap tires, recycling would mean the use of recycled tire rubber as a compounding ingredient for new tires. In a broader sense, recycling is referred to as grinding scrap tires into crumb rubber while removing steel, fiber and other contaminants. In North America, the markets and applications for recycled tire rubber ("crumb rubber") have developed tremendously in the past decade.

Rubber Recycling Methods

Chemical Methods

- Reclaiming
- Chemical probes
- Catalysis
- Grafting
- Dissolution by o-dichlorobenzene

Advantages: low cost compared to virgin rubber

Disadvantages: time consuming, contaminated with some hazardous compounds, additional sludge disposal problem, poor mechanical properties such as green strength, toughness and tensile strength

Mechanical Methods

- Ambient grinding (up to 10 phr)
- Thermo mechanical grinding (up to 20 phr)
- Cryogenic grinding (up to 40 phr)

Disadvantages : relatively large particle size and hence poor mechanical properties, high cost of grinding with improving fineness

Wave Methods

- Microwave Technique – only for polar rubbers
- Ultrasonic Technique

The tire recovery technology -"Redox"

Rodex is an integrated approach that involves separating tires into their component parts, modifying and recovering the material and re-intergrating the output into parts manufacturing. The flexible system separates the crumb rubber, steel and fibre, all of which can be reused or sold in the market. A proprietary technology modifies granulated rubber into a new higher value material, that is partially depolymerized rubber, for use in place of virgin rubber. The environmentally friendly walls buffer the noise and no emissions are released into the atmosphere. Rodex has also developed technology to fabricate rubber casings for maintenance holes and catch basins from recycled tyres. The rubber frame is precast to a steel reinforced concrete ring and the entire assembly is mounted directly on the maintenance hole structure. Each frame utilizes rubber from about seven used tires. It is a longer lasting alternative to the conventional concrete frame and also helps reduce stockpiling of used tires.

New rubber devulcanization process

Levgum Ltd. has developed a means of recycling rubber tires and rubber waste using a new chemical modifier which produces a dry chemical reaction and does not emit dangerous chemicals into the atmosphere, cause hazardous sewage nor is toxic to the environment. With Levgum's new rubber devulcanization process, the price of one ton of non-subsidized, recycled rubber is significantly less expensive than one ton of virgin rubber, thus encouraging rubber producing companies to use a larger quantity of recycled rubber in their products. After two years at GreenTech, Levgum's patent pending modifier has been successfully tested and is ready for marketing. Licensing agreements are available for the modifier, and Levgum has been approached by companies from the United States, England, Canada, India and Bulgaria.

Advances in Industrial Energy-Efficiency Technologies

Waste tires are accumulating in dumps at the rate of about 190 million pe year, adding to the existing inventory of 2 billion to 3 billion. These huge dumps of waste tires represent an enormous repository of lost energy, materials, and money. Yet today's methods of recycling or reusing tires barely put a dent in the waste tire inventory. About 20% of the energy used to make a tire can be reclaimed through incineration, but the material properties of the rubber are lost.

A new, cost-effective method of using scrap tire rubber would help open up a new market for the waste, displacing energy-intensive materials such as virgin rubber andRealizing that such a method could provide substantial energy savings while reducing the waste tire inventory, industry proposed new research ideas for funding by the U.S. Department of Energy (DOE). These proposals have resulted in a 3-year partnership between DOE's Office of Industrial Technologies (OIT) and Air Products and Chemicals, Inc. The aim of research was to create a composite material of old rubber and new rubber or plastic that had good mechanical properties - a feat that had not been possible because of the poor bonding characteristics of old rubber. The cost-shared research resulted in a novel method of treating waste rubber to allow it to be mixed with polyurethane and other polymers. The treatment method reduces the inertness of the rubber, improving its bonding characteristics.

The result is a polyurethane-rubber composite that can contain up to 40% recycled rubber without any significant loss in mechanical properties.The method works by exposing the rubber to reactive gases in a proprietary process. The process causes the surface of the rubber to become chemically active. Air Products' engineers tested a mixture of the treated rubber with polyurethane; the rubber formed bonds with the plastic that were stronger than the rubber itself.

