

**FIVE-YEAR STUDY OF THE WATER
QUALITY EFFECTS OF TIRE SHREDS
PLACED ABOVE THE WATER TABLE**

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A field trial was constructed beneath a secondary state highway in North Yarmouth, Maine to investigate the water quality effects of tire shred fills placed above the groundwater table. Samples were collected in three 3-m square geomembrane lined basins located beneath the shoulder of the road. Two of the basins are overlain by 0.61m of tire shreds with a 75-mm maximum size topped by 0.72 to 1.37m of granular soil. The basin serves as a control and is overlain only by 0.72m granular soil. Quarterly samples for inorganic constituents were taken from January 1994 through June 1999. In addition, samples were taken for volatile and semivolatile organic compounds on three dates. Filtered and unfiltered samples were analyzed for the following substances that have a primary drinking water standard: (Ba), cadmium (Cd), chromium (Cr), lead (Pb), and selenium (Se). There was no evidence that the presence of tire shreds altered the concentrations of these substances from the naturally occurring background level. In addition, there was no evidence that tire shreds increased the levels of aluminum (Al), zinc (Zn), chloride (Cl) or sulfate (SO₄), which have secondary (aesthetic) drinking water standards. In a few samples, iron (Fe) levels exceeded their secondary standard. Manganese (Mn) levels consistently exceeded their secondary standard; however, this is an esthetic based standard. Three sets of samples were tested for organics. Negligible levels of organics were found.

Tire shreds are waste tires that been cut into pieces that are generally 50 to 300mm(1). They offer the following advantages when used as a fill material: lightweight, low lateral pressure, low thermal conductivity, and free draining (1). They offer the following advantages when used as fill material: lightweight, low lateral pressure, low thermal conductivity, and free draining (1). Because of these advantages they have been used on more than 100 road construction projects across the United States. While the potential effect on groundwater quality is thought to be small when used for highway applications, there have been few extended studies of the effects for field conditions.

Previous laboratory leaching studies have shown that tire shreds are not a hazardous waste as defined by the Resource Conservation and Recovery Act (as amended). However, these same studies detected low levels of some metals and organic compounds in the leachate (2-6). This indicated that testing the effects of tire shreds on water quality under field conditions was warranted.

A limited field study was performed for the Minnesota Pollution Control Agency (3). Unfortunately, samples were taken on only one date from open boreholes. This sampling procedure casts doubt on the validity of the results. Edil and Bosscher (4) installed two pan lysimeters beneath tire shred layers in a test road

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Embankment. The water-quality effects of tire shreds placed above the water table. The study includes a control section to measure the amounts of substances naturally present in the water (8). The results and conclusions from the 5.5-year monitoring period are presented here. Another purpose of the field trial was to measure the effect of a compressible tire shred layer on asphaltic concrete pavement performance. To date there has been no difference in pavement performance for sections underlain by tire shreds compared with the control section (9,10). A separate study was performed on water-quality effects of tire shreds placed below the groundwater table. In the latter study 1.4 metric tons (1.3Mg) of tire shreds was buried below the water table in glacial till, marine clay, and peat. Preliminary results are described by Downs et al. (6).

SITE AND MONITORING WELL DESCRIPTIONS

The North Yarmouth field trial is located on Route 231, a secondary highway in North Yarmouth. It consists of four 33-m-long sections, each with a 0.61-m-thick tire shred layer (9, 10). The tire-shred layer was covered with 0.76 to 1.37m of granular soil before paving. The granular soil was composed of 0.635m of subbase gravel and the balance was granular common borrow. The pavement was 0.127m thick. About 100,000 tires were used in this test project. In addition, there was a 33-m-long control section designed according to Maine Department of Transportation standards with conventional soil fill. A longitudinal cross section is presented in Figure 1. Two seepage collection basins were installed beneath sections with tire shreds passing the 75-mm sieve to collect samples for water-quality testing. The shreds were made from a combination of steel- and glass-belted tires. Steel belts were exposed at the cut edges of the shreds. The seepage collection basins were 3x3m in plan and were lined with a high-density polyethylene (HDPE) geomembrane. A drain in the center of the liner led to a collection tube located along the side of the embankment as indicated in Figure 2. The design was similar to that used by Edil and Bosscher (4). New pavement is nearly impervious, so, to obtain infiltration, the basin projected beyond the edge of the pavement. This allowed water that ran off the edge of the pavement to infiltrate into the embankment

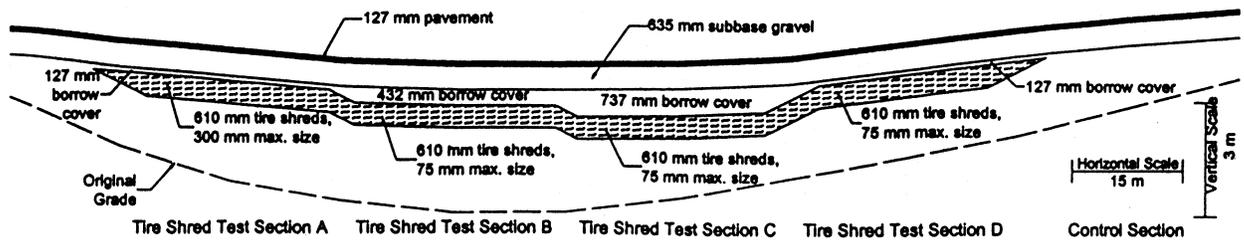


FIGURE 1 Longitudinal section.

