

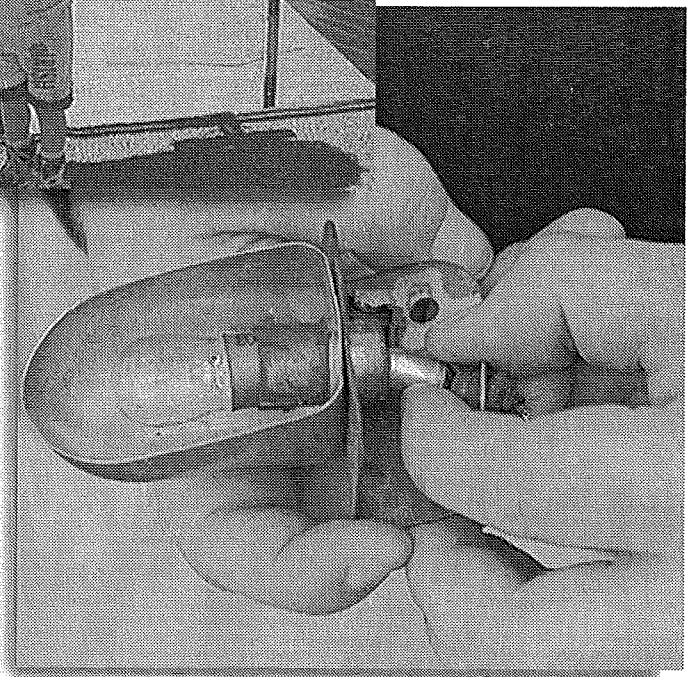
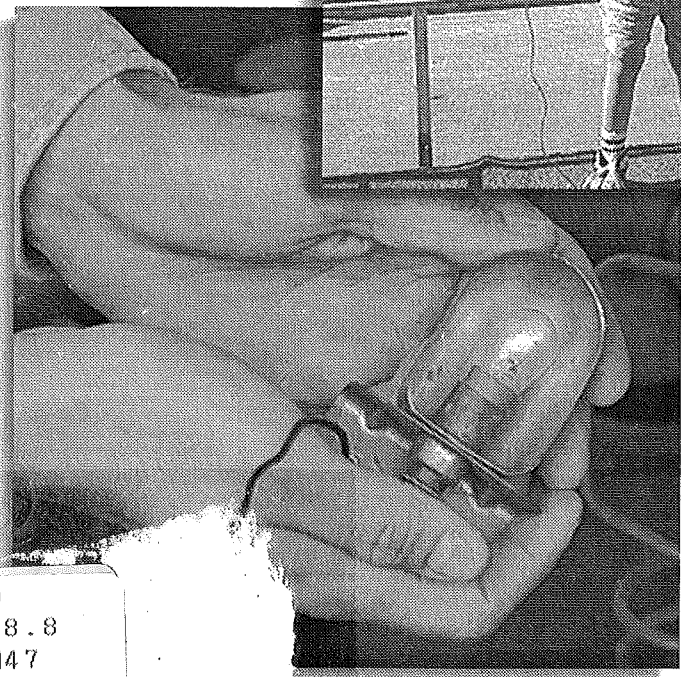
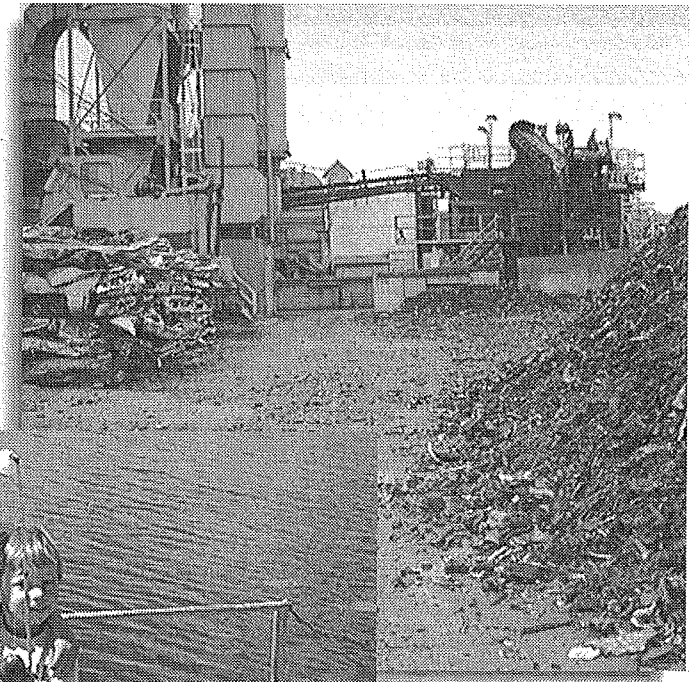
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# AUTOMOBILE SHREDDER RESIDUE R E P O R T



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Minnesota Pollution Control Agency

## Automobile Shredder Residue Report

An Evaluation of Mercury Switches, the Heavy Metal Composition of the Components in Automobile Shredder Residue, and Their Potential Effect on the Environment and Human Health

June 1995

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Minnesota Pollution Control Agency  
Ground Water and Solid Waste Division  
Program Development Section  
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**Presented To:**

The Minnesota Legislative Commission on Waste Management  
June 1995

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Clean Washington Center, Washington D.C.

Glass Aggregate Manufacturing and Engineering Inc., St. Paul, MN

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## Preface

This report was written by a team from the Ground Water and Solid Waste division of the Minnesota Pollution Control Agency (MPCA). Salvage yard research was conducted at a local auto salvage facility. Other sampling and research was done at local area automobile repair shops and dealers. Automobile "fluff" or Automobile Shredder Residue (ASR) is the result of plastics, glass, and other non-recycled materials being shredded and separated from the ferrous metal portions of an automobile. Although some technologies have been developed to recycle some of the ASR, most of the plastics, glass and fluids are currently being landfilled. This topic was researched because of concerns about what to do with the growing volume of potentially toxic auto fluff that is being generated. Research was conducted as outlined in legislation (14):

"...To the extent possible under state and federal law, the commissioner shall encourage reduction in the amount of residue generated, allow beneficial use of the residue, and minimize costs of management and disposal. The commissioner shall study all reasonably ascertainable alternatives for management of the residue, including use as cover material at solid waste disposal facilities, use in manufacture of refuse derived fuel, and any other resource recovery management technique."

The information gathered in this report identifies specific components of ASR along with their individual contributions of heavy metals (cadmium, chromium, lead, mercury, nickel, and zinc). Research was conducted to examine current work on ASR recycling methods. Recommendations made in this report have been developed to aid in improved recycling methods for ASR.

