Using Crumb Rubber from Recycled Tires for Storm Water Pollution Control: Regulation Summary and Market Report

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Executive Summary

This report documents the first steps in a research study, funded by the Colorado Department of Public Health and Environment (CDPHE), whose objective is to study the technical feasibility of using crumb rubber from recycled tires for storm water pollution control. Before conducting detailed research into the technical aspects of filtering storm water with crumb rubber filters, the research team investigated two preliminary questions: (1) What regulations are applicable for using waste tires for this purpose? (2) What is the potential demand for crumb rubber for storm water filters in Colorado? This report answers these questions. In particular, with regard to the demand for crumb rubber, this market report first estimates the number of waste tires required to replace sand in existing storm water filters, and then estimates the *potential* demand for waste tires if crumb rubber filters are shown to be successful.

In 1977, the Federal Water Pollution Control Act was amended and became what is commonly known as the Clean Water Act. Among other functions, this act gave the Environmental Protection Agency the authority to establish water control standards for point and non-point pollution discharges. The Clean Water Act requires that cities and companies use the "best management practices" to reduce the amount of pollutants that are allowed into public waters. The disposal of waste tires is regulated by CDPHE's Hazardous Materials and Waste Management Division.

In order to determine the demand for crumb rubber to replace sand in existing storm water filters, municipalities throughout Colorado and the Colorado Department of Transportation were contacted to determine that there are currently at least 132 sand filters in Colorado. The size of these existing filters was then estimated. According to this estimate, 1.3 million waste tires would be required to replace the sand in these existing filters, which is equivalent to 2.4% of Colorado's current inventory of waste tires. In addition, to prevent clogging, an expected 110 thousand tires would be required annually, equivalent to 2.2% of Colorado's current annual disposal of waste tires.

The *potential* market for crumb rubber filters was estimated from the volume of storm water requiring treatment, which is called the water quality control volume. This volume, in turn, was calculated from the estimated percent imperviousness of urban areas throughout Colorado. Assuming that storm water runoff from 1.0% of the urban area will be treated with a crumb rubber filters, the potential demand for waste tires is nearly 11 million tires for initial construction, equivalent to 20% of Colorado's current inventory, with an additional 910 thousand tires required annually for maintenance, equivalent to 18% of Colorado's current annual disposal.

1. Introduction

As cities and their populations increase, so do the amount of roads, parking lots, and buildings. These surfaces accumulate the byproducts of the urban lifestyle in the form of gasoline, oil, fertilizers, or any number of other pollutants (Federal Highway Administration 2006). During a storm, the streets and buildings are rinsed of the contaminants, which are then carried to our waterways, and if left untreated will adversely affect the health of humans, animals, and plants. The purpose of storm water treatment is to remove these pollutants before they have a chance to find their way into Colorado's waters.

Another potential environmental risk in Colorado is the ever growing stockpile of waste tires which have the potential of hazardous fires and other health implications. Although great efforts are being made throughout the state to recycle waste tires, the numbers of tires left at the end of each year continues to rise due to a lack of recycled tire end use markets and increasing capacity at tire storage facilities.

This report, funded by the Colorado Department of Public Health and Environment (CDPHE), investigates the technical feasibility of using crumb rubber for storm water pollution control. Specifically, this report provides a brief overview of the environmental regulations on storm water treatment and tire disposal, and then estimates the demand for crumb rubber for treating storm water. It should be emphasized that this study is based on the assumption that crumb rubber provides effective pollution control for storm water. Testing this assumption is the goal of this CDPHE funded research. However, the work reported in this study does indicate that further research is merited, since the potential demand for crumb rubber for storm water treatment is substantial.

2. Methods

2.1. Regulation Summary

Information regarding storm water regulations was gained through publications from the Environmental Protection Agency (EPA), specifically the Clean Water Act and the National Pollutant Discharge Elimination System, and Urban Drainage and Flood Control District's (UDFCD's) *Criteria Manual* (Volumes I and III). To determine the relevant regulations pertaining to the disposal of tires in Colorado, a review of CDPHE's Hazardous Materials and Waste Management Division Regulation 6 CCR 1007-2 PART 1 was conducted. Special focus was given to Recycling (Section 8), Scrap Tire Facilities (Section 10), Waste Motor Vehicle Tire Haulers (Section 15), and Disposal of Motorized Equipment Wastes (Section 16).