Side slope and enter the basin. With this design, there is no opportunity for substances leached from the tire shreds to sorbed onto the soil before sampling. The basins were located directly below the tire shred layer. One basin (Section C) was overlaid by 0.61m of shreds followed by 1.37m of granular soil, and the other basin (Section D) was overlaid by 0.61m of shreds followed by 0.72m of granular soil. A third seepage collection basin was installed in the control section. It was overlaid by 0.72m of granular soil.

SAMPLING AND TESTING PROCEDURES

Quarterly samples for inorganic constituents and water-quality index tests were taken from January 1994 through June 1999, giving a total of 22 sets of samples. In addition, samples were taken for volatile organic compounds (VOCs) and semivolatle organic compounds (SVOCs) on December 28, 1995; April 5, 1996; and June 22, 1999.

For the period January 1994 through September 1995, samples were taken from the water that had accumulated in the collection tube since the previous sampling period. This procedure raised the concern that sediments could accumulate in the bottom of the tube. For this reason, the sampling procedure was changed starting with the this reason, the December 1995 sample. From that date onward, the tubes were bailed dry 2 to 3 weeks before the desired sampling date. Samples were taken from the water that had accumulated during that short period. Samples were obtained with disposable 1-L capacity HDPE bailers.

The following sample types were taken from each well: leachate filtered through a 0.3-um filter and preserved with nitric acid (1.5mL/L) as appropriate for determination of dissolved metals (11); unfiltered leachate preserved with nitric acid (1.5mL/L) for determination of total for total metals; and unfiltered leachate with no acid for water-quality index tests such as pH. Samples were stored in HDPD bottles and were refrigerated to minimize degradation of sample quality. In addition, on five dates samples were taken to determine biological oxygen demand (BOD₅)

These samples were tested were for the substances listed in Table 1. Samples for metals analysis except

for lead selenium were prepared in accordance with U.S. Environmental Protection Agency (EPA) Method 200.7 (Inductively Coupled Plasma-Atomic Emission Spectrometric Method for Trace Element Analysis (12). Samples for lead and selenium were prepared in accordance with EPA Method 200.9 (Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry (12). The tests were carried out in accordance with EPA Method 7421 Lead (Atomic Absorption, Furnace Technique) and EPA Method 7740 Selenium (Atomic Absorption Furnace Technique) (13). Chloride and sulfate were measured in accordance with EPA Method 300.0 (Determination of Inorganic Anions by Ion Chromatography) (14). Water-quality index tests such as pH, alkalinity, BOD₅, chemical oxygen demand (COD), conductivity, total dissolved solids, and hardness were also performed.

For most substances, tests were performed on both acid-preserved filtered and acid-preserved unfiltered samples. The unfiltered samples generally contained some fine-grained particles that imparted a slight turbidity to the water. Because wells for drinking water are designed to prevent any significant amount of particulate matter from entering the well, it would not be representative to compare the results from unfiltered samples with drinking water standards. Thus, results from unfiltered samples provide supplementary information only and were not compared with drinking water standards.

Samples were taken for VOCs and SVOCs on three dates. The containers used for the VOC samples were clear 40-mL borosilicate glass vials with polypropylene closures and Teflon-faced silicone septa. The samples were preserved by adding four drops of ultrapure hydrochloric (HCl) to each vial before collecting the samples. Leachate from the bailer was placed directly in the vial with no sample preparation. The VOC samples were tested in accordance with EPA Method 8260 (Determination of Volatile Organics by Purge-and Trap Capillary Column GC/MS). A total of 82 VOCs were targeted for analysis based on the chemical composition of tires and

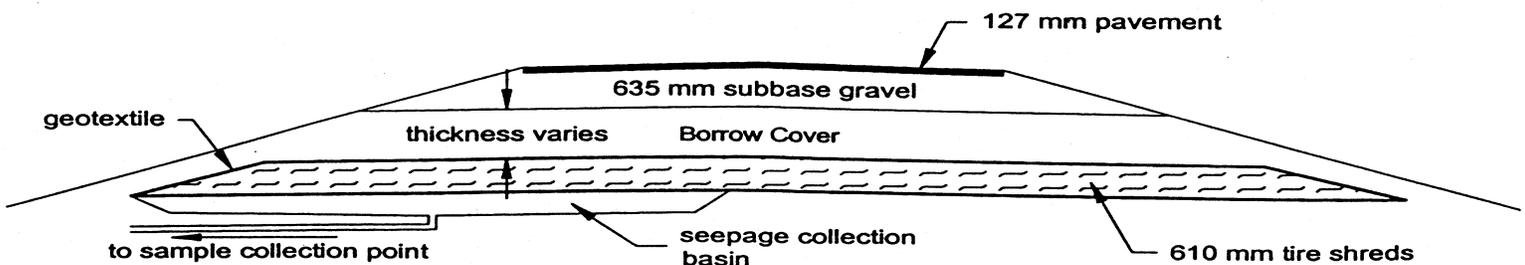


FIGURE 2 Typical cross section showing location of seepage collection basin.