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## Executive Summary

Automobile Shredder Residue (ASR) is made up of a variety of components which contain varying levels of heavy metals. The secondary metals industry recovers roughly 40 million tons of ferrous scrap annually in the United States (U.S.). The largest portion of the ferrous metal scrap comes from the obsolete automobile (8). For every ton of recyclable metal recovered, roughly 500 pounds of non-recyclable residue remains. The amount of plastic, aluminum, and rubber used in automobiles is expected to increase in the upcoming years. High levels of heavy metals (cadmium, chromium, lead, mercury, zinc, nickel, and copper) contained in the non-ferrous portion of ASR can have negative impacts upon the environment and human health. Research was conducted pursuant to Minnesota Laws 1993, Chapter 172, Section 90 and Minn. Stat. Ch. 115A.909 which states:

“...To the extent possible under state and federal law, the commissioner shall encourage reduction in the amount of residue generated, allow beneficial use of the residue, and minimize costs of management and disposal. The commissioner shall study all reasonably ascertainable alternatives for management of the residue, including use as a cover material at solid waste disposal facilities, use in manufacture of refuse derived fuel, and any other resource recovery management technique.”

This legislation was intended to encourage reduction in the amount of shredder residue generated and suggest methods for reducing the toxicity of ASR. The study examines the individual components of ASR for heavy metal content and potential leachability as well as the number of mercury switches that are found in salvaged vehicles. Research was conducted on mercury switches to gain a better understanding of their potential impacts upon overall ASR toxicity. Volume reduction methods and recycling technologies were also explored. Both volume and toxicity were explored in our research because both aspects effect the long-term outcome of ASR recycling. Our examination of mercury switches arose from our obligation to examine ways to reduce ASR toxicity.

We recommend that more research be conducted to provide a better understanding of the issues involving ASR recycling and the disposal of automotive mercury switches. The two initial goals of this study were:

- 1) to identify the most toxic components of ASR; and
- 2) to look for improved ASR recycling methods. Due to information gathered during this study about mercury switches in automobiles, equal attention is given to this issue.

### Mercury Switch Collection Study

The MPCA discourages the use of mercury bearing products due to the potential negative impact mercury can have on the environment and human health. Due to recent awareness about the use of mercury switches in automobiles, and their potential effect on ASR toxicity, four salvage yards were asked to collect mercury switches from the vehicles they processed for the month of March 1995. This was done to get a preliminary estimate of the number of mercury switches that are generated by salvaged vehicles annually in Minnesota. Although more information needs to be gathered, emphasis needs to shift to requiring alternatives to mercury switches. Programs that recycle existing mercury switches and seek to remove them from production altogether are important because not only do they cover the clean-up aspect of pollution prevention, but they also seek to prevent the pollution at its source.

Thirty-four percent of the 605 vehicles sampled contained one or more mercury switches. The average rate of mercury switches is 43 for every 100 vehicles sampled. By extrapolating from the mercury switch collection study data, we estimate that about 86,000 mercury switches are generated by salvaged vehicles in Minnesota annually. Based on the average weight of mercury found in mercury switches (0.8-1.0 grams), we estimate the total amount of mercury generated from salvaged vehicles in Minnesota to be from 152 to 190 pounds per year. As a way of reducing the overall emissions of mercury into the environment, we recommend that automobile manufacturers discontinue the use of mercury switches. This recommendation is derived from the MPCA's strategy of eliminating the use of mercury in products unless the manufacturer acts as a steward and recovers the mercury at the end of the product life. Alternatives to mercury switches are available (such as ball-bearing tilt switches). More extensive research should be conducted to study the presence and abundance of mercury switches in automobiles. Additionally, research should examine the fate of mercury switches. It is believed that mercury switches are either removed by salvage yards, torn open by the shredder, melted down by the ferrous metal furnace, or are left to decay in landfills. Due to the potential environmental and health effects that are associated with mercury being released in to the environment, we believe that the mercury switches currently found in vehicles should be removed and recycled. The cost of removing mercury switches from salvaged vehicles is difficult to pinpoint with 100 percent accuracy because it is difficult to put a dollar value on the labor that would be involved in removing the switches from the vehicles. All of the costs associated with removing and recycling mercury switches include:

- 1) labor for removal;
- 2) labor for removal of switch from light housing;
- 3) collection and transportation costs; and
- 4) recycling charge.

The cost of recycling an individual mercury switch that is removed from its light housing is approximately 3.5 cents. The time and cost of labor involved with removing the switches from



vehicles and from their light housing is minimal and should not amount to more than a few cents per switch. Costs of collection and transportation should also be minimal, but more will be known about these charges when the salvage yard task force publishes its mercury switch fact sheet.

#### ASR Component Composition Study: Phase One and Phase Two

Twenty-four types of automobile components were sampled and tested in vehicles that were ten years old or newer. Two phases of sampling were conducted. The first phase was conducted with salvaged vehicles to determine which ASR components contained high levels of heavy metals. There were 113 samples taken and analyzed for total composition of heavy metals. The second phase was conducted in newer vehicles to ascertain any differences between new and old components and to determine how those metals might leach out in a landfill over time. Thirty-five samples were taken and analyzed. Eight of the initial 24 types of auto components contained high levels of cadmium, chromium, lead, zinc, and copper. Similar components from new vehicles were sampled in Phase Two of the sampling effort for both total composition and the Toxicity Characteristic Leaching Procedure (TCLP). Three out of the eight Phase Two component types that were sampled leached significantly. Those samples were paint, dashboard material, and wire casing. Comparison of the data between Phase One and Phase Two testing revealed the same or similar levels of heavy metals in the various automobile components. Comparison of the total composition of sample components also revealed little or no change in heavy metal composition from 1985 to 1995.

Due to the high volumes of ASR that are being generated, decreasing landfill space, and the cost of disposing of ASR, research and recycling efforts were explored. Current methods of recycling ASR, such as gasification, pyrolysis, and incineration, have not gained wide acceptance by industry. Attempts at using ASR as an intermittent cover layer at landfills has had some success, but still remains a temporary solution in the long run. Argonne National Laboratory has developed a process which can recycle portions of the plastic ASR waste stream. Initial data suggests that this process could potentially decrease ASR volumes by as much as 75 percent. Argonne National Laboratory is conducting further tests on their process to see how it functions on a commercial scale. ASR volume and toxicity levels could be reduced by employing the Argonne process along with selective dismantling procedures (removal of automobile components which contain high levels of heavy metals).

Alternatives to disposing of automobile windshield glass in landfills are available, but difficult to employ at this time. The primary reason for the difficulty in recycling is because of the difficulty of removing the vinyl layer that is built into automobile windshield glass. Research of methods to successfully remove the vinyl coating and create a market for recycled automobile glass are only in the early stages of development.

