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Recycled Rubber Products in Landscaping Applications

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Abstract

Rubber from scrap tires is a waste material that is ideal for use in landscaping applications. By using recycled rubber products, landscapers can create cost-effective, high-quality, and environmentally beneficial projects. The landscaping market is potentially large enough to recover all the scrap tires that are currently discarded in landfills or tire piles.

- 281 million scrap tires were generated in 2001.
- 218 million scrap tires were recovered for beneficial use in 2001.
- Landscaping applications such as playground surface cover, paving, athletic field turf amendment, and running track construction is a potential market for 1,990 million scrap tires.
- Benefits from using recycled rubber in landscaping projects include project cost savings, and improved product performance and safety. Greenhouse gas and public health benefits result from diverting tires from landfills and tire piles.

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1. Summary of Results

Scrap Tire Supply, Demand, and Potential Use - Scrap tires are generated at the rate of one passenger car tire equivalent per person per year.[1] 281 million scrap tires were generated in 2001. Of these tires, 218 million are used in beneficial applications leaving 63 million to be disposed of in landfills or scrap tire piles.[2] The number of scrap tires discarded in landfills or tire piles represents the supply of rubber that can be potentially utilized in landscaping applications.

Ground rubber, a product that can be made from scrap tires, is used in a variety of landscaping applications (trail and path paving projects, playground surface cover, running track construction, and athletic field turf establishment and maintenance). Currently, ground rubber consumes 33 million tires per year. Potential additional scrap tire consumption as a result of increased use of ground rubber in landscaping applications is estimated at 1,990 million tires. Doubling the use of ground rubber in landscaping applications would be enough to consume both the scrap tires in existing tire piles and those that are generated each year and not consumed by other markets.

Benefits - Using ground rubber in landscaping applications results in significant cost savings from decreased project maintenance and from the benefits related to improved product performance (e.g. safety and/or suitability). Additional benefits from using ground rubber in landscaping applications include benefits related to avoided disposal - space savings (landfill space, land space), reduced risks to human health from tire piles, and avoided emissions from tire pile fires.

Project Size - Ground rubber application rates vary for paving, athletic turf application, and playground surfacing projects. Application rates and conversion factors presented in section 5 of this report can be used by landscapers to develop project specifications.

In the following sections, we explain the current recycled rubber supply and demand structure as well as the potential for using recycled rubber in landscaping projects. Next, we present the benefits of using recycled rubber instead of conventional landscaping materials. The final section, a description of application recommendations and unit equivalents, will aid landscapers in calculating costs and benefits associated with using recycled rubber for a particular project.

2. Current Tire Generation, Recovery, Disposal, and Markets

According to the Rubber Manufacturers Association, approximately 281 million scrap tires are generated each year in the United States. Scrap tire markets (tire derived fuel, civil engineering, miscellaneous uses, export, and products such as ground rubber) utilize 218 million of these tires. The remaining 63 million tires are either discarded in landfills or monofills or stockpiled in

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[1] Reschner, K. *Scrap Tire Recycling*. Online: < http://home.snafu.de/kurtr/str/en.html > (Feb. 4, 2003).

[2] Rubber Manufacturers Association. *Facts & Figures*. Online: < http://www.rma.org/scrap_tires/scrap_tire_markets/facts_and_figures > (Feb. 3, 2003).

tire piles (legally and illegally). Currently, an estimated 300 million tires are stored in above-ground tire piles.[3] Tire piles are dangerous because they provide breeding sites for mosquito vectors of human disease and they pose a fire risk. Tires in landfills are problematic because they take up large amounts of space, do not compact, and can 'float' to the top, potentially damaging or breaking the landfill cap.

State legislation regarding scrap tires was initiated in the 1990's to combat problems related to the disposal of tires in landfills and piles. Currently, scrap tire management is governed by state legislation in all but two states. Many states are actively working to clean up tire piles, 38 states ban whole tires from landfills, and 11 states ban all scrap tires from landfills.[4] More recent amendments to original scrap tire legislation represent a shift in the focus of tire legislation toward reducing the obstacles of developing scrap tire markets. The details of these amendments vary from state to state. For example, Oregon passed legislation to create a Waste Tire Program. The legislation did not ban tires from landfills, but created a $1 fee on each new tire sold at retail. The revenue from this fee was allocated to scrap tire recycling programs. The legislation and the program were successful for several years; recovery rates for scrap tires reached 98%. When one of the major markets for scrap tires (fuel) was eliminated, landfills became the most popular low-cost option for disposal. The scrap tire recovery rate declined, prompting new legislation that supported research into methods for increasing tire recovery, reuse, and recycling.[5] As states reduce tire stockpiles and subsequently shift the focus of their legislation concerning scrap tire management, scrap tire markets will likely be strengthened and encouraged.