Scrap tires yield fuel

In the United States, the University of South Alabama has licensed a new tire recycling technology, developed at the United States' College of Engineering, that could yield more that 12 million barrels of synthetic crude oil per year . Compared with conventional recycling precesses, the supercritical fluid tire recycling technique produces 20-30 per cent more oil and is 40 per cent cheaper.

Tire Derived Fuel (TDF)

The use of tire derived fuel (TDF) in cement kilns, paper mills or power plants is a perfectly reasonable use for scrap tires, if recycling is not a viable option. While uncontrolled fires cause substantial air and ground pollution, the incineration of whole tires or tire chips in a controlled furnace is environmentally safe. On average, the BTU value of scrap tires or TDF exceeds that of coal, while the sulfur content is in the same order of magnitude or even lower. Cement kilns are by far the largest users of TDF. Some cement companies have the capacity to incinerate whole tires, thus being able to omit the comparatively expensive size reduction process.

Pyrolysis of Waste Rubber

Pyrolysis of rubber is an old concept. It has been found that the heat content of rubber tire is greater than that of coal. Therefore, used tires can be used as a fuel source. However, environmental aspects need to be addressed since the gases emitted may contain acidic compounds and heavy metals.

The "Foster Weeler pyrolysis" technology[1] is a process in which, used, shredded tires are heated in the absence of air to produce a light fuel oil, solid fuel and high grade steel. Hot gases (600 °C) containing no oxygen are passed through the bed of tires causing pyrolysis to occur. Oil in the vapour phase is condensed and collected in the quench column. Remaining gases either fuel the process or are recycled through the reactor. Solid products are continuously removed from the reactor.

According to one research, limonene, the main ingredient in the oil of lemons and other citrus fruits, can be obtained from used tires. When shredded tires are fed into an airless reactor set at about 725 °C, a thick dark oil containing polyisoprene seeps out. Then the polyisoprene is heated and vaporized, breaking into individual isoprene molecules.

The vaporized isoprenes, rather than reforming into the long, complex polyisoprene chains, naturally tend to bond together in simple pairs to form limonene.This tire juice may find applications in lemon-scented soaps and cleaners and even as a flavoring in sodas.

A waste tire pyrolysis technique has been developed for commercialization at the Sumitomo Cement Co. Ltd., in Japan[4]. In this process there is a possibility of some zinc being discharged into the atmosphere in vapor form. Zinc is recoverable at a high temperature of over 1700 °C. However, zinc removal at low temperature of 800 °C, has been patented.

In this process waste tires inserted into cartridges are fed into the pyrolysis furnace from the upper part with a hoist crane. First heavy oils is combusted upon heating. Within 60 minutes of commencement of combustion, the furnace temperature rises to 160 °C and a vaporized gas is generated and it is used partly as a fuel, and combustion is continued. The waste tires are completely decomposed in about 3 hours. One ton of waste tires provides 350-450 kg of heavy oil with a calorific value of 10,450 kcal, 340 kg of carbon black and 150 kg of iron scrap. About 90 kg of the generated oil is used as fuel.

There are several pyrolysis processes available, namely
1). Molten salt pyrolysis 2). Atmospheric, inert gas pyrolysis
3). Vacuum pyrolysis 4). Flash pyrolysis 5). Thermal plasma pyrolysis

The scarp tires can produce approximately 55% oil, 10% gas, and 35% char. The gases emitted have been identified as a mixture of H_2, CO, CO_2, CH_4, C_2H_6 and C_4H_6 with lower concentrations of other hydrocarbon gases.