TABLE 1 Inorganic Substances Tested for in Study

Aluminum (Al)*	Magnesium (Mg)
Barium (Ba)*	Manganese (Mn)*
Cadmium (Cd)*	Selenium (Se)*
Calcium (Ca)	Sodium (Na)
Copper (Cu)*	Zinc (Zn)*
Chromium (Cr)*	Chloride (Cl ⁻)*
Iron (Fe)*	Sulfate (SO ₄)*
Lead (Pb)	

*Has secondary drinking water standard.

*Has primary drinking water standard.

likely breakdown products. SVOC samples were collected in 1-L amber borosilicate glass bottles with polypropylene closures Teflon lines. Leachate from the bailer was placed directly in the bottles with no sample preparation. The SVOC samples were tested in accordance with EPA Method 8270 (Determination of Semivolatile Organics by Capillary Column GC/MS). A total of 69 base-neutral extractable, acid extractable, and polyaromatic hydrocarbon SVOCs were targeted for analysis based on the chemical composition of tires and likely breakdown products.

WATER-QUALITY INDEX TESTS

The pH of the samples varied from slightly greater than 8 to about 6 as indicated in Figure 3. There was no apparent pattern with date or with the sample location. Overall, the pH was near neutral. The results of this study are applicable to similar pH conditions. The dissolved and total solids varied from about 100 to 4000mg/L. On a given date, the concentration was about the same in the two tire shred sections as in the control section. The concentration was generally the highest in the sets of samples taken in April and lowest in

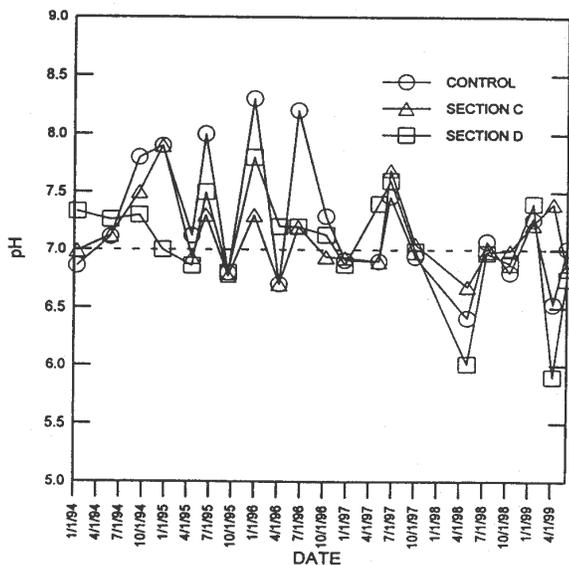


FIGURE 3 pH values of field samples.

he sets of samples taken in December or January. The BOD5 was very low and varied between about 0.5 and 3.0mg/L. On a given date, the COD was about the same in the tire shred sections as in the control section. It varied from a low of about 0 to a high of about 600mg/L, with no apparent pattern versus date.

INORGANIC RESULTS

Substances with Primary Drinking Water Standards

Substances with a primary drinking water standard are a known or suspected health risk. The following metals with this classification were included in the analysis: barium, cadmium, chromium, copper, lead, and selenium. Results for filtered and unfiltered samples of barium and chromium are presented in figures 4 and 5. These two substances are present in the control section, which indicates that they are naturally occurring in the soil. However, the levels found in the two tire shred sections are essentially the same as in the control section. This indicates that the presence of the tire shred layer does not cause a measurable alteration of the naturally occurring background concentrations of barium and chromium.

The concentrations of cadmium, copper, lead, and selenium were generally below the test method detection limits (MDLs). Although, the MDLs varied slightly over the course of the study, the following are applicable to most test dates: 0.0005mg/L for cadmium, 0.009mg/L for copper, 0.002mg/L for lead, and 0.00017mg/L selenium. The limited number of samples that exceeded the MDLs are discussed in the next paragraph. Cadmium was below the MDL for all but three samples. The filtered cadmium sample from the control section taken in April 1995 and the filtered and unfiltered

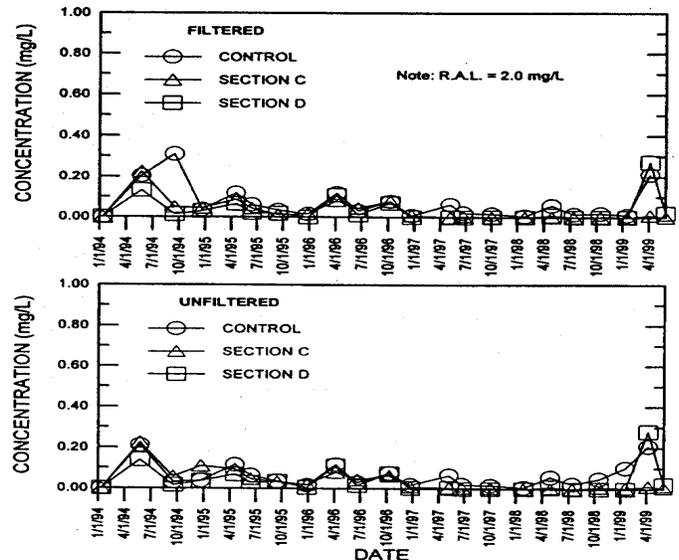


FIGURE 4 Filtered and unfiltered barium concentrations.