2.2. Market Report

To determine the market potential for crumb rubber in storm water filters, two areas were evaluated: (1) replacing current sand filters, and (2) *potential* demand for crumb rubber filters.

2.2.1. Replacing Current Sand Filters

The demand for crumb rubber for replacement of sand in Colorado's existing filters was determined by contacting various municipalities in Colorado and the Colorado Department of Transportation (CDOT) to obtain the current number of sand filters and any plans for future installation. This information was used to estimate the total area of existing filters, the quantity of crumb rubber required to replace the sand in these filters, and the amount of crumb rubber needed to perform regular maintenance.

2.2.2. Potential Demand for Crumb Rubber Filters

The potential volume of storm water that could be treated with crumb rubber filters was determined by methodology recommended in UDFCD's *Criteria Manual* (2005). Aurora, Colorado Springs, Denver, Fort Collins, Grand Junction, and Pueblo were used as sample cities to determine basic land use patterns. These land use patterns were used to determine percent imperviousness, which was then used to calculate total water quality control volume (WQCV), the volume of storm water runoff requiring treatment. Specifically, the estimated percent imperviousness for residential, park, and commercial areas were used to determine the relevant WQCV using UDFCD's (2008) Figure SQ-2, which is reproduced here as Figure 1. For residential areas, the percent imperviousness was taken from UDFCD's (2008) Figure SQ-8 for two-story single-family dwellings, which is reproduced here as Figure 2.

3. Results

3.1. Regulation Summary

Beginning in 1972 with the Federal Water Pollution Control Act, the Federal Government, acting through the EPA, started to take steps to reduce the pollutants in waterways across the country. In 1977, the Federal Water Pollution Control Act was amended and become what is commonly known as the Clean Water Act. Among other functions, this act gave the EPA the authority to establish water control standards in order to regulate pollutants introduced by point source and non-point source discharges (EPA 2009). The Clean Water Act also established the National Pollutant Discharge Elimination System (NPDES), which "regulates storm water discharges from three potential sources: municipal separate storm sewer systems ..., construction activities, and industrial activities" (EPA 2009).

Phase I of the NPDES began in 1990 and focused on eliminating non-point source pollution from construction sites larger than five acres, companies that fall into predetermined categories of industry, and municipalities with populations greater than one hundred thousand people, which included the City and County of Denver, the City of Aurora, and the City of Colorado Springs. In 1999 the EPA implemented Phase II, which expanded the Phase I requirements to include construction sites between one and five acres in size and urban areas that were not previously covered in Phase I. Some examples of the Phase II sites include Colorado Springs