Based upon the results of Phase One and Phase Two of this report, we conclude that some components of ASR contain high levels of heavy metals. Other components of ASR are less toxic, but when shredded and combined with the other components of ASR, they add to the overall heavy metal levels in ASR. Because of this and the fact that ASR volumes are increasing,

we recommend that more research be conducted to find ways to reduce and recycle ASR. Although groups like Argonne National Laboratory are helping to provide long-term solutions associated with recycling ASR, more research and analysis needs to be done if we are to find recycling options that will be implemented by industry.

## Conclusions and Recommendations

When studying the composition of ASR components and examining ways in which ASR volumes could be reduced, we discovered that this is a problem that can not be solved with short-term strategies and thinking. It is our opinion that solutions to reducing the volume and toxicity of ASR will be found in projects similar to the one being conducted by Argonne National Laboratory and North Star Steel Company. Many barriers exist which may hinder the successful implementation of an ASR recycling program, but with continued persistence, a viable, long-term solution can be found.

When this project began, we researched the existing data concerning ASR. We believe that our recommendations along with other research will lead to implementation of successful ASR recycling, reduction, and reuse programs. The following is a summary of our conclusions and recommendations concerning the mercury switch collection study and the old and new component composition study. We have also included our general recommendations for the reduction of the volume and toxicity of ASR.

Upon reviewing the study results and assessing the mercury switch estimates for Minnesota salvage yard operations, we have made the following conclusions and recommendations.

- 1) Automobile manufacturers should be required to stop using mercury switches in automobiles as long as an economically and environmentally viable alternative exists. Guidance outlining the environmental problems associated with using mercury switches should be provided. This guidance material should also include information about the economic impacts of using other technology (benefits and drawbacks). It should also address how difficult changing to an alternative form of switch might be. Preventing the use of mercury switches by automobile manufacturers will be dealing with the problem at its source. This will save the time, effort, and resources that are currently being spent on removing mercury switches and dealing with them as an afterthought.
- 2) The volume of mercury switches in salvage yards is high enough to continue removal and recycling efforts. The work that is being done concerning the removal and recycling of mercury switches should continue until these switches are no longer found in automobiles, salvage yards, or at shredders.
- 3) More comprehensive research needs to be conducted to properly ascertain the abundance of mercury switches that are in salvage yards now as well as to determine the number of switches that will be coming into salvage yards in the near future (i.e., what companies are using them and how many are they using). This study is a good indicator of the number of switches that may exist and it indicates that there is cause for alarm. However, more thorough research is needed if we are to fully understand

how mercury switches may impact us in the future. Manufacturers need to carefully examine how future automobiles can be produced without mercury switches and thoroughly understand the impact that these switches can have on the environment. In addition, we need to determine the fate of the mercury in these switches from the point at which a vehicle is salvaged to the time it is disposed of at a landfill. These conclusions and recommendations are based upon the MPCA's goal of zero addition of mercury to products.

Analysis of ASR component samples from salvage yards (Phase One) revealed the following:

- 1) of the 24 ASR component types that were examined, eight had high total composition of heavy metals;
- 2) the three metals of concern (lead, cadmium, and chromium) are present at high and low levels in the various samples with some of the samples also containing high levels of zinc and copper as well;
- 3) mercury levels in the individual ASR components that were sampled were not present at high levels when compared with the recommended EPA limit but were higher than background levels (over 0.01 PPM); and
- 4) some of the samples with red pigment contained high levels of lead and cadmium.

Along with these results, Phase One of the sampling effort helped define the set up of Phase Two. The most important question that was answered in Phase Two was which components should be re-sampled for total composition and TCLP testing. Phase Two also helped confirm our results from Phase One (by comparing the total composition results from Phase One to Phase Two) and give a better understanding of the relationship between the total composition of automobile components and their tendency to leach.

Analysis of ASR components from the new component study (Phase Two) revealed the following:

- 1) total composition of the same types of automobile components were similar between Phase One and Phase Two testing;
- 2) the top three automobile components that have the highest levels of heavy metals and have a high potential to leach are: paint, dashboard material, and wiring; and
- 3) these three component types leached at levels that could be hazardous to environmental and human health.

This study was a step-by-step process that evolved as we gained a better understanding of ASR components. Not only did we get greater clarification on the types of ASR components that

are potentially more toxic than others, but we also were able to explore other areas of potentially hazardous heavy metal pollution (e.g., the mercury switch collection study). Most of what was done throughout this project covered new territory. More research should be done to gain a better understanding of the presence and abundance of mercury switches. This report is an important examination of issues that will help to promote better automobile recycling and dismantling efforts in the future.

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## Introduction

This study was conducted due to concern about the growing volume of the non-ferrous portion of Automobile Shredder Residue (ASR) that is primarily being disposed of in landfills. The non-ferrous portion of domestic automobiles (plastic, glass, aluminum, rubber, and automotive fluids) has increased from 5.0 percent in 1978 to 7.7 percent in 1992 (8). The increase in plastic and aluminum composition in automobiles is expected to continue. Our goal in conducting this study was to learn more about the specific parts of automobiles that make up ASR (seat foam, carpeting, bumpers, etc.) and to determine if there are better methods of recycling these components prior to shredding. The two initial areas of concern are:

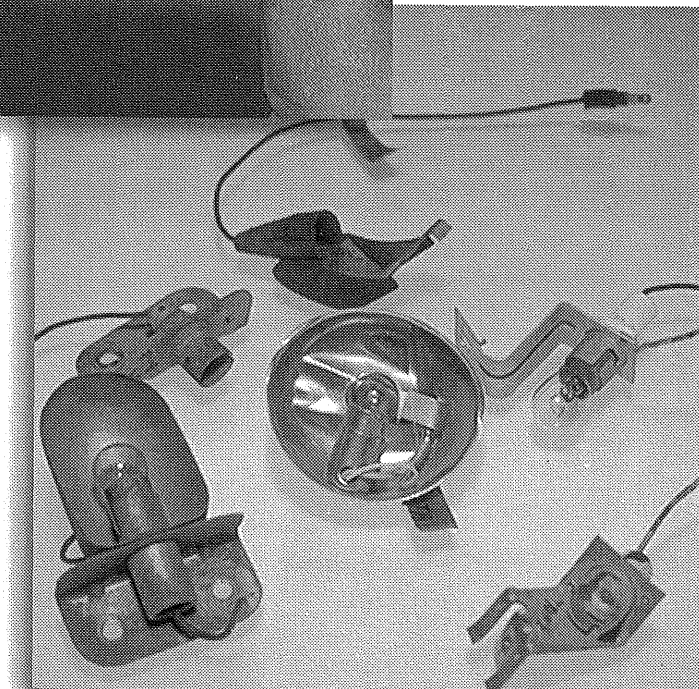
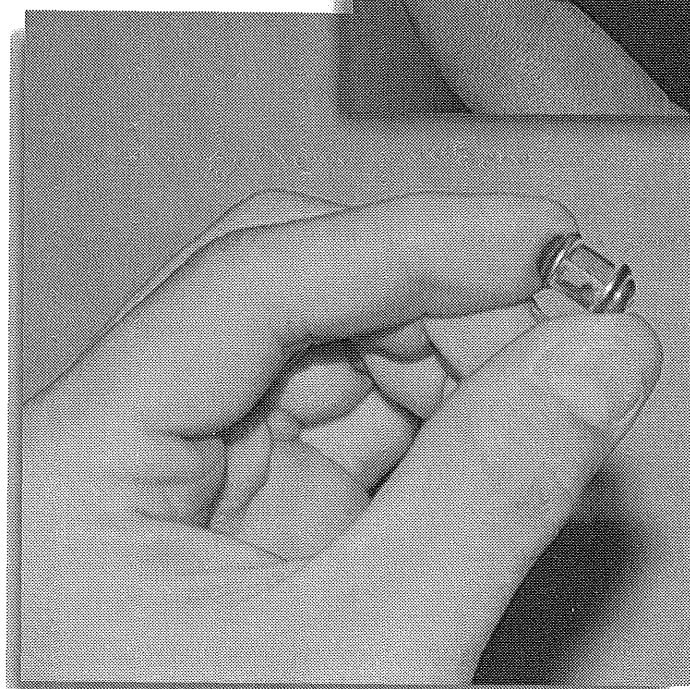
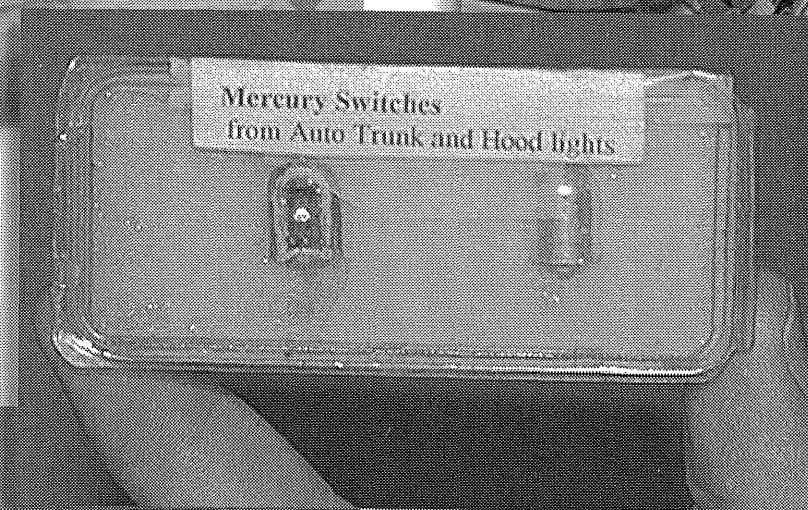
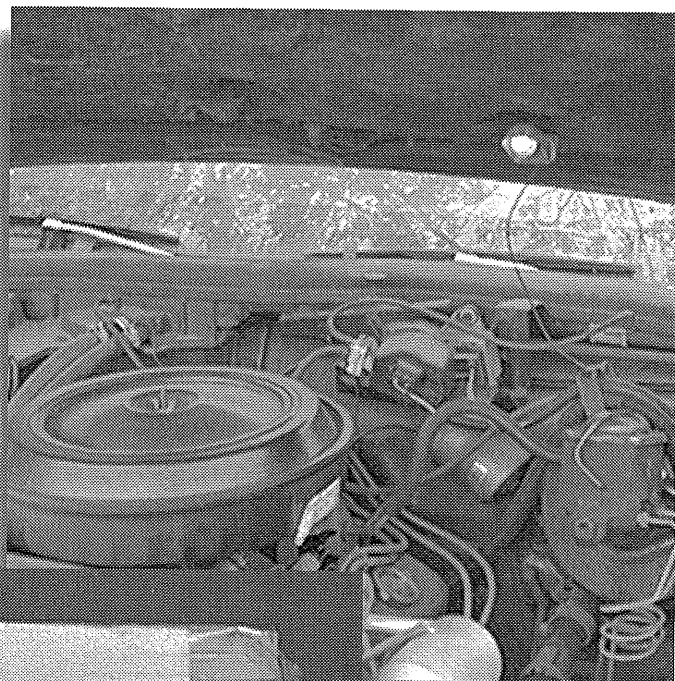
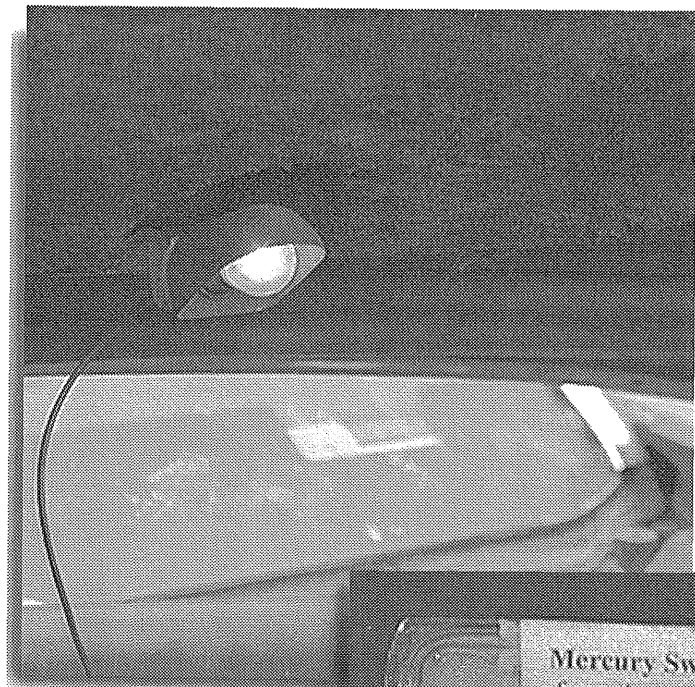
- 1) the growing volume of ASR being generated and landfilled; and
- 2) ways of reducing the toxic levels of heavy metals that may be present in ASR.

During the preliminary research and sampling phase of the study, we discovered the presence of mercury switches in automobiles. While conducting our sampling efforts at local salvage yards, we decided to conduct a study about the presence and abundance of mercury switches in automobiles. The results of this study proved to be valuable, and because of this, we begin this report with research and findings from the mercury switch collection study. The mercury switch study is followed by our findings from the ASR volume and toxicity sampling effort.