As noted above, scrap tires are reused and recycled in a variety of ways. Ground rubber, a product that can be made from scrap tires, currently consumes 33 million scrap tires per year. Ground rubber can be used in landscaping applications, including:

- Loose cover - Ground rubber is used under and around playground equipment to provide a cushioning ground cover.
- Rubber surfacing products - Recycled rubber is used in playground surfacing products (pre-cast tiles and mats and poured-in-place surfacing).
- Paving and surfacing - Asphalt rubber and other recycled rubber surfacing products are made from rubber recycled from tires. Asphalt rubber is made by adding crumb rubber (rubber particles sized ⅜" or less) to asphalt cement to create a binder. The asphalt rubber binder is then mixed with aggregate to create asphalt concrete.[6] The asphalt rubber material can be used in most paving applications. Landscaping use of

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[3] Rubber Manufacturers Association. *U.S. Scrap Tire Markets 2001*. Online: < http://www.rma.org/publications/pdf/US_Scrap_Tire_Markets_2001.pdf > (Dec. 18, 2002).

[4] Rubber Manufacturers Association. *Facts & Figures*. Online: < http://www.rma.org/scrap_tires/scrap_tire_markets/facts_and_figures > (Feb. 3, 2003).

[5] Task Force on Tire Recycling. *Tire Recycling Final Report: Executive Summary*. Online: < http://www.leg.state.or.us/comm/commsrvs/int_tire_executivesummary.pdf > (Feb. 3, 2003).

[6] Federal Highway Administration. *Scrap Tires Material Description*. Online: < http://www.rmrc.unh.edu/Partners/UserGuide/index.htm > (Dec. 9, 2002).

asphalt rubber includes the substitution of asphalt rubber for traditional asphalt in bike path, walking path, and golf course cart path paving projects.

- Turf - Ground rubber is used in turf topdressing applications and incorporated into turf soil.
- Running tracks - Ground rubber is used in running tracks.

The United States Rubber Manufacturers Association annually publishes statistics of scrap tire use. Table 1 shows the 2001 U.S. ground rubber markets classified by application.

Table 1. U.S. Ground Rubber Markets by Application[7]

Application	**Estimated Scrap Tire Rubber Poundage (whole tire generated ground rubber only)**	**Tire equivalent**
Asphalt Rubber*	220 million pounds	20 million tires
Athletic/field turf applications	50 million pounds	4.5 million tires
Loose cover	30 million pounds	2.7 million tires

*Includes asphalt rubber used in all paving projects. This report focuses on the use of asphalt rubber in landscaping paving projects, such as bike and walking paths and golf course cart paths.

3. Current potential use

There is currently strong potential for the use of recycled rubber in landscaping projects. Recreational projects include playground surfacing, athletic field turf, and running tracks. Paving projects include bike paths, walking paths (often the two are combined), and golf course cart paths. Table 2 presents statistics and information on the potential utilization of recycled rubber in landscaping applications. As Table 2 shows, a modest increment in the utilization of ground rubber in landscaping applications has enormous potential for consuming the 63 million tires that are annually disposed of in landfills, monofills and tire piles and the 300 million tires that are already in stockpiles.

[7] Rubber Manufacturers Association. *U.S. Scrap Tire Markets 2001*. Online: < http://www.rma.org/publications/pdf/US_Scrap_Tire_Markets_2001.pdf > (Dec. 13, 2002).

Table 2. Potential Utilization of Recycled Rubber in Landscaping Applications

Location/Site Description	Number in United States	Application Rate	Potential Additional Tire Use (millions)	Notes
Rail-trails	28,300 miles (11,833 miles open, 16, 467 miles proposed or under construction) [8]	615 tires per mile	17.4	From 1998 to 2000, $2.7 billion federal Transportation Enhancements funds were spent on bike and walking path projects (including rail-trails). This represents expenditures for 8,055 projects.[9] The 1991 ISTEA act and the 1998 update made a total of $6.4 billion dollars available to Transportation Enhancement projects.[10]
Golf Courses	17,816[11]	615 tires per mile, 4 miles per course	43.8	At the end of 2001, there were an additional 652 courses under construction and 905 in planning.[12] Most golf courses have an estimated 3 to 5 miles of paths.
Elementary Schools	80,661[13]	5,445 ft^3 crumb rubber per playground, 14 lbs crumb rubber per .5 ft^3	1,118	Potential applications include playgrounds.
Secondary Schools and Colleges	41,184[14]	4,280 tires per track	176.3	Potential applications include athletic fields and running tracks.
Cities and Towns	>35,000[15]	5,445 ft^3 crumb rubber per playground, 14 lbs crumb rubber per .5 ft^3; 4,280 tires per track	634.9	Potential applications include playgrounds, athletic fields, and running tracks.
Total			1,990.4	

[8] Rails-to-Trails Conservancy. *Trail Facts and Information*. Online: < http://railstrails.org/news/trailfacts/natmilcount.asp > (Dec. 18, 2002).

[9] National Transportation Enhancements Clearinghouse. *Transportation Enhancements – Summary of Nationwide Spending as of FY 2001*. Online: < http://www.enhancements.org/misc/tedatafy01.pdf > (Dec. 19, 2002).

[10] National Transportation Enhancements Clearinghouse. *A Guide to Transportation Enhancements*. Online: < http://www.enhancements.org/ > (Dec. 19, 2002).

[11] National Golf Foundation. *Frequently Asked Questions about the Game and Business of Golf in the United States.* Online: < http://www.ngf.org/cgi/whofaq.asp#2 > (Feb. 3, 2003).