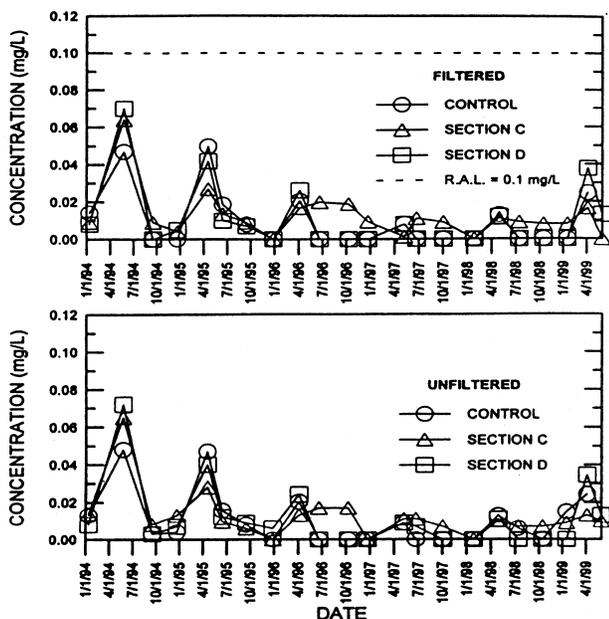


FIGURE 5 Filtered and unfiltered chromium concentrations.

samples in section D take in June 1995 slightly exceeded regulatory allowable limit (RAL) of 0.005mg/L. It is believed that the three samples that exceeded the RAL are not representative of the overall cadmium concentration was less than the MDL of 0.0005mg/L on the sampling dates.

For all other substances with primary drinking water standards, the levels were well below the applicable RAL. Copper was present above the MDL in filtered samples on two dates in the control section, two dates in Section C, and one date in Section D, but the highest concentration was 0.010mg/L, compared with a RAL of 1.3mg/L. Lead was present in filtered samples at levels above the MDL on two samples in the control section (highest concentration 0.009mg/L) and in three samples in tire shred sections (highest concentration, 0.0024mg/L. The concentration was less than the RAL for lead, which is 0.015mg/L. Lead was present above the MDL in 33 percent of the unfiltered samples from the control section, with the highest concentration at 0.054mg/L, and in 17 percent of the unfiltered samples from shred sections, with the highest concentration at 0.016mg/L. Overall, filtered and unfiltered lead concentration appeared to be higher in control section than in the tire shred sections.

Substances with Secondary Drinking Water Standards

Substances with a secondary drinking water standard are of aesthetic concern, which may impart, some taste, odor, or color to water but they are not a health concern. Filtered unfiltered results for aluminum, iron, manganese, and zinc are plotted versus date in Figures 6 through9. The filtered and unfiltered concentrations of manganese and zinc are about the same. However, the Unfiltered

Concentrations of aluminum and iron often are higher than the filtered concentrations. For aluminum this is most likely due to soil sediment that was present in the samples, especially those taken from the control section in 1998. For iron this is most likely due to particulate iron oxide that passed directly from the tire shreds into the collection tube. As discussed previously, drinking water standards should be compared only with results of filtered for filtered samples.

Aluminum, iron, manganese, and zinc are a naturally present in the soil as evidenced by the occurrence or these metals is samples from the control section; however there is no evidence that tire shreds increased the concentrations of aluminum or zinc. In fact concentrations are generally higher in the control section than in two- tireshreds section(Fig.9). This is an interesting finding because the steel belts in tires are often zinc coated and zinc oxide is present in rubber. The filtered iron concentrations in the tire shred and control sections are about the same on most sampling dates. However, on a few dates the iron levels in the tire shreds sections are higher than in the control section and the level exceeds the secondary RAL. In contrast, the unfiltered iron was consistently higher in the tire shreds sections than in control section. On almost all-sampling dates the concentrations of manganese are higher in the shred sections than in control sections. On almost all-sampling dates the concentrations of manganese are higher in the tire shred sections than in the control section. Manganese is present as an alloy in the steel belts at a rate of 2to3 percent by weight of steel. The manganese levels in the filtered samples from the shred sections generally exceed the RAL by a factor of 10to400.

The levels of chloride are presented in Figure 10. Concentrations higher than the applicable secondary RAL are generally present for samples taken in April. This is most likely due to infiltration from road salt. There was no evidence that tire shreds increase the concentration of sulfate, magnesium, and sodium as indicated in Figures 11 through 14.