The ASR portion of this report looks at 24 key ASR components. By studying these components, we hope to ascertain what heavy metal levels each component contains and consider different methods of recycling or disposal prior to shredding. If large amounts of pollutants are found to be contained in one or more specific components, these components could be removed for safer disposal or recycled rather than shredded and landfilled. Background research was conducted to examine potential ways of recycling ASR.

This report is an internal examination of ASR components and mercury switches. As far as we know, most of what we analyzed in this report is new and different from previous ASR research. As future research and analysis of this data occurs, all stakeholders, industry and otherwise, should be included in the decision making process. The following is a look at our mercury switch collection study findings and an examination of ASR components.

# MERCURY SWITCH COLLECTION STUDY





## Mercury Switches and Potential Contamination in Automobile Salvage Operations

Since as early as 1968, mercury switches have been used by the automobile industry in a variety of lighting applications (10). A reason that mercury switches are used is because they are easy to install and they are reliable. Some of the known applications for mercury switches include trunk lights, hood lights, and glove compartment lights. Other potential sites for mercury switches in vehicles include: side-impact fuel pump shut-off controls and seat belt lock detection devices. With their many applications and cost effectiveness, it is easy to see why mercury switches have been used for so long.

Until recently, mercury switches have been completely ignored when a vehicle is salvaged for parts and sent off to a shredding facility. This means that the 0.8-1.0 grams\* of mercury that each switch contains, is either released to the soil, released to the atmosphere (through volatilization), or landfilled while still contained within the switch (in which case, decay could eventually release the mercury to the environment). Recently, some salvage yards in Minnesota have started to collect the mercury switches found when a vehicle is salvaged. These switches are currently being kept in storage bins on-site and will eventually be sent to a mercury recycling facility in the Twin Cities.

The proposed recycling facility (Recyclights) would take the mercury out of the switches using a mechanical and chemical recovery process. Recyclights uses a single distillation process after which the distilled mercury (99 percent pure) is sold as feedstock to other mercury refineries who triple distill the mercury for sale to mercury users. Initial figures indicate that Recyclights will charge \$4.50 per pound for recycling the mercury switches. The average weight of a mercury switch is approximately 3.5 grams (if it is already removed from its light housing). Using this weight, Recyclights will charge approximately four cents per switch to recycle the mercury. The procedure of pulling mercury switches out of salvaged vehicles prior to shredding has been shown by local area salvage yards to be a relatively simple task. Salvage yards that have started pulling mercury switches have reported no problems with the procedure.

Five local salvage yards were contacted by the MPCA and asked to participate in a mercury switch collection study. The study looked at the number of mercury switches that were generated by salvaged vehicles for the month of March 1995. One of the yards that agreed to participate in the collection study was not included in the final results because it did not conduct its normal processing of vehicles for the month of March. Data from the other four salvage yards was recorded and tabulated as a representative sample. The following is a summary of the study which includes:

- 1) purpose of the study (goals);
- 2) study design;

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\* This value range is based upon measurements that were taken from a dozen mercury switches

- 3) study results; and,
- 4) study conclusions and recommendations.

### Purpose of the Study and Goals

The purpose of the mercury switch collection study was to determine the amount of mercury that is generated by mercury switches in salvaged vehicles for the state of Minnesota. Since automobile mercury switches have only recently become recognized as a potential pollutant source, it was determined that a study should be designed to get a preliminary figure for the volume of mercury that salvaged vehicles generate over a set period of time. Some of the specifics that were determined by the study are:

- 1) the number of switches generated in a month;
- 2) the number of cars required to generate that many switches;
- 3) the approximate age of each switch and the volume of mercury in each switch;  
and
- 4) an estimate for the total amount of mercury that is generated by mercury switches in Minnesota salvage yards on an annual basis.

### Study Design

Four salvage yards participated in the mercury switch collection study. All of the salvage yards agreed to begin collecting the mercury switches (specifically for the study) in a separate container from March 1, 1995, to March 31, 1995. It was agreed that the switches would be collected, tagged with the date and make of the vehicle, and stored separately for the month of March. By setting up the study in this way, we achieved sound, preliminary results with minimal effort and cost.

The primary goal of the mercury switch collection study was to get some feel for the quantity of mercury switches that are being generated at salvage yards in Minnesota. The design of the study was kept simple. This made it relatively easy for the participating salvage yards to complete the collection according to the outline of the study. The four salvage yards were selected because they were already collecting the mercury switches. This made it easier from the standpoint that they were already familiar with the process of removing the mercury switches from automobiles. Their knowledge of the removal process and the fact that they initiated the removal of switches on their own gave us a much better feeling about the reliability of the collection procedure. The other benefit of this study design was the short data collection time required. The period of the study was one month. The yearly figures for mercury generated by mercury switches came from the one month collection period.

The final reason for implementing a study design of this nature was to have actual data and results for the amount of mercury generated from automobile mercury switches. This data may only provide an approximate estimate but it provides us with an important, first look at the situation. It also provides us with a good foundation for future study. The following is a summary of our results, collection process, and other miscellaneous data.

### Interpretation of Study Results and General Conclusions

Table 1 shows the number of mercury switches collected for March 1995, the number of cars that were processed, the number of mercury switches that were found singly or in pairs, rates of switches occurring in vehicles, percentages of vehicles having switches, and the overall totals for the four participating yards. The number of vehicles containing mercury switches among the four salvage yards was 34 percent. Most of the switches that were pulled from the vehicles did not come in pairs as initially thought. One hundred forty-six cars had single switches and 57 cars had pairs of switches out of the total 605 vehicles. Another interesting fact about the switches was that they were found in all sorts of makes and models of vehicles, but almost exclusively in American cars. It has not been determined if this means that foreign cars do not use many mercury switches in their vehicles, the number of foreign cars processed during the collection period was low, or if there is some other explanation. One factor to consider is that the majority of vehicles purchased in the United States (U.S.) are American made. This may mean that the majority of vehicles found in U.S. salvage yards are American made; however, more data would need to be gathered to determine this. Table 2 shows the distribution of the study vehicles that contained mercury switches. Switches were found in everything from Escorts to Audis contradicting the assumption that mercury switches would be found mostly in the more expensive vehicles. Also, mercury switches were found in vehicles ranging from 1968 to present, contradicting the assumption that only older vehicles contained mercury switches.

Extrapolation from the study data provided some idea about the amount of mercury found each year at salvage yards in Minnesota. The following figures are intended to show how many mercury switches there may be in Minnesota salvage yards and the total amount of mercury those switches may contain.