[12] Ibid.

[13] Ibid.

[14] National Center for Education Statistics. *Education Statistics at a Glance*. Online: < http://nces.ed.gov/pubs2002/digest2001/tables/dt005.asp > (Jan. 7, 2003).

[15] National Atlas of the United States. *Cities and Towns: Map Layer Description File*. Online: < http://www.nationalatlas.gov/citiesm.html > (Feb. 3, 2003).

While individual project sizes will vary in each location, each elementary school and municipality can be assumed to have at least one playground. Each secondary school, college, and municipality can be assumed to have at least one athletic field and one running track. In smaller communities, these facilities may be shared. In larger communities, the number of facilities will increase to support the needs of the population.

4. Benefits

The use of recycled tires in landscaping applications provides benefits related to cost savings, waste diversion, and in many cases, a better suited product for the application.

Project cost savings

There are a variety of cost savings associated with using recycled rubber products such as asphalt rubber and ground rubber. The initial costs of some recycled rubber products are less expensive than traditional products. In almost all cases, recycled rubber products have a longer lifetime than traditional products, creating decreased life cycle costs from maintenance and replacement savings. Cost savings also result from avoided costs of playground-related injuries (medical and liability costs).

Surfacing materials can be either loose fill or synthetic cover. Loose fill surfacing options include crumb rubber, wood mulch or chips, pea gravel, and sand. Synthetic cover surfacing options include rubber mats, tiles, and poured-in-place surfaces. Recycled crumb rubber, recycled rubber mats, tiles, and poured surfaces all meet ASTM standards for cushioning materials for playground applications. Loose fill surfacing materials have lower initial costs than synthetic cover materials. Of the loose fill materials, crumb rubber has the best shock-absorbing capability, is clean and durable, and is the least likely to compact, which reduces maintenance and replacement costs. A recent research project determined that crumb rubber "can be applied safely on top of existing sand, pea gravel, grass or wood chip surfaces without the costly removal of the old … surface material."[16] As a result, installation costs for such projects are only related to the costs of materials and application. The researchers also surveyed current users of crumb rubber playground surfacing and found that these users were pleased with the safety of the surface and with the small number of maintenance issues compared to other loose fill materials (sand and pea gravel).

Synthetic cover surfacing products have high initial costs due to surface preparation, material costs, and installation. However, the surface requires little maintenance and life cycle costs are low.[17] Unlike loose fill materials, synthetic surfaces such as recycled rubber mats, tiles and poured surfaces do not require multiple applications or installations over time.

[16] Amme RC, Meredith G, Gould N and N Laramie. "Scrap tires in full swing." *Resource Recycling* 22 (March 2003): 32-35.

[17] U.S. Consumer Product Safety Commission. *Handbook for Public Playground Safety.* Online: < http://www.cpsc.gov/CPSCPUB/PUBS/325.pdf > (Mar. 19, 2003).

Cost savings in asphalt rubber projects are due to both a reduction in the amount of asphalt used and decreased maintenance costs. Asphalt rubber projects often use half as much asphalt than is used in traditional paving projects.[18] The California Department of Transportation has created structural equivalencies for overlay (e.g. resurfacing) thickness guidelines. The equivalencies compare asphalt rubber hot mixes to conventional asphalt concrete, and show that less asphalt rubber is needed to achieve the required structure.[19] The decrease in the amount of materials used results in a decrease in the cost of construction. Rubber asphalt has a longer lifetime than traditional pavement and is highly resistant to reflective cracking. The performance-related advantages of asphalt rubber are summarized in Table 3.

Table 3. Asphalt Rubber Performance Factors[20, 21]

Performance Factor	Source of Improved Performance (comparison with traditional asphalt)	Quantification
Resistance to surface initiated cracking	Higher binder content	
Resistance to fatigue and reflection cracking	Higher binder content, binder elasticity	
Resistance to low temperature cracking	Binder elasticity and resultant pavement flexibility	
Resistance to rutting	Higher viscosity over a wider range of temperature, higher softening point	Traditional asphalt temperature range: 136.4° F high, -18.4° F low; Rubber asphalt temperature range: 147.2° F high, -29.2° F low[22]
Lifetime (durability)	Increased tensile strength, ductility, toughness, resiliency, tenacity; Decreased hardening susceptibilities	

[18] Rubberized Asphalt Concrete Technology Center. *Cost Comparisons*. Online: < http://www.rubberizedasphalt.org/cost.htm > (Dec. 16, 2002).

[19] Rubber Pavements Association. *Crumb Rubber Modifier in Asphalt Pavements*. Online: < http://www.rubberpavements.org/library/fp25_ch2.asp > (Dec. 18, 2002).

[20] Hicks, R.G. *Asphalt Rubber Design and Construction Guidelines, Volume 1*. Online: < http://www.rubberizedasphalt.org/ar_design_guide/Vol_1.pdf > (Dec. 18, 2002).

[21] Glover, C.J. et al. *A Comprehensive Laboratory and Field Study of High-Cure Crumb Rubber Modified Asphalt Materials*. Online: < http://tti.tamu.edu/product/catalog/reports/1460-1.pdf > (Dec. 18, 2002).