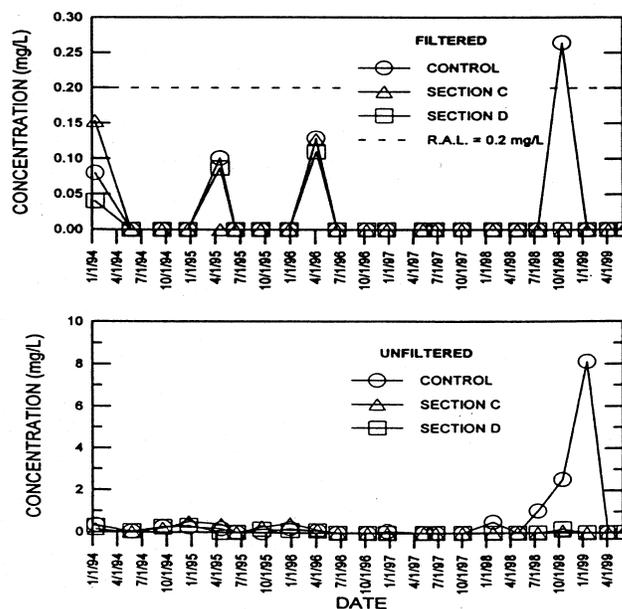


FIGURE 6 Filtered and unfiltered aluminum concentrations.

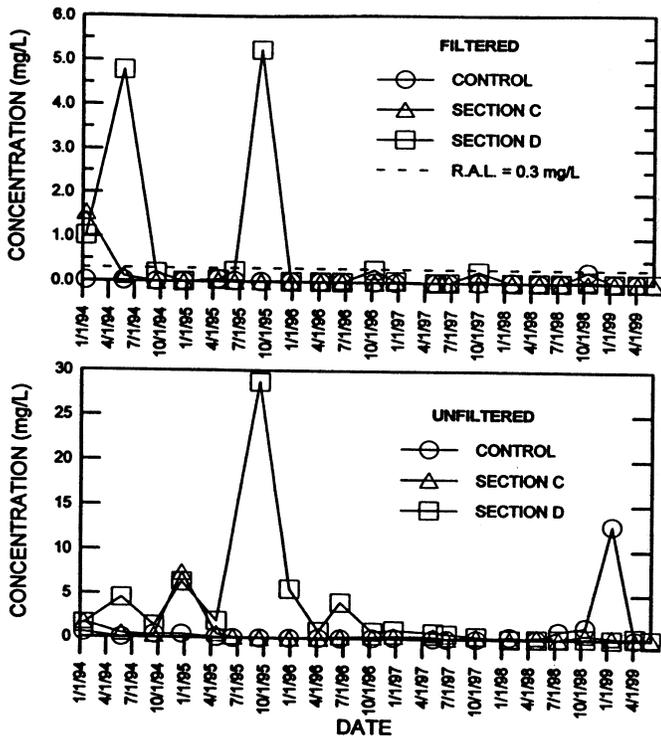


FIGURE 7 Filtered and unfiltered iron concentrations.

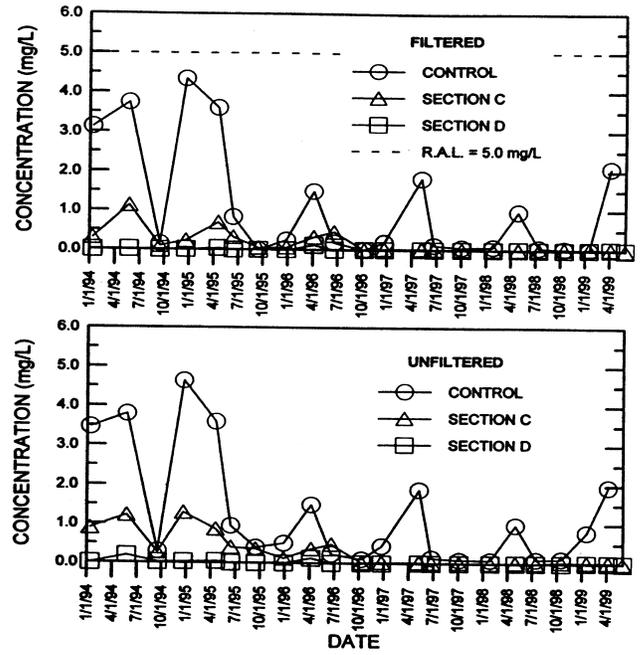


FIGURE 9 Filtered and unfiltered zinc concentrations.

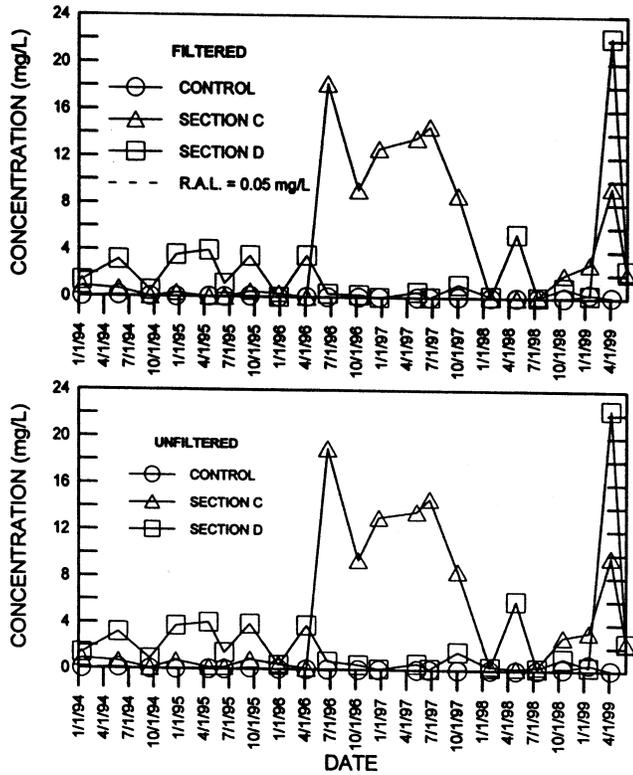


FIGURE 8 Filtered and unfiltered manganese concentrations.