Rubber Recycling - "Delink"

A novel process that can devulcanize rubber to a point where it regains up to 80% of its virgin properties has been patented in Malaysia. This new recycling technology offers a commercially viable solution by reducing production cost by eleminating waste. The recycled rubber can be added to virgin rubber to obtain various rubber products without any major change in the quality of products. In this process a compound called "Delink "is added in pellet form to the ground waste rubber or crumb rubber, mixed in shearing machines for 10 minutes at room temperature.This result in "Devulc " sheets of rubber stripped of its latex origins. The non-toxic odorless Delink is required in small amounts-2.5 parts for every 100 parts of rubber waste. About 1 Kg of rubber waste can be converted into reusable form at a cost of about US$ 0.66

Waste Tires in Paving Applications

- Waste tires can be ground and used in a variety of paving applications.
- This ground tire product is also known as Crumb Rubber Modifier (CRM).
- CRM can be blended into hot liquid asphalt, resulting in what is known as Asphalt-Rubber Binder (ASTM D8 and D6114).
- Asphalt Rubber Binder can be used in traditional Hot Mix Asphalts, crack sealers, Open Graded Friction Courses, Stress Absorbing Membranes, and subgrade seals.

Production of rubber pavements

A highly versatile product that can be used for school and private playground coverings, track runways, athletic centers and weight rooms, throughout commercial workshops, agricultural uses, sidewalks, hiking and walking trails as well as golf cart paths and landscaping projects. Current tire reuse technologies offer a considerable opportunity to generate valuable materials from what is essentially worthless scrap. Considering all of potential markets for crumb rubber as polymer filler, the one with the greatest potential is the production of rubber pavements.

This new asphalt has improved settling characteristics, resistance to fatigue, and resistance to thermal cracking. The asphalt also has better high-temperature viscosity and the curing time reduced by half compared to traditional crumb rubber blends.

The obvious benefit of adding rubber to asphalt is that the rubber imparts elasticity to the binder, which helps the pavement fatigue and resistance, as well as reducing reflective cracking. The increased flexibility decreases the pavement's susceptibility to low-temperature cracking. Rubber-modified pavements have been shown to improve skid resistance even under ice conditions. Crumb rubber also has been found to increase the tensile strength, toughness, ductility, and thus durability of the pavement.

Activated carbons produced from waste tire rubber

Waste tire rubber has proven to be a suitable precursor for the production of high quality activated carbons. The performance of these carbons in commercial applications such as water treatment or gas purification is highly dependent on their surface characteristics. This paper presents an in-depth investigation of how production conditions may affect the yield and characteristics of activated carbons produced from tyre rubber.For this purpose, three tire rubbers of different particle sizes were consecutively pyrolysed and then activated in a steam atmosphere at 925 øC using a laboratory-scale rotary furnace. Activation was conducted at different intervals over 80-640 min to achieve different degrees of carbon burn-off.The resulting carbons were analysed for their elemental composition, ash content and nitrogen gas adsorption characteristics.

The BET and t-plot models were used to investigate various aspects of their porosity and surface area characteristics. SEM analyses were also conducted for visual examination of the carbon surface. Results show that pyrolytic chars, essentially mesoporous materials, developed a very narrow microporosity during the initial stages of the activation process (up to 15-25 wt. burn-off). Further activation resulted in the progressive enlargement of the average microprobe width and a gradual development of the mesoporous structure. Total microprobe volumes and BET surface areas increased continuously with the degree of activation to reach values up to 0.498 cm3g-1 and 1070 m2g-1 respectively, while external surface areas developed more rapidly at degrees of activation above 45 wt. burn-off. Results presented in this work also illustrate that carbons produced from powdered rubber developed a narrower and more extensive porosity, both in the microprobe and mesopore range, than those produced from rubber of a larger particle size.

Granulate rubber slabs

The tires are chopped into granular fragments; metal particles are removed and the granules are then graded for their requirements and rebonded in moulds with a special resin to form the very strong, dry, safe and hard wearing one metre square slab. These slabs will give years of use. The slabs have 'feet' which form a honeycombed underside.