[22] Curran, R. *Black Art (adding rubber into asphalt to improve asphalt's properties)*. Online: < http://www.p2pays.org/ref/11/10504/html/biblio/asphalt/rat4.txt > (Dec. 18, 2002).

As a result of these performance characteristics, projects using rubber asphalt have reduced maintenance costs. One manufacturer states that substituting rubber asphalt for traditional asphalt in road paving projects decreases maintenance costs by 80%.[23] A Texas Transportation Institute study found that the lifetime of rubber asphalt pavement used on roads needed to increase by 16% in order to cover the additional initial costs of materials and installation. The study concluded that such an extended life was feasible due to the improved performance of the rubber asphalt product.[24]

The advantages of asphalt rubber have resulted in an increased use of the material in highway paving projects. The benefits of asphalt rubber have also been recognized and applied to other types of projects, such as off-road projects. The cost of materials for off-road projects can be decreased in cities where transportation departments are already using asphalt rubber. An example of an off-road project is an overlay of 19 miles of an existing Sacramento bike and pedestrian trail with rubberized asphalt. The Sacramento County Parks and Recreation Department chose rubberized asphalt for the project because it is more flexible and more porous than traditional asphalt. The increased flexibility reduces maintenance costs, and the increased porosity benefits the bicyclists using the path because there are fewer puddles. In addition, bicycle tires grip more effectively on the modified pavement.[25] Bike and pedestrian paths made of asphalt rubber are "smoother and quieter while remaining flexible enough to keep moisture from seeping through to undermine [the path]."[26] Resurfacing projects using asphalt rubber chip seals to control fatigue cracking are more cost effective than conventional chip seals because of their longer performance life.[27] The use of asphalt rubber in off-road paving projects is a new practice that results in cost and performance benefits.

While most bike paths are paved, golf course cart paths can be made with either a paving material (asphalt or concrete) or a loose material (for example, gravel). However, as the purpose of a golf course cart path is "to minimize wear problems and improve aesthetics" on the course, asphalt paths are frequently used because they require much less maintenance than paths made with less stable materials such as gravel or wood-chips.[28] Rubber asphalt can be substituted for traditional asphalt in golf course cart path paving projects to further decrease maintenance costs due to the improved performance factors noted above.

Cost savings in playground surfacing projects also include avoided medical and liability costs of playground-related injuries. According to the National Program for Playground Safety, each year approximately 205,860 children incur injuries on playground equipment. In 1999, 75% of these injuries occurred on public use equipment. Further, "falls to the surface" contributed to

[23] Stratco. *CRM Asphalt*. Online: < http://www.stratco.com/CRMAsphalt.asp > (Dec. 18, 2002).

[24] Texas Transportation Institute. *'Rubber Roads' perform well.* Online: < http://tti.tamu.edu/researcher/v37n1/rubber%5Froads.stm > (Dec. 18, 2002).

[25] Personal Communication. Sacramento County Parks and Recreation Department. Mar. 28, 2003.

[26] Rubber Pavements Association. *Sacramento Bike Trail Cited for Innovative Use of Asphalt-Rubber*. Online: < http://www.rubberpavements.org/newsletter/sum2002/pg6.html > (Jan. 6, 2003).

[27] Rubber Pavements Association. *Cano and Way Brief Federal Agencies.* Online: < http://www.rubberpavements.org/newsletter/fall2002/pg6.html > (Mar. 27, 2003).

[28] Oatis, D. *Common Sense Cart Paths.* Online: < http://www.usga.org/green/download/golf_cource_management/common_sense_paths.html > (Dec. 18, 2002).

79% of all injuries on playground equipment.[29] Cushioning, shock-absorbing surfacing materials are therefore critical to achieving a safe playground area and reducing injury rates. The American Academy of Orthopedic Surgeons determined that "in 2000, playground injuries cost the U.S. $8.4 billion in medical, legal and liability, pain and suffering, and work loss expenses."[30] Because 79% of playground-related injuries result from falls to the surface, it can be estimated that improving the safety of playground surfaces through the use of recycled rubber surfacing products would avoid approximately $6.6 billion in injury-related costs per year.

Product performance - safety and suitability

Using recycled rubber in landscaping products and applications results in a high quality product and project that often has superior performance compared to that of a traditional product. Improved quality and performance often results in decreased maintenance costs, as in the cases of playground surfacing materials and asphalt rubber noted earlier. The following paragraphs describe the suitability of two crumb rubber applications: athletic fields and running tracks. The use of crumb rubber in these applications provides benefits to athletes using the facilities and is a superior product in terms of lifetime and product performance.

The original "all-weather" (meaning durable and suitable in all types of weather) running track was called an asphalt-bound track, and was made of a combination of asphalt and rubber. Temperature affects asphalt-bound tracks; the track material becomes soft in hot weather and hard in cold weather. The track material also hardens over time, and loses its pliability. To counter these problems, tracks made of bound rubber particles were developed. Rubber tracks are more durable than asphalt-bound tracks, and the tracks can be impermeable.[31]

Athletic fields with heavy use can be difficult to maintain. Fields in poor condition present safety hazards and maintenance issues, and unsatisfactory field conditions are not enjoyable for athletes. A horticulturist, listing several attributes of "a good sports field," noted that the field should have good traction and hardness, a uniform smoothness, be unfrozen, and have good cushioning.[32] These characteristics can be achieved and/or improved through the addition of crumb rubber to the field.