Based upon industry figures, approximately 200,000 automobiles are salvaged annually in Minnesota. The average rate of mercury switches in the automobiles sampled was 43 switches per 100 vehicles. These figures suggest that approximately 86,000 mercury switches are in salvaged vehicles annually. Using the weight of 0.8-1.0 grams of mercury per switch, approximately 68,800-86,000 grams of mercury are generated from mercury switches annually in Minnesota salvage yards (the 0.8-1.0 grams of mercury was derived from weighing the mercury from 12 mercury switches). When converted to pounds, the range is from 152 to 190 pounds of mercury produced by mercury switches per year in Minnesota salvage yards. It needs to be emphasized that these values are only

preliminary estimates. More research and sampling would need to be done on a larger scale to determine if these figures are representative of the true number of mercury switches in Minnesota salvage yards. The point of these calculations is to have some idea about how much mercury these switches might contain on an annual basis. We believe that these figures, though preliminary, indicate a large enough volume of mercury switches in salvage yards to cause concern.

**Table 1****Mercury Switch Collection Study Data Sheet**

	<u>salvage 1</u>	<u>salvage 2</u>	<u>salvage 3</u>	<u>salvage 4</u>	
<u># of cars processed</u>	97	62	168	278	<b>TOTAL=605</b>
<u># of switches found</u>	31	36	53	140	<b>TOTAL=260</b>
<u># of cars w/ one switch</u>	17	34	25	70	<b>TOTAL=146</b>
<u># of cars w/ two switches</u>	7	1	14	35	<b>TOTAL=57</b>
<u># switches/# of cars processed</u>	31/97	36/62	53/168	140/278	<b>TOTAL=260/605</b>
<u>rate of switches (average per 100 cars)</u>	32	58	32	50	<b>AVERAGE=43</b>
<u># of cars w/ one or more switch/ # of cars processed</u>	24/97	35/62	39/168	105/278	<b>TOTAL=203/605</b>
<u>average # of cars with one or more mercury switches</u>	25%	57%	23%	38%	<b>AVERAGE=34%</b>

**Table 2****Breakdown of Study Vehicles That Contain Mercury Switches**

Vehicle Make	Vehicle Year(s)	Vehicle Model
Ford	1974-1994	Tempo Escort LTD F250 Ranger Taurus Crown Victoria Thunderbird Topaz Bronco II Cougar
Buick	1977-1990	LeSabre Regal Park Avenue Celebrity Skyhawk Skylark Century Firenza
Pontiac	1984-1990	Sunbird Bonneville Grand Am
Oldsmobile	1977-1990	Cutlass Ciera Cutlass Supreme Calais Toronado Regency Delta
Chevrolet	1981-1990	Beretta Caprice Lumina
Chrysler	1975-1994	New Yorker Le Baron Shadow Cordoba Laser Reliant Sundance Aries
Cadillac	1979	DeVille Cimarron
Audi	1984	Make Not Available
Honda	Data Not Available	Accord

From this data, we have determined several basic facts that should be recognized and explored further:

- 1) mercury switches are still being used in vehicles in significant numbers (one third of the vehicles sampled had one or more mercury switches);
- 2) until recently, mercury switches have been left in vehicles (some salvage yards are now pulling these switches);
- 3) other applications of mercury switches may be found in vehicles (that are not currently known at this time);
- 4) automobile manufacturers are still producing vehicles with mercury switches in them; and
- 5) other technologies exist that could replace mercury switches in electronic and lighting applications (19).

Bearing these facts in mind, substitutes for mercury switches in automobiles need to be explored. If manufacturers had to bear the cost of recovering and recycling mercury switches from their automobiles, they might switch to other alternative lighting applications. Alternatives do exist that could completely replace the need for mercury switches (19). In 1994, a national shoe company had to replace the mercury switches it used in a line of "light" shoes. The mercury switches were replaced with a similar ball-bearing switch. This type of replacement switch is just one viable, cost-effective option that automobile manufacturers have. If industry was made aware of the drawbacks (both environmental and economical) of using mercury switches, and had alternatives available to them for replacing the switches, mercury switch usage would probably decline. One pertinent example of the environmental impact of mercury is the level of mercury that can cause fish consumption advisories. The current fish consumption advisories in Minnesota are caused by the atmospheric deposition of one gram of mercury for each 20 acres of lake surface (20).

This next section of the report is a summary of Phase One of the project that explains our ASR component study of vehicles from salvage yards. This portion of the report will answer three main questions:

- 1) why we want to understand ASR components on an individual basis;
- 2) how to study that effectively; and
- 3) what the final results of our sampling effort are.

The following is a brief introduction to ASR, current methods that are used to deal with it, and a description of the Minnesota shredder residue grant legislation.

### **ASR: Past, Present, and Future Recycling Methods**

The secondary metals industry recovers roughly 40 million tons of ferrous scrap annually (8). Obsolete automobiles are the number one source of recovered metals, contributing 10-12 million tons each year, with white goods (i.e., refrigerators, washing machines, appliances) as a lesser contributor (3, 8). When automobiles become obsolete, several parts (tires, lead-acid batteries, and automotive fluids, etc.) are removed. The vehicles are crushed to one-half or less of their original height, and then sent to shredder facilities for processing. The vehicles are shredded into fist sized pieces. The ferrous metal pieces are then separated by rotating magnets and recycled. The rest of the pieces are processed using either a water elutriator or an air classifier. The water elutriator separates non-ferrous metals from non-metals via water and gravity. The materials separate into three types of scrap: magnetic materials (ferrous metals), non-magnetic materials like aluminum, copper, non-foam plastic, and "air" materials like polyurethane foam (PUF) and rubber. For every ton of recyclable metal recovered, roughly 500 pounds of non-recyclable residue remains (3). The remaining material, called automotive shredder residue (ASR) then needs to be dealt with in some way.

ASR is a heterogeneous mixture of materials that contains plastics, glass, fibers, foam, dirt, gravel, sand, and automotive fluids (crankcase oil, transmission fluid, etc.) (2). Analysis of ASR can be difficult due to its heterogeneous nature; however, research indicates that metals such as cadmium, lead, chromium, zinc, and copper, occur in ASR at high levels. ASR tends to contain low levels of mercury. The amount of plastic found in ASR is predicted to increase significantly in the near future because of increases in use of plastics in automobiles over the past twenty years (1). Landfilling has been the most common disposal method for ASR. However, with increased environmental regulations, increasing costs of landfilling, possibilities of long-term liability, and decreasing landfill space, companies are looking for alternatives (1, 8).

#### **Automobile Shredding in Minnesota**

Throughout the U.S., there are roughly two hundred automobile shredders currently operating. These shredder operations are supplied by 12,000 vehicle dismantlers and salvage yards. In the Midwest (Minnesota, Wisconsin, Iowa, North Dakota, and South Dakota), there are six primary automobile shredder facilities. Five of those six facilities are located in Wisconsin and Iowa. Minnesota has one facility while the Dakota's have none. Minnesota's only automobile shredding operation, North Star Steel Company, processes a number of different items. Along with vehicles, North Star Steel Company shreds scrap steel and most of the "white goods" in the state. Each year, North Star Steel Company processes approximately 180,000 automobiles. This is the largest segment of the company's business. The total amount of ASR generated by North Star Steel Company each year is around 45,000 metric tons (15, 16). Several options have been developed that are currently being used to dispose of ASR. Those methods are: tertiary recycling, secondary recycling, incineration, and use as a daily landfill cover or "cap." The

following is a look at the current methods of dealing with ASR, an explanation of the processes, and their overall effectiveness.