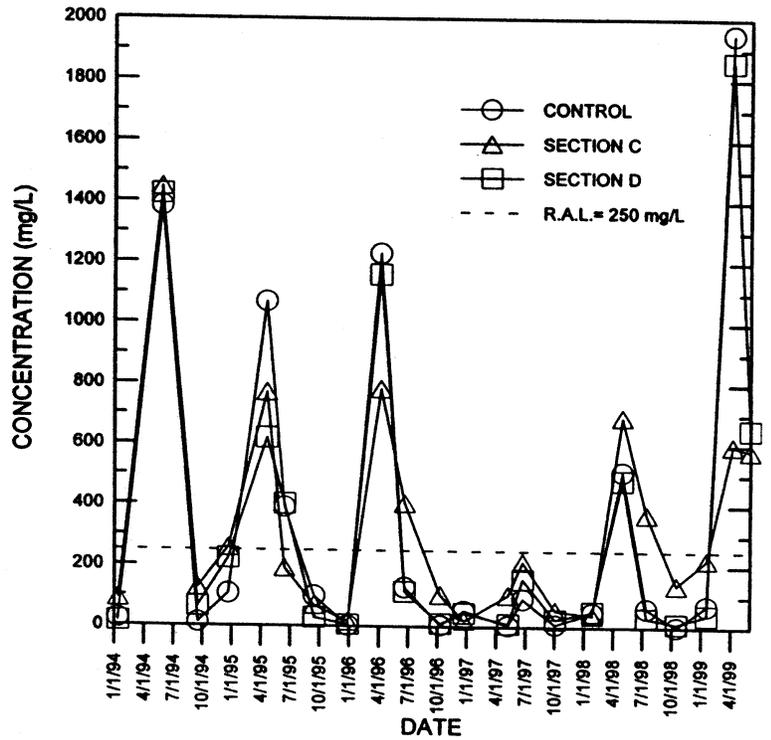


FIGURE 10 Filtered chloride concentrations.

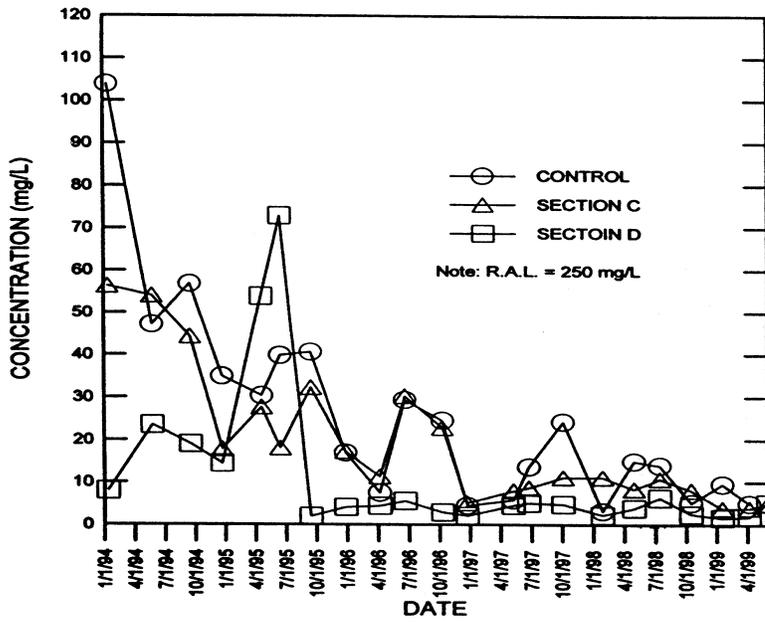


FIGURE 11 Filtered sulfate concentrations.