There are two methods of incorporating crumb rubber into an athletic field to create an improved playing surface. In the topdressing method, a layer of crumb rubber is sprinkled on top of the turf. This method does not disrupt the field. The benefits of topdressing with crumb rubber are decreased wear on the turf, a lengthened growing season, insulation against frost, and conservation of water through reduced soil compaction. The crumb rubber achieves these benefits because it remains on top of the soil and supports the turfgrass crown area (other

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[29] National Program for Playground Safety. *Playground-related Statistics from the U.S. Consumer Product Safety Commission*. Online: < http://www.uni.edu/playground/resources/statistics.html > (Dec. 18, 2002).

[30] American Academy of Orthopaedic Surgeons. *Playground injuries increase in 2000, surgeons urge playground safety vigilance*. Online: < http://www.aaos.org/wordhtml/press/playgr01.html > (Mar. 27, 2003).

[31] United States Tennis Court and Track Builders Association. *Buyer's Guide for Track Construction*. Online: < http://www.ustctba.com/buyersguide_track.html > (Dec. 19, 2002).

[32] Minner, D.N. *Q & A: What are some characteristics of a good sports field?* Online: < http://www.greenmediaonline.com/st/1998/0298/0298qa.html > (Dec. 19, 2002).

topdressing materials such as sand move into the soil profile, which results in a shorter period of benefits to the grass).[33] The other method of crumb rubber application is to mix the crumb rubber with the soil base layer. Incorporation of the crumb rubber has the same benefits as topdressing. In addition, the method improves the field in the following ways: it retards weed growth, increases cushioning, and decreases the need for fertilizer or pesticides. Furthermore, crumb rubber in soil does not decay and does not attract pests or insects. Most of these benefits contribute to decreased maintenance and a longer lifetime for the turf field, which results in decreased maintenance costs.[34] Some of the benefits increase the cushioning and stability of the field, creating a safer playing surface.

Divert tires from landfills

Landfill space is saved when tires are recycled rather than landfilled. The landfill space benefit from diverting tires from landfills is shown in Table 4.

Table 4. Benefits from Use of Recycled Rubber

Material	**Landfill Space Saved (Ft^3/ton)**
Rubber in tires	225

Divert tires from tire piles

When discarded tires are not disposed of in managed landfills or monofills, they can end up in tire piles. In 2001, there were an estimated 300 million tires in these piles. The piles range in size; for example, Pennsylvania's largest known pile contains 5.9 million tires, and one of California's largest piles (which has been removed) was 40 acres in size and six stories deep. Tire piles take up land space and are unsightly. Further, tire piles are a breeding ground for disease-carrying mosquitoes and a fire risk.

Avoided costs from mosquito diseases generated in tire piles

When tires are piled and not covered, such as in a stockpile, water and leaf littler pools in the tires. The combination of water, decaying leaf litter, and heat (absorbed by the dark colored tires) creates an ideal breeding ground for mosquitoes.[35] Further, interstate shipping of scrap tires can increase the spread of exotic mosquito species.[36] Some of the mosquitoes that are supported by tire piles are disease-carrying insects, such as the species that carries West Nile

[33] Rogers, J.N. III and J.T. Vanini. *Stretching Your Dollars with Crumb Rubber*. Online: < http://www.greenmediaonline.com/st/1997/1097/1097al.html > (Dec. 19, 2002).

[34] Texas Natural Resources Conservation Commission. *The Many Uses of Crumb Rubber.* Online: < http://www.tnrcc.state.tx.us/permitting/r_e/eval/we/tires/crumb.pdf > (Dec. 20, 2002).

[35] Centers For Disease Control and Prevention (CDC). National Center for Infectious Diseases. Division of Vector-Borne Infectious Diseases. *Arboviral Encephalitides*. Online: < http://www.cdc.gov/ncidod/dvbid/arbor/tires.htm > (Dec. 9, 2002).

[36] University of Rhode Island, Division of Agriculture, Department of Environmental Management, Office of Mosquito Abatement Coordination. *Mosquitoes Disease and Scrap Tires*. Online: < http://www.uri.edu/research/eee/tires.html > (Dec. 9, 2002).

virus. There are a variety of costs related to mosquito-borne diseases, including costs of patient medical care and costs of insecticide applications. One source notes, "the EPA estimates that over $5,500,000 is spent each year to combat mosquito borne diseases."[37] Additional costs of hospitalization can range from $21,000 to $3,000,000 per case.[38] Suppressing mosquitoes in tire piles using insecticides is a costly process. It is extremely difficult to reach adult or larval mosquitoes in tire piles because the insects live at the bottom of the pile. The most effective larvicide has a material cost of $2.43 per tire per treatment. Total treatment costs include repeated applications (the treatments are effective for only 7 to 10 days) and costs of application (spraying from a helicopter).[39] The most cost-effective method of reducing mosquito-related disease is to avoid creating tire piles or to eliminate the piles by finding another use for the tires.