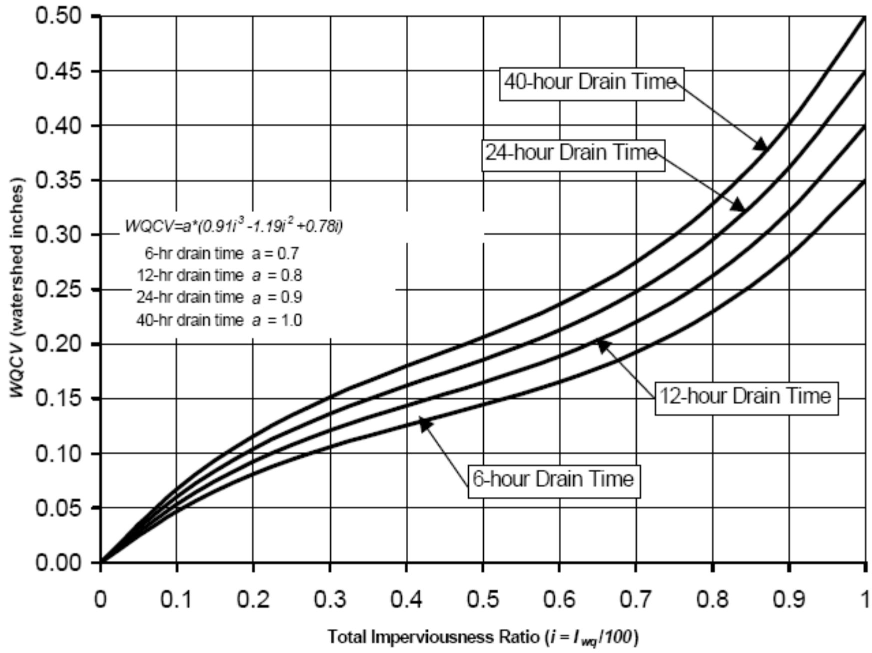

Figure 1: For urban areas, the water quality control volume (WQCV) depends on the percent imperviousness. Larger WQCVs are required for longer drain times. (source: Figure SQ-2 in UDFCD's *Criteria Manual*)

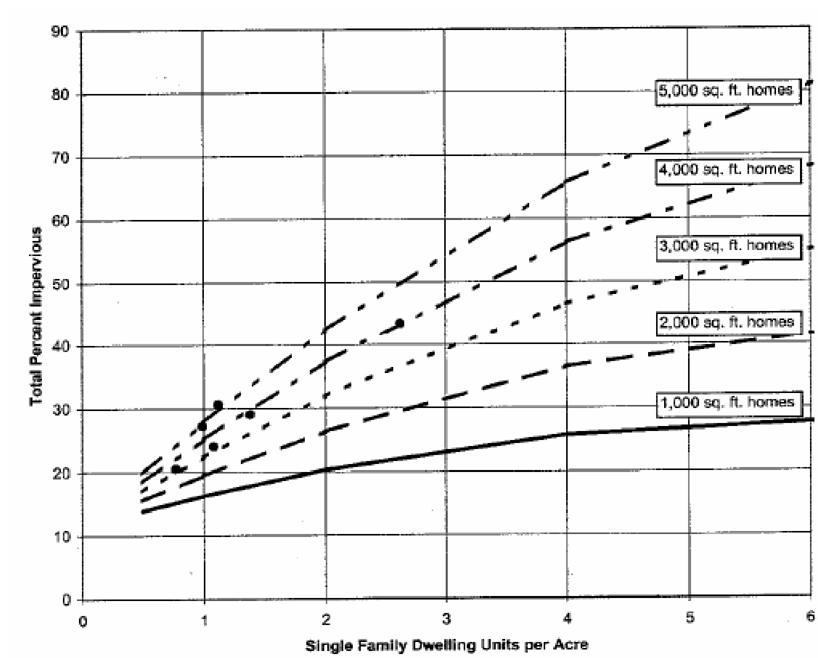

Figure 2: For residential areas, the percent imperviousness depends on the number of single family dwelling units per acre, on the building type (here assumed two-story dwellings), and on the average area per dwelling. (source: Figure SQ-8 in UDFCD's *Criteria Manual*)

School District Number 11 and the University of Colorado in Boulder (UDFCD 2008). All organizations that fall under the NPDES permits are required to design and implement a storm water management program and are required to use "best management practices" and the "best technology available" to control contamination (Ken MacKenzie, UDFCD, personal communication, 2009).

The regulations for disposal of waste tires that are residentially generated in Colorado are established in the CDPHE's Hazardous Materials and Waste Management Division 6 CCR 1007-2, Part 1, Section 16.6.1. The land disposal of waste tires generated residentially is prohibited and can only be disposed of by delivery to approved locations. The approved locations are "a retailer engaged in waste tire collection or recycling, a wholesaler engaged in waste tire collection or recycling, a waste tire monofill that has a certificate of designation, and a collection facility engaged in waste tire collection; or a recycling facility engaged in waste tire recycling" (CDPHE 2008). In accordance with House Bill 04-1428, an annual report on the status of waste tire recycling in Colorado must be submitted to Colorado's Transportation Legislation Review Committee. This report contains the current state of Colorado's stockpile of waste tires, the amount of tires generated in Colorado for that year, and the amount of tires that were recycled (Snapp et al. 2009).