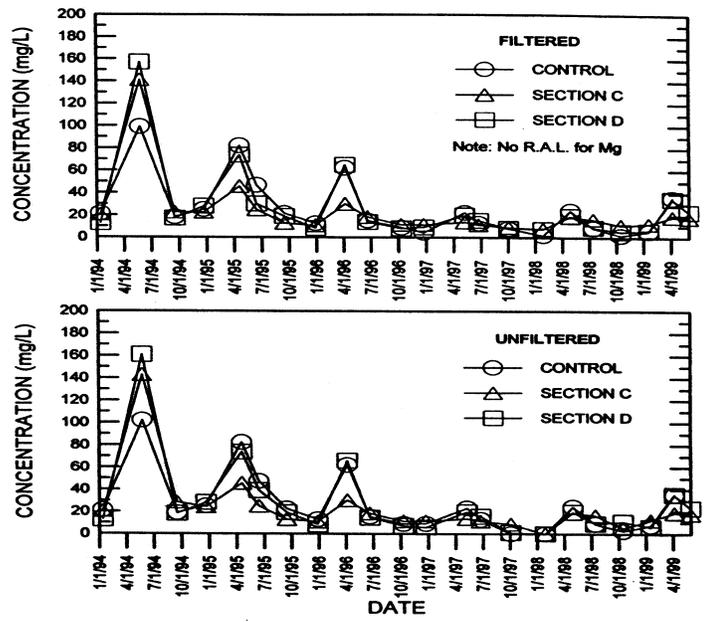


FIGURE 13 Filtered and unfiltered magnesium concentrations.

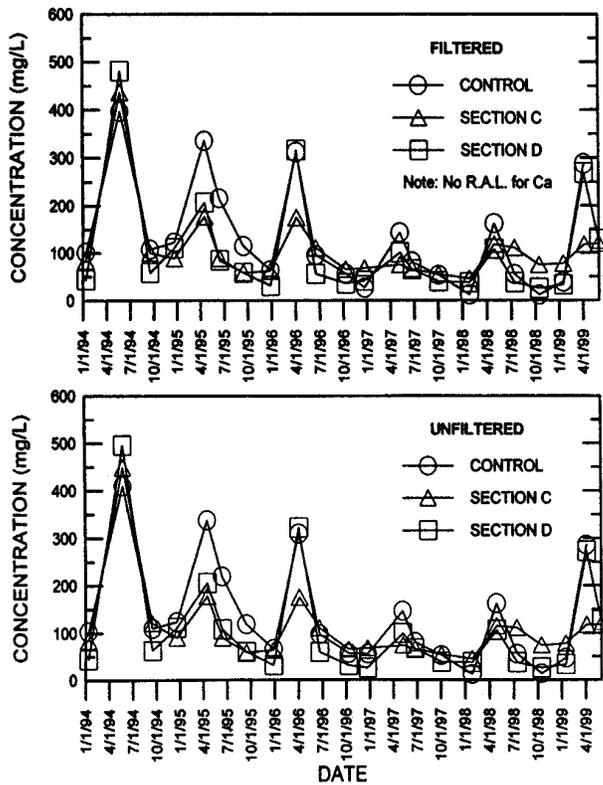


FIGURE 12 Filtered and unfiltered calcium concentrations.

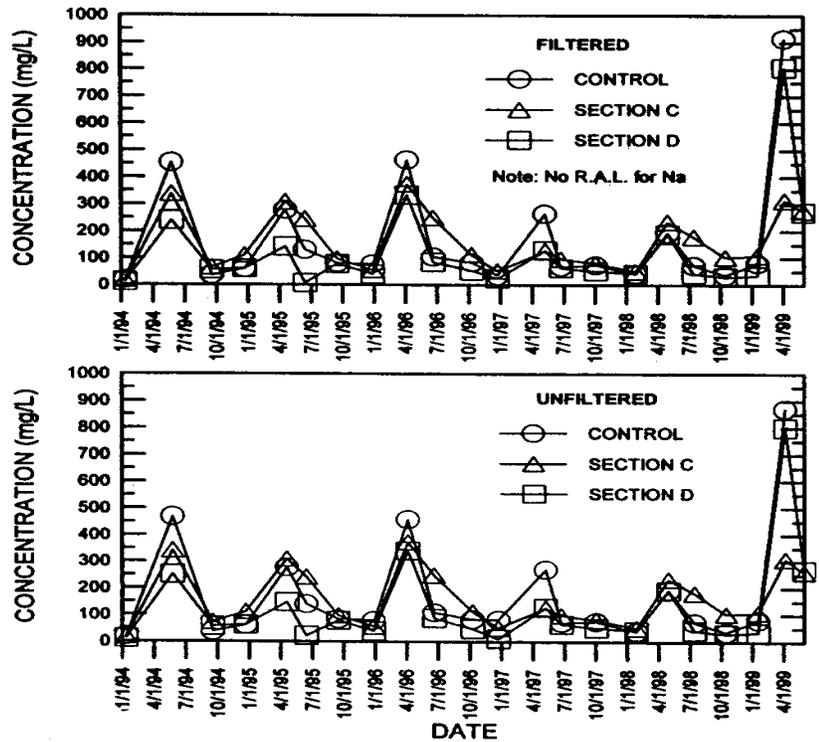


FIGURE 14 Filtered and unfiltered sodium concentrations.

ORGANIC RESULTS

Samples taken on December 28, 1995; and June 22, 1999 were tested for VOCs and SVOCs. ON the first two sampling dates the levels for all compounds were below the test MDLs. In the control section on the third sampling date one VOC was found (toluene at a concentration of 0.070mg/L) and three SVOCs were found [3-(and4--) methylphenol, 0.100mg/L; benzoic acid, 0.025mg/L; and phenol, 0.074mg/L]. The source of these compounds is unknown. They were not present in the two tire shred sections.