Tire pile fire prevention and avoided emissions

Another danger of tires placed in a stockpile is fire. Tire piles can catch fire accidentally, and depending on the size of the pile, can burn for weeks. The fires are difficult to extinguish, produce oil runoff when doused with water, and emit toxic pollutants as they burn. Long-term problems following an open-tire fire include the contamination of soil, groundwater, and surface water. The costs associated with tire pile fires include costs of containing, suppressing, and cleaning up the fire, costs of managing runoff and other contaminants (for example soil contamination) from the fire, and costs associated with any property damage, business interruption, and/or bodily injury related to the fire. The costs of tire pile fires vary – an example clean up cost for a large fire is $3.30 per tire.[40] This cost does not include all of the costs associated with environmental damage from the fire emissions. The airborne emissions and associated health hazards from open tire fires are listed in Table 5. Overall, research has shown that emissions from open air tire fires are "more toxic (e.g. mutagenic) than those of a combuster, regardless of the fuel."[41]

Table 5. Open Tire Fires: Airborne Emissions and Associated Health Hazards[42]

Emissions	Health Hazards
particulates, carbon monoxide, sulfur oxides, nitrogen oxides, volatile organic compounds, dioxins, furans, polynuclear aromatic hydrocarbons, hydrogen chloride, benzene, polychlorinated biphenyls, metals	irritation of skin and eyes, respiratory problems, central nervous system problems, mutagenic, cancer

[37] Rubber Pavements Association. *FAQ*. Online: < http://www.rubberpavements.org/faq.asp > (Dec. 9, 2002).

[38] CDC. National Center for Infectious Diseases. Division of Vector-Borne Infectious Diseases. *Fact Sheet: Eastern Equine Encephalitis.* Online: < http://www.cdc.gov/ncidod/dvbid/arbor/eeefact.htm > (Dec. 9, 2002).

[39] University of Rhode Island, Division of Agriculture, Department of Environmental Management, Office of Mosquito Abatement Coordination. *Mosquitoes Disease and Scrap Tires*. Online: < http://www.uri.edu/research/eee/tires.html > (Dec. 9, 2002).

[40] King County Environmental Purchasing Program. *King County Procurement Bulleting #27: Scrap Tires in Civil Engineering Applications*. Online: < http://www.metrokc.gov/procure/green/bul27.htm > (Mar. 19, 2003).

[41] EPA. *Air Emissions From Scrap Tire Combustion*. (EPA600-R-97-115). October 1997. p.viii.

[42] Ibid.

Other pollutants generated during an open tire fire include those in oil and water runoffs. Table 6 summarizes the typical contaminants contained in oil and water runoff from tire fires.

Table 6. Contaminants Found in Oil and Water Runoff from Open Tire Fires[43]

Runoff Type	Contaminants Present
Oil	Heavy metals, polynuclear aromatic hydrocarbons
Water	Heavy metals, cyanide, polynuclear aromatic hydrocarbons, benzene, zinc, phenol, ammonia

Decreased use of virgin petroleum products

Traditional asphalt is a combination of an aggregate product and a liquid binder (also called asphalt cement). There are different types and compositions of binder products. Traditional asphalt cement is defined as "a black petroleum residue."[44] The bitumens used to make asphalt cement are found in nature and are also obtained in petroleum processing.[45] When recycled rubber is used in asphalt projects, the rubber is added to the binder. The addition of the rubber decreases the overall amount of traditional materials in the liquid binder. Asphalt rubber reduces the amount of virgin petroleum products that are used in asphalt production by decreasing the amount of asphalt cement in the binder material and by decreasing the overall amount of pavement that is used in a project. The amount of petroleum that is saved depends on the characteristics of the traditional asphalt cement and the project size specifications.

5. Project Size

Projects using recycled rubber vary greatly in size and in construction details. Crumb rubber or rubber mats and tiles can be used under playground equipment. Off-road asphalt rubber projects include bike, walk, or golf course path paving or resurfacing. Rubber can also be added to running track surfaces and athletic fields. The following paragraphs present details of various projects using recycled rubber. Landscapers can use the specifications to estimate the amount of recycled rubber required for a specific project and to estimate project costs.

While there is no typical project size for loose crumb rubber or tiles/"poured-in-place" surfacing made from recycled rubber in playground applications, general safety guidelines indicate suggested design guidelines. As one playground equipment company notes, "The total space [of the 'fall zone' under and around playground structures] is dependent on the type of equipment within the play area. However, in general, the [covered] surface should extend a minimum of 6 feet in all directions from the edge of stationary playground equipment. … For standard swings, the minimum fall zone to the front and back is twice the height of the crossbeam. … The fall

[43] Rubber Manufacturers Association. *The Prevention and Management of Scrap Tire Fires*. Online: < http://www.rma.org/scrap_tires/scrap_tires_and_the_environment/fire_prevention.pdf > (Dec. 13, 2002).

[44] Dee Concrete Accessories. *Concrete and Paving Glossary*. Online: < http://www.deeconcrete.com/concreteglossary.html#asphalt > (Dec. 27, 2002).