3.2. Market Report

3.2.1. Replacing Current Sand Filters

In order to determine the number of tires that could be used in existing sand filters, information was retrieved from the cities listed in Table 1 to determine the number filters already installed. The total volume of crumb rubber required to replace the sand in these filters was determined as follows: Because most sand filters are located near highly impervious areas, the local percent imperviousness for these existing filters was assumed to be 0.9. Assuming a 40-hour drain time, the UDFCD (2005) chart in Figure 1 gives a WQCV of 0.4 watershed inches. Sand filters can treat watersheds ranging from five to fifty acres (Federal Highway Administration 2006) so a conservative watershed area of 5 acres was assumed for each filter. The equation for required storage, measured in acre-feet, was used (UDFCD 2005).

$$Required\ storage = \left[\frac{WQCV}{12}\right](Area)$$

The calculation is:

→ Required Storage = (0.4 watershed-in)(1 ft/12 in)(5 ac) = 0.17 ac-ft.

Once the required storage for each filter was calculated, the surface area of the average filter could be determined by dividing the required storage volume by the recommended water

Table 1: Cities contacted with sand filters listed alphabetically
* indicates organizations with unknown quantities
† indicates the midpoint of the reported range of 10-20

City	Number of Filters
Arvada	2
Aurora*	0
Boulder	6
Broomfield	0
C-DOT	56
Colorado Springs	16
Denver	8
Englewood	0
Ft. Collins†	15
Littleton	2
Thornton	27
sum	**132**

depth of 3 feet (UDFCD 2008) and then multiplying this value by the conversion factor of 43,560 square feet per acre:

→ Surface Area = (0.17 ac-ft/3 ft)(43,560 ft^2/ac) = 2,420 ft^2.

With these assumptions, the total filter area is

→ Total Surface Area = (2,420 ft^2/filter)(132 filters) = 319,440 ft^2.

Assuming a minimum granular media depth of 18 in or 1.5 ft, the required volume of crumb rubber is

→ Crumb Rubber Volume = (319,440 ft^2)(1.5 ft) = 479,160 ft^3.

Finally, since there are an average of 2.8 waste tires per cubic foot of crumb rubber (Edil et al. 2004), this initial volume would require the following number of waste tires:

→ Waste Tires Required = (479,160 ft^3)(2.8 tires/ft^3) = 1,341,648 tires ≈ 1.3 million tires.

According to UDFCD (2008) guidelines, the amount of granular media that should be replaced to prevent filter clogging is the top three inches, or one quarter foot, once every two to five years. For this estimate a time cycle of 2 years was used. The volume of the replacement media was determined by multiplying the surface area by the depth:

→ Replacement Crumb Rubber Volume = (0.25 ft)(319,440 ft^2)/(2 yr) = 39,930 ft^3/yr.

Again using an average of 2.8 tires per cubic foot (Edil et al. 2004), this volume was converted to an annual demand for tires as follows:

→ Replacement Waste Tires Required = (39,930 ft^3)(2.8 tires/ft^3) = 111,804 tires/year.

It should be noted these calculations are based on several assumptions leading to an estimated current number of storm water sand filters in Colorado, and a corresponding volume of crumb rubber. A more accurate estimate would be possible based on the surface area and depth of all current filters. However, collecting this level of information was beyond the scope of the current study.

3.2.2. Potential Demand for Crumb Rubber Filters

The potential demand for crumb rubber in storm water filters, and the corresponding annual demand for maintenance, was determined by first establishing the WQCV for the entire state. This was done by breaking Colorado's urban area into three basic land use categories: residential, parks, and commercial. Data was taken from the U.S. Census Bureau (U.S. Census Bureau 2007) to determine the area of each city and the total number of residential units (Table 2). The residential area for each was estimated by multiplying the number of residential units by the average lot size in the United States of 0.29 acres (Heimich and Anderson 2001). The proportion of the city's area that is residential was determined by dividing the residential area by the total city area. Once the samples of six cities were evaluated in the same manner, the area-weighted average of the cities was taken to find the total percent of Colorado's urban areas that are residential, which came to 46%.