### Tertiary Recycling

Tertiary recycling is one method of converting the portion of the plastic ASR stream that is composed primarily of hydrocarbons. These plastics are broken down through pyrolysis, hydrolysis, and gasification to produce resources such as liquid fuels, light hydrocarbons, and monomers (2). The following is a brief discussion of the three primary methods of tertiary recycling: hydrolysis, pyrolysis, and gasification.

Hydrolysis involves water reactions at high temperatures and is generally considered for the treatment of Polyurethane foam (PUF) in ASR. The two main products generated through hydrolysis of PUF are amines and polyols. Amines are recycled and sold to the chemical industry. Polyols can be used to manufacture high quality, low density PUF if they are produced from a clean waste stream. When polyols are produced from a clean waste stream, they still need to be incorporated with 50 percent new materials. This is a significant percentage when compared to the 90 percent of new materials needed to mix with polyols that are recovered from uncleaned PUF. Clean PUF is already used as a raw material for the backing on rugs, which currently sells from \$0.25-40.40/pound. It is often more cost effective to sell the clean PUF directly than to process and convert it using hydrolysis (7).

Of these three methods of tertiary recycling, pyrolysis is one of the most recognized by industry. Pyrolysis is a chemical process that decomposes organic materials through thermal reactions. This process breaks down the long-chain molecules in plastics into chemical constituents that can be incorporated into "new" polymeric materials. Compositions of the final product can be influenced by altering either the time or temperature of the process or both. The biggest reason that pyrolysis has not had large commercial acceptance is probably due to the fact that after processing is complete, products usually need to be further treated to bring them up to petrochemical industry standards. In addition, capital costs are high. Some of the advantages of pyrolysis versus other methods are: energy production, reduction in incineration, and reduced ASR volumes.

The third method that is traditionally used for processing ASR, is gasification. Gasification is a process that converts solids (hydrocarbons) into a low-BTU synthesis gas that can be used as an industrial boiler fuel. By processing the gas further, a higher grade of pipeline gas can be synthesized. Most facilities who use the gasification technique, use its recycled fuel on-site because the cost of transporting the product off-site is expensive. Gasification is also an expensive process to set up and maintain. The cost of this process and transportation problems are the main reasons this method has not been embraced by industry.

### Secondary Recycling

Secondary recycling is a process that uses heat to remelt ASR thermoplastics into "new" products. Some common examples of these are:



- 1) lamp posts;
- 2) shingles;
- 3) park benches; and
- 4) miscellaneous construction materials (4).

Two main problems with this form of recycling are:

- 1) the fact that they have a limited market (there are only so many park benches that are needed); and
- 2) the cost of maintenance on the processing equipment is high.

The problem with maintenance is due to the hard particles of glass and grit that quickly wear down machinery. Also, because ASR's composition fluctuates, the process designed to deal with it must be extremely flexible in order to continuously meet product standards and prevent machinery from becoming obsolete.

#### Incineration

The least desirable of the three methods is incineration. With the passage of the Federal Air Quality Act of 1967 (and subsequent amendments in 1970, 1974, and 1977) and growing concerns over such issues like ozone depletion, incineration must be approached with care. Two benefits of incineration include reduced volume and use of waste as a fuel source. Another point to consider with regard to incineration is the current movement towards a sustainable society. Incineration is a method of volume reduction that does not allow materials to be recycled back into society for reuse. In other words, incineration is not something that promotes a long-term, recyclable commodity but rather a waste product that requires disposal.

#### Using ASR as a Daily Landfill Cover

Recently, ASR has been used by landfills as an experimental daily cover. ASR replaces the soil that is traditionally used as daily cover for landfills. Since this is a relatively new method of ASR usage, the benefits are not completely known. However, early data suggests the following benefits of using ASR as a daily landfill cover:

- 1) ASR reduces the amount of run-off from a landfill;
- 2) ASR compacts to 5 centimeters (cm) versus the 15 cm layer that is required if soil is used;
- 3) decreased erosion;

- 4) increased stability;
- 5) soil that was previously used for daily cover can be used for other purposes; and
- 6) ASR has shown the ability to reduce the amount of leaching of heavy metals that may be contained in the landfill (4).

Regardless of the benefits found from using ASR as a daily landfill cover, it is important to understand that this is only a short term solution to the problem of recycling ASR. Other methods need to be realized, researched, and implemented by industry if we are to successfully close the recycling loop on ASR.

Most of these methods of reusing or recovering ASR via chemical processes have limitations. They are either high maintenance and high cost or they only slightly reduce and recycle the total amount of ASR that is currently being generated by industry. Again, these are only short or medium-term solutions. The focus for ASR volume reduction and recycling needs to move toward developing sustainable, long-term solutions rather than short-term, temporary, solutions.

Because of the need for long-term ASR recycling solutions, several national research and development groups have begun working on new alternatives for ASR disposal and recycling. One of those research facilities, Argonne National Laboratory, is a federally funded group located on the campus of the University of Chicago. The laboratory is primarily funded by the Department of Energy. Argonne National Laboratory is one of a few organizations that is heavily involved in developing a process to selectively remove plastics from ASR. Later in this report, we will discuss the "Argonne method" of recycling ASR.

#### Shredder Residue Management Activities in the U.S.

As part of the research process for this report, MPCA staff wanted to find out what shredder residue management activities were taking place throughout the U.S.. We sent a survey to all 50 state agencies that deal with environmental regulation and requested information on the number of facilities shredding motor vehicles and appliances. This survey also requested information about any potential uses for shredder residue, the disposal practices for this material, testing results for heavy metals that may be in the shredder residue, current state regulations for shredder residue, and any research being conducted about this material.

It is estimated that there are approximately 200 shredders located throughout the country. Results from this survey neither confirmed nor rejected this estimate because a number of states do not specifically track or monitor shredding facilities. These shredding facilities may have permits required by federal regulation, but some states do not require additional regulation at the state level.

One use found for shredder residue was daily cover. Of the 40 states that responded to this survey, six states are currently using this material as an intermittent or daily cover. Those states include California, Florida, Maryland, Nevada, Oregon, and Wisconsin. States where use of shredder residue as daily cover has been proposed are Minnesota, New York, Rhode Island and Utah. In Connecticut, shredder residue was used as daily cover, but did not function adequately. Other states may be using this material as daily cover, but it is not regulated by these states or not reported to them.