[45] The Asphalt Institute. *Asphalt Industry Glossary of Terms*. Online: < http://www.asphaltinstitute.org/faq/definitions/definitionsA.htm > (Dec. 27, 2002).

zone at the exit of the slide should extended a minimum of 6 feet from the end of the slide … [and a maximum of] 12 feet."[46] Depth of the loose crumb rubber or thickness of the rubber tile/surface is another component of the design process. These design specifications correspond with safety regulations regarding the drop height of the play area structure (the maximum height where a child could stand). Table 7 presents sample suggested surfacing product depths corresponding with the ASTM requirements for critical fall height.

Table 7. Suggested Surfacing Product Depths Corresponding with Critical Fall Heights

Product	**Fall Height**	**Product Depth**
Crumb Rubber[47]	10 ft	6"
Rubber Tiles[48]	4 ft	1 ¾"
	6 ft	2 ⅜"
	8 ft	3 ⅜"
	10 ft	4"
Pour-in-Place Rubber Surfacing[49]	4 ft	1"
	5 ft	1 ½"
	6 ft	2"
	7 ft	2 ½"
	8 ft	3"
	9 ft	3 ½"
	10 ft	4"

The amount (in pounds or tons) of crumb rubber needed for a specific depth can be calculated using a per unit rate. One company calculates that 1 lb of their crumb rubber product covers a .07 ft^2 area at a depth of .5 ft (or 14 lbs of the product covers a 1 ft^2 area at a depth of .5 ft).[50]

The construction and maintenance of asphalt trails is dependent on a variety of factors, including the anticipated type of trail use and the terrain and climate of the trail site. Design specifications for bike and walking paths are closely related to the anticipated use of the path and the location of the path site. General standards have been established for the width of shared use paths.

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[46] Creative Outdoor Designs. *Surfacing Products and Equipment*. Online: < http://www.creativeoutdoordesigns.com/sur.html > (Dec. 19, 2002).

[47] North West Rubber Mats. *Play Ground Safety Surfacing.* Online: < http://www.northwestrubber.com/products/recreational/playground.htm > (Dec. 19, 2002).

[48] Surface America, Inc. *Spec Data PlayBound Tile Playground Surfacing*. Online: < http://www.surfam.com/images/pdf/playboundTile_SD_12174.pdf > (Dec. 27, 2002).

[49] Surface America, Inc. *Spec Data PlayBound Poured-in-Place Playground Surfacing*. Online: < http://www.surfam.com/images/pdf/playboundPip_SD_12173.pdf > (Dec. 27, 2002).

[50] North West Rubber Mats Ltd. *Play-Ground Safety Surfacing*. Online: < http://www.northwestrubber.com/products/recreational/playground.html > (Dec. 19, 2002).

These paths allow for travel in both directions. The guidelines note that trails should be at least 10 feet wide (in urban or high use areas this width will likely need to increase to 12-14 feet).[51]

Golf cart path design specifications depend on the location of the path. Concerns that are to be addressed in cart path design include drainage potential and aesthetics. The minimum width of a cart path has been noted as 8 feet in single cart areas and 12 feet in areas that have heavy use by course maintenance staff or are locations where multiple carts drive at the same time.[52]

Running tracks vary in their construction and therefore in their rubber content. There are two types of tracks that use rubber granules in the surfacing: latex and polyurethane. Running tracks consist of one or several layers of materials. The simplest track is one made of bound rubber that is paved in place. Other tracks have a base mat covered with several layers of material, including the surface coat. The base mat is made of rubber or asphalt and the upper layers are made of rubber granules combined with a binder. The rubber used can be either crumb rubber or rubber strands. The EPA's recommended recycled content for running tracks is 90 to 100% post-consumer content,[53] and this recommendation applies to the crumb or strand rubber used in the track layers. According to the United States Tennis Court and Track Builders Association, latex or polyurethane-bound rubber surfaces should be installed to a depth of ⅜" to ½" on top of the base layers.[54] Table 8 presents the ranges of rubber bulk density that correlate with this thickness. Using values for the actual area and depth of a running track project, the amount of rubber used can be calculated.

Table 8. Rubber Bulk Density Ranges for ½" Surface System Thickness[55]

Rubber Type	**Shape**	**Lbs/Yd^2**
Black SBR (synthetic, usually by-products or recycled material)	Granule	10.0 – 12.0
Black SBR	Strands	8.5 – 10.0
Black EPDM (virgin rubber)	Granule	10.5 – 12.0
Colored EPDM	Granule	13.0 – 15.0

Crumb rubber can be added to turfgrass surfaces (primarily athletic playing fields) to improve the "turfgrass wear tolerance and prevent soil compaction." The amount of crumb rubber needed in this type of topdressing application has been reported as 1,200 to 1,800 pounds of crumb

[51] Pedestrian and Bicycle Information Center. *Rails and Trails: Design of Trails*. Online: < http://www.walkinginfo.org/rt/design/printerversion.html > (Dec. 19, 2002).

[52] Oatis, D. *Common Sense Cart Paths.* Online: < http://www.usga.org/green/download/golf_course_management/common_sense_paths.html > (Dec. 18, 2002).

[53] EPA. *Running Tracks*. Online: < http://www.epa.gov/cpg/products/running.htm#productinfo > (Dec. 20, 2002).