The honeycomb design permits air flow and drainage of fluids under the slabs; fluids are also able to pass through the special crumb construction of the slabs, which helps keep a dry surface. New slabs have a wax residue, which will disperse after a few days under normal use. To see the drainage properties of the rubber sample, the wax can be removed by washing with any water based washing-up liquid; then pour some water over the slab and see it run through.

Example of use includes horse stable/boxes and animal pens for this type of applications the high quality 45mm (1_") thick honeycombed slabs are used with these a vast reduction in bedding material can be obtained. This is unlike other types of thinner virgin (solid) rubber mats, which still require bedding, and are not as warm, hard wearing or dry. Reduced bedding saves on the cost of the material, labor and disposal of the used bedding. Total cost is under œ1.95 per week. (Based on 12 x 12 stable with 14 slabs and 5 years use).

CONTINUOUS ULTRASONIC DEVULCANIZATION OF VULCANIZED ELASTOMERS

This invention relates to a continuous ultrasonic method for selectively breaking the carbon-sulfur (C-S), sulfur-sulfur (S-S), and if desired, carbon-carbon (C-C) bonds in a vulcanized elastomer. It is well known that vulcanized elastomers having a three-dimensional chemical network, cannot flow under the effect of heat and/or pressure. This creates a hugh problem in the recycling of used tires and other elastomeric products. Through the application of certain levels of ultrasonic amplitudes in the presence of pressure and optionally heat, the three-dimensional network of vulcanized elastomer can be broken down. As a most desirable consequence, ultrasonically treated cured rubber becomes soft, thereby enabling this material to be reprocessed and shaped in a manner similar to that employed with uncured elastomers. To date, the following materials have been processed using this technology: Ground Tire Rubber (GTR), tire buffings, EPDM, Nitrile, Butyl, SBR, Ethylene Vinyl Acetate (EVA), fluoroelastomers, and silicon. Other materials will continually be added to the list in the future. This experimental processing permits the requestor to evaluate the chemical, physical, and mechanical properties after ultrasonic treating. Experimental processing information is held confidential and the requestor is not required to disclose recipe details.

Civil Engineering Applications

Tire derived products, " tire chips are sometimes used to replace conventional construction material, e.g., road fill, gravel, crushed rock or sand. The benefits of using tire chips instead of conventional construction materials are amongst others: reduced density, improved drainage properties and better thermal insulation.

The examples such as lightweight fill for embankments and retaining walls, leachate drainage material at municipal solid waste landfills, alternative daily cover at municipal solid waste landfills , insulating layer beneath roads and behind retaining walls are some projects where scrap tire chips have been successfully used in civil engineering applications. Civil engineering applications of scrap tires are expected to become more widespread as more and more applications can be proven to be technically and economically viable.

Landfilling

Most landfills accept whole scrap tires only at a hefty tipping fee because tires are awkward to handle and difficult to compact. In some instances, scrap tires have worked their way to the top of a closed landfill, causing costly damage to the landfill cover. Nonetheless, a significant part of the current scrap tire generation still ends up in landfills. Since a ban on landfilling whole tires was implemented in most States, scrap tires are usually cut into pieces or shredded before landfilling in the U.S. A variation of landfilling is **monofilling**, which means that scrap tires are not mixed with other waste materials, but stored at a dedicated, licensed location. Once the monofill has reached its capacity, it is covered like any other landfill to reduce the fire hazard and also prevent mosquito breeding.

Export and Miscellaneous

From an environmental standpoint, the use of a waste material for its originally intended purpose is the most preferential recycling method. The active international trade with used tires, mostly going from industrialized countries to lesser developed countries, is a clear sign that this route of disposal is economically sensible well. It is a fair assumption that at least 10% of scrap tires generated in industrialized countries are sold as used tires, especially to in Eastern Europe, Africa & Latin America.

The Technology Watch Centre (TWC) was established in May 2001 at the National Science Foundation (NSF) under the Ministry of Economic Reforms, Science and Technology, funded by the ADB Science and Technology Personnel Development Project, with a view to acquiring information on technology, screening for relevancy and applicability and disseminating it to the local industry.

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