On the June 22, 1999, sample date the volatile compounds 1,1-dichloroethane and 4-methyl-2-pentanone were present at trace levels(<0.005mg/L) in Section D. The SVOC 2-(4-morpholinyl) benzothiazole was tentatively identified in the two tire shred sections on the date.

These results are consistent with the results of another field study in which tire shreds were used as backfill for a roadway edge drain on the University of Maine campus (15). For this project, water emerging from edge drain was sampled for VOCs and SVOCs on June 27 1997. All compounds were below the detection limit.

The negligible levels of VOCs are supported by results of a laboratory leaching study (6). In this study, tire shreds and tire shred-soil mixtures were placed in a glass reactor, and the reactor was filled with water and then sealed for 10 months. Six VOCs were above the detection limit but the concentrations were <5mg/L. This is an important check on the results of the field study because the design of the seepage collection basins and sampling tubes leave open the possibility that VOCs volatilized from the leachate before sampling

CONCLUSIONS

- Most of the inorganic substances that can potentially leach from tires are naturally present at low levels in groundwater. These include aluminum, barium, chromium, iron, lead, manganese, and zinc. Thus it is critical that a control section be used to measure the natural background levels of these substances. This allows changes in level caused by the tire shreds to be separated from background levels.
 - No evidence was found that tire shred concentration of substances that have a primary drinking water standard including barium, cadmium, chromium, including barium, cadmium, copper, lead and selenium
 - No evidence was found that tire shreds concentration of the following substance, which have a secondary drinking water standard: aluminum, chloride, sulfate and zinc. There was some evidence that tire shreds could increase the levels of iron and exceed the secondary drinking water standard under some conditions.
 - Tire shreds increase the level of manganese, which has secondary drinking water standard. It is likely that the levels will exceed this standard. However, manganese is of aesthetic concern only.
 - Negligible levels of organics were measured in three sets of samples taken from the North Yarmouth field trial.
 - Tire shreds placed above the water table had a negligible impact on water quality for the near-neutral pH conditions found at the North Yarmouth field trial. This opens the way for tire shreds to be used as lightweight embankment fill, retaining wall backfill insulation to limit frost penetration, and backfill for the edge drains on a wide range of highway projects.

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REFERENCES

1. *Standard Practice for Use of Scrap Tires in Civil Engineering Applications*. American Society for Testing and Materials, West Conshohocken, Pa., 1998
2. Radia Corporation. *A Report on the RMA TCLP Assessment Project*. Rubber Manufacturers Association, Washington D.C., 1989
3. Twin City Testing Corp. *Environmental Study of the Use of Shredded Waste Tires for Roadway Sub-Grade Support*. Groundwater and Solid waste Division, Minnesota Pollution Control Agency, St. Paul, 1990
4. Edil, T. B., and P.J. Bosscher. *Development of Engineering Criteria for Shredded Waste Tires in Highway Applications*. Final Report to Wisconsin Dept. of Transportation, Madison 1992
5. Ealding, W. *Final Report on Leachable Metals in Scrap Tires*. Scrap Tire Task Force, Virginia Dept. of Transportation, 1992
6. Downs, L.A. D.N. Humphrey, L. E. Katz and C. A. Rock, *Water Quality Effects of Using Tire Shreds Below the Groundwater Table*. Department of Civil Environmental Engineering, University of Maine, Orono, 1996
7. Humphrey, D.N., and L.E. Katz. *Water Quality Testing for Dingley Road Shred Tire Test Project*. Report for the Town of Richmond Department of Civil Environmental Engineering, University of Maine, Orono, 1995
8. Humphrey, D.N., and L.E. Katz, M. Blumenthal. *Water Quality Effects of the Tire Chip Fills Placed Above the Groundwater Table. Testing Soil Mixed with Waste or Recycled Materials*. ASTM STP 1275, ASTM Philadelphia, PA., 1997, pp299-313.
9. Nickels, W.L. Jr *The Effects of Tire Shreds as Subgrade Fill on Paved Roads*. M.S. Thesis. University of Maine Orono, 1995
10. Humphrey, D.N., and W. L. Nickels, Jr. *Effect of Tire Shreds as Lightweight Fill on Pavement Performance*. Proc., 14 International Conference on Soil Mechanics and Foundation Engineering, Hamburg, Germany, Vol.3, Balkema, Rotterdam, Netherlands, 1997, pp1617-1620.
11. Clesceri, L.S., A. E. Greenberg and R. R. Trussel. *Standard Methods for the Examination of Water and Wastewater*, 17th ed. American Public Health Association, Washington D.C. 1989
12. *Methods for Determination of Metals in Environmental Samples*. Report No., EPA/600/4-91/010. U.S. Environmental Protection Agency, Washington, D. C. 1991.
13. *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*. U.S. Environmental Protection Agency, Washington D.C., 1987
14. *Methods of Chemical Analysis of Water and Wastes*. Report No. EPA 600/4-79-020. U.S. Environmental Protection Agency, Washington, D. C., 1983.
15. Humphrey D.N. *Water Quality Results for Whitter Farm Road Tire Shred Field Trial*. Department of Civil Environmental Engineering, University of Maine, Orono, 1999.