[54] United States Tennis Court and Track Builders Association. *Buyer's Guide for Track Construction*. Online: < http://ustctba.com/buyersguidetrack.html > (Dec. 19, 2002).

[55] United States Tennis Court and Track Builders Association. *Guidelines: Track Surfacing – Latex.*. Online: < http://www.ustctba.com/guidelines-track/section3g1.html > (Dec. 20, 2002).

rubber per 1,000 ft^2.[56] Researchers further suggest that crumb rubber be topdressed between ⅜ and ½ inch.[57] Another method of using crumb rubber in the maintenance of playing fields is to incorporate the crumb rubber into the soil. Preliminary research on this method suggests using soil with 20% crumb rubber (by weight).[58]

While the costs for construction of an asphalt rubber bike, walking, or golf course path are varied based on project size, unit cost information can be helpful when evaluating the costs of an individual project. Available unit cost information for several types of projects is presented in the following list:

- Playground surfacing materials made of recycled rubber include loose crumb rubber or rubber tiles (or mats) made from crumb rubber. To determine the cost of a project using loose crumb rubber, the area that will be covered is measured (length and width), and the depth of the coverage is selected. An example crumb rubber product, made of 100% recycled rubber, costs $0.35 per ft^3.[59] By weight, crumb rubber prices range between $0.12 and $0.15 per pound.[60]
- Initial cost of conventional asphalt or concrete surface is $125,000 per mile; initial cost of unpaved surface (e.g. dirt or sand) is $40,000 to $50,000 per mile.[61]
- Rubber asphalt hot mix (asphalt cement mixed with rubber particles) costs approximately $2.50 per yd^2 (conventional asphaltic concrete costs approximately $1.55 per yd^2).[62] By weight, a crumb rubber modifier mix with 7.5% asphalt by weight of mix costs $4.50 to $5.00 per ton.[63]

Finally, the following conversion factors are useful in determining the number of tires that are recycled to create a given project.

- The Texas Natural Resource Conservation Commission states that 1 recycled tire produces 10 to 12 pounds of crumb rubber.[64]

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[56] Rogers, J.N. III and J.T. Vanini. *Topdressing with Crumb Rubber from Used Tires on Athletic Fields and other High Traffic Turf Areas*. Online: < http://www.css.msu.edu/Crumb_Rubber.cfm > (Dec. 18, 2002).

[57] Rogers, J.N. III and J.T. Vanini. *Stretching Your Dollars with Crumb Rubber*. Online: < http://www.greenmediaonline.com/st/1997/1097/1097al.html > (Dec. 19, 2002).

[58] Southern Illinois University. *Tires for Turf*. Online: < http://www.siu.edu/~perspect/00_sp/survey1.html > (Dec. 18, 2002).

[59] American Rubber Technologies, Inc. *Rubberstuff Playground Surfacing Pricing*. Online: < http://www.americanrubber.com/rubberstuff/pricing.html > (Dec. 19, 2002).

[60] Rubber Pavements Association. *FAQ*. Online: < http://www.rubberpavements.org/faq.asp > (Dec. 9, 2002).

[61] Pedestrian and Bicycle Information Center. *Rails and Trails: Design of Trails.* Online: < http://www.walkinginfo.org/rt/design/printerversion.html > (Dec. 19, 2002).

[62] Rubber Pavements Association. *FAQ*. Online: < http://www.rubberpavements.org/faq.asp > (Dec. 9, 2002).

[63] Hicks, R.G. *Asphalt Rubber Design and Construction Guidelines, Volume 1*. Online: < http://www.rubberizedasphalt.org/ar_design_guide/Vol_1.pdf > (Dec. 20, 2002).

[64] Texas Natural Resource Conservation Commission. *The Many Uses of Crumb Rubber*. Online: < http://www.tnrcc.state.tx.us/permitting/r_e/eval/we/tires/crumb.pdf > (Dec. 20, 2002).

- One company's 24" square rubber playground tiles recycle 2.5 tires per tile.[65]
- In road paving applications, about 2,000 tires are used per 2 inch thick lane mile.[66] Using these values, a mile of a smaller width paving application (e.g. a 2" thick, 8 foot wide bike path) uses approximately 615 tires.
- Reports of the amount of rubber used in running tracks vary. In Illinois, several running tracks surfaced with recycled rubber used between 34,782 and 50,600 pounds of scrap rubber (equal to between 2,193 and 4,280 tires).[67, 68]

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[65] Environmental Molding Concepts. *Kid Kushion Playground Safety Tile*. Online: < http://www.emcmolding.com/kidkusion.html > (Dec. 19, 2002).

[66] Rubber Pavements Assocation. *FAQ*. Online: < http://rubberpavements.org/faq.asp > (Dec. 9, 2002).

[67] Beloit Daily News. *Kinnikinnick district gets grant for new track.* Online: < http://www.beloitdailynews.com/400/trak24.html > (Dec. 20, 2002).

[68] Illinois Wesleyan University. *IWU gets state grant money for track surface.* Online: < http://www.iwu.edu/~iwunews/newsrlse/tw415.htm > (Dec. 20, 2002).