Table 2: The total area of each city with the number of housing units and the area of parks in acres. The area dedicated to housing in acres is also given.

City	Area (acres)	Area Weight	Housing Units	Residential (acres)	Parks (acres)
Aurora	96,640	24%	109,260	32,156	1,800
Colorado Springs	118,400	30%	148,690	43,760	15,266
Denver	97,920	25%	251,435	73,999	9,000
Ft. Collins	37,248	9%	47,755	14,055	600
Grand Junction	19,200	5%	18,784	5,528	659
Pueblo	30,059	8%	43,121	12,691	682
sum	**399,467**	**100%**			

It should be noted that an average lot size of 0.29 acres may be too small for Colorado, which would overestimate the WQCV. If 0.29 acres were too small, then the residential area would be underestimated, and consequently the commercial area would be overestimated. Since commercial areas are assumed to have larger percent imperviousness, overestimating the commercial area would lead to overestimating the WQCV and therefore the demand for waste tires for crumb rubber.

To determine the areas of parks for each city, the websites for the individual cities were used (Appendix A). The area of parks was divided by the total area of the city to provide each city's percentage of land dedicated to parks. Once again the area-weighted average of all six cities was determined to return 7%, the percentage of Colorado's urbanized area used as parks.

The percentage of a city's area used for commercial was determined by subtracting the sum of percentage of residential area and park area from 100%. Again the weighted average was taken and a total commercial percentage was found to be 47%.

For illustration, the following is an example calculation for Denver:

→ Residential (251,435 houses)(0.29 ac/house)/(97,920 ac) = 76%

→ Parks (9,000 ac)/(97,920 ac) = 9%

→ Commercial 100% - 76% - 9% = 15%

The information regarding the number of housing units, number of acres dedicated to parks, and the city's total land area are listed in Table 2, and the percentages of each city assigned to each of the three land use categories is listed in Table 3.

Table 3: List of percentages of each city dedicated to each of the three land use categories with the state percentages provided.

City	Residential	Parks	Commercial
Aurora	33%	2%	65%
Colorado Springs	37%	13%	50%
Denver	76%	9%	15%
Ft. Collins	38%	2%	61%
Grand Junction	29%	3%	68%
Pueblo	42%	2%	56%
average	**46%**	**7%**	**47%**

According to the Colorado Department of Personnel and Administration, the total land area of Colorado is 104,247 square miles or 66,718,080 acres. Assuming that 1.2% of Colorado is urbanized (Amanda Weaver, University of Colorado Denver, Department of Geography and Environmental Sciences, personal communication, 2008) the total urbanized area of Colorado would be calculated by:

→ Total Urbanized Area = (66,718,080 ac)(1.2%) = 800,617 ac

Once the total urbanized area has been calculated the amount of urbanized land used for each of the three land use categories can be established by multiplying the percentages for each category by the total urbanized area. The calculations and the values for each land use category are as follows:

→ Total Urbanized Residential Area = (800,617 ac)(46%) = 365,146 ac

→ Total Urbanized Park Area = (800,617 ac)(7%) = 56,132 ac

→ Total Urbanized Commercial Area = (800,617 ac)(47%) = 379,339 ac

By using Table RO-3 in UDFCD's (2005) *Criteria Manual*, imperviousness values were given as: Residential, 36%, assuming an average home size of 2000 square feet; Parks, 5%; and Commercial, 80-95%. In this study the assumed imperviousness for commercial areas was 0.90. Once the percentage imperviousness is known, the UDFCD (2005) *Criteria Manual* is again used to determine the WQCV by referencing Figure 1. By using a 40 hour drain time (Federal Highway Administration 2006) the WQCV for Residential, Parks, and Commercial is given as 0.17 inches, 0.03 inches, and 0.4 inches, respectively. The required storage volume (RSV) was then calculated for each:

→ $RSV_{residential}$ = (0.17 inches / 12 inches per foot)(365,146 ac) = 5,173 ac-ft

→ RSV_{parks} = (0.03 inches / 12 inches per foot)(56,132 ac) = 140 ac-ft

→ $RSV_{commercial}$ = (0.4 inches / 12 inches per foot)(379,339 ac) = 12,645 ac-ft

The RSVs were then added together giving a total required storage volume of 17,958 acre-feet. Assuming that only 1.0% of the total watershed would be treated by crumb rubber filter, and using a maximum design water depth of 3 feet and a minimum filter media depth of 18 inches (UDFCD 2008) the total filter area and total filter volume were calculated. The figure of 1.0% is an estimate, and should be interpreted as an educated guess. This figure is, however, consistent with discussion with numerous Colorado storm water managers, who stated that sand filters are primarily suitable for locations with small amounts of suspended particles and which require a relatively small footprint.

→ Total Filter Area = (17,958 ac-ft/3 ft)(43,560 ft^2/ac)(1.0%) = 2,607,482 ft^2

→ Total Filter Volume = (2,607,482 ft^2)(1.5 ft) = 3,911,223 ft^3

Once again using the value of 2.8 tires per cubic foot published by Edil et al. (2005) this provides a total of 10,951,425 ≈ 11 million tires for the initial installation. Then, assuming that the crumb rubber filters would require the same regular maintenance as sand filters, the yearly amount of tires required was determined in the same manner as the replacement needed for existing filters, giving an annual requirement of 912,619 ≈ 910 thousand tires.

4. Conclusion

According to the 2009 annual report on the status of waste tire recycling in Colorado (Snapp et al. 2009), Colorado generated 5,158,468 tires during 2008. Approximately 4 out of 5 of these tires were recycled, leaving the others to join the already large number of stockpiled tires, estimated at 55 million at the end of 2008. If crumb rubber filters prove to be an acceptable method for treating storm water it will help increase the number of tires that are recycled in Colorado each year. Specifically, if crumb rubber is slowly introduced into existing filters to replace sand, the research reported here estimates that 1.3 million tires would be required for initial replacement, plus another 110 thousand annually for maintenance. These numbers correspond to 2.4% of the existing stockpile, and 2.2% of the annual disposal, respectively. In the case that 1% of the entire WQCV for the State of Colorado is treated, the research reported here estimates that nearly 11 million tires would be required for initial filter construction, plus another 910 thousand annually for maintenance. These numbers correspond to 20% of the existing stockpile, and 18% of the current annual disposal, respectively.

By necessity, this market report is based on a number of assumptions. Some of the more important assumptions are: (1) crumb rubber filters for storm water pollution control will follow UDFCD's guidelines for sand filters; (2) UDFCD's relationship between percent imperviousness and WQCV is applicable to urban areas statewide; (3) existing sand filters drain an average of 5 acres each; and (4) 1.0% of Colorado's urban WQCV could potentially be treated by crumb rubber filters. Although these estimates are believed to be reasonable, it would be difficult to quantify the possible numerical range for each estimate. Accordingly, no confidence intervals have been estimated for the results of this market report. Certainly, the results reported here should be qualified as preliminary.

Nevertheless, these results indicate that using crumb rubber from recycled tires for storm water pollution control *does* have the potential to provide a beneficial use for many of Colorado's stockpiled waste tires. Nothing in this report indicates whether (or not) crumb rubber is, indeed, an appropriate material for use in storm water filtration. However, this report does indicate that additional research is merited, since this application could potentially help Colorado to manage its waste tire inventory.

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U.S. Census Bureau (2007). “State and County QuickFacts”. <http://quickfacts.census.gov/qfd/states/08000.html>. (August 14,2009)

Appendix A

Websites used to determine the area of parks:

Aurora
http://www.auroragov.org/AuroraGov/Departments/Parks___Open_Space/index.htm

Colorado Springs
www.discover-colorado-springs.com/colorado-springs-parks-and-recreation.html

Denver
http://www.denvergov.org/Default.aspx?alias=www.denvergov.org/parksandrecreation

Fort Collins
http://www.fcgov.com/parks/

Grand Junction
http://www.gjcity.org/CityDeptWebPages/ParksRecreation/ParksRecreation.htm

Pueblo
http://www.pueblo.us/cgi-bin/gt/tpl_page.html,template=14&content=1678&nav1=1&