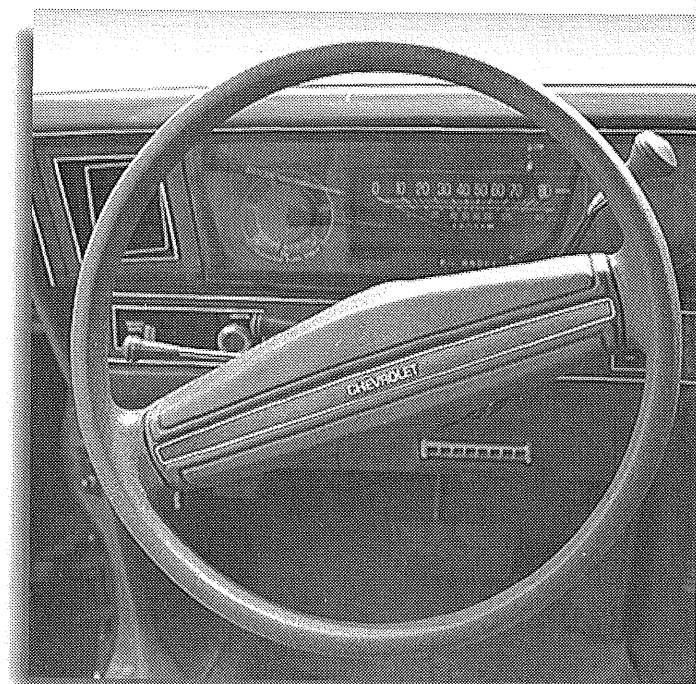
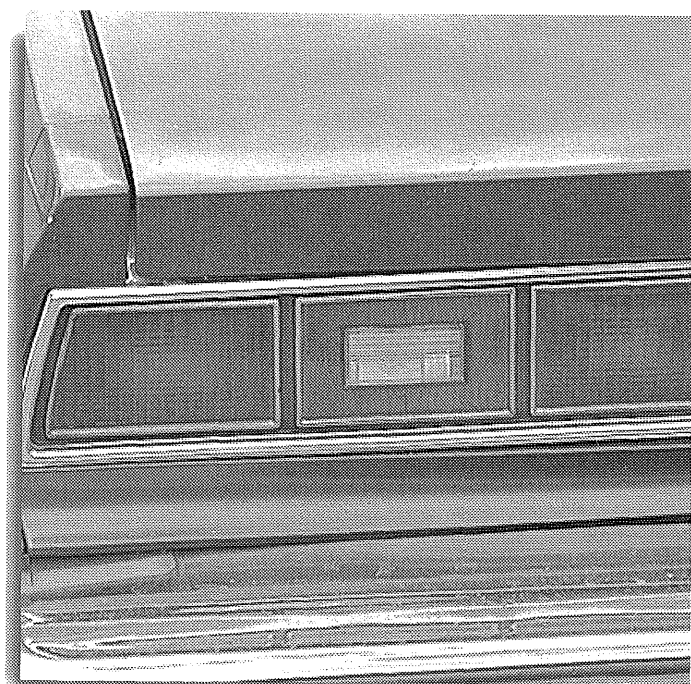
Looking at disposal practices, one disposal method used for ASR is incineration. Four states are currently incinerating ASR. They are Maine, Massachusetts, Rhode Island, and West Virginia. A test burn of shredder residue has been proposed in Minnesota, but has not taken place yet. Although some ASR is incinerated nationally, the majority of ASR is still landfilled.

With regard to heavy metal testing, some states did report problems with Polychlorinated Biphenyl's (PCB's) above the U.S. Environmental Protection Agency's (EPA) Toxicity Characteristic Regulatory Level. Other heavy metal concentrations were present in this material, but did not appear to be above the hazardous waste regulatory level on a regular basis.

Regulation of ASR in other states is similar to, or less restrictive than, requirements in Minnesota. Most states require this material to be sent to a lined landfill, a municipal solid waste landfill, an industrial landfill or one that meets Subtitle D requirements. Also, other states may require that the ASR be tested for heavy metals. Finally, many states hold the individual shredders responsible for determining if their waste is hazardous and expects them to deal with it accordingly.

The final survey question that was asked dealt with new research being conducted within each state. It appears that any research being conducted is being done solely by individual shredders or individual companies with an interest in the ASR waste stream. A copy of the survey form is found in Appendix B.

# PHASE ONE: OLD VEHICLE COMPONENT COMPOSITION STUDY



### **Phase One: Old Vehicle Component Composition Study**

In order to clearly understand what makes up ASR, we designed a sampling plan that examined the primary components of ASR. Separation of these components from the heterogeneous ASR mixture after shredding would be difficult. Because of the difficulty in separating ASR into its constituent components, we decided that a preshredding sampling effort should be undertaken to determine the composition of ASR components individually. In this way, we would develop a better understanding of how each component contributed to the overall levels of heavy metals in ASR. Salvage yards were selected as a sampling population for the following reasons:

- 1) they have a readily available supply of automobiles;
- 2) components can be extracted with relative ease and efficiency at one location;
- 3) large amounts of samples can be taken to obtain the most accurate results;
- 4) samples taken will give some idea of the current composition of ASR that is being landfilled;
- 5) cost of sampling will be negligible (costs would only come from time spent sampling) especially when compared with the enormous cost that would be incurred from purchasing the components; and
- 6) good comparisons can be drawn from data obtained at the salvage yard and the new component sampling portion of the study.

The next step in the sampling process involved component sample selection. After examining research on ASR composition, we decided that 24 types of sample components would be examined. These samples represent the majority of ASR and provide a good look at the possible sources of heavy metals in ASR. Table 3 provides a complete listing of the 24 types of sample components that were taken. The following is a description of the survey design that was used as a general guideline for the sampling effort.

**Table 3****List of Initial Automobile Component Samples Taken For Analysis**

<b>Sample Code</b>	<b>Sample Description</b>
1	Brake fluid
2	Crankcase oil
3	Transmission fluid
4	Rear axle lubrication
5	Radiator fluid
6	Radiator core
7	Dashboard material
8	Steering wheel
9	Seatbelt material
10	Carpeting
11	Seat foam
12	Body panels
13	Bumper material
14	Taillight material
15	"Ding" protective strip
16	Wiring
17	Fanbelt
18	Paint shavings
19	Glass
20	License plate
21	Headliner
22	Air cleaner
23	Radiator hose
24	Hubcap (plastic)

### Study Design For Measuring Heavy Metal Levels in Automobile Components

The first step in the study design was to state an objective for the study as precisely as possible. We determined that our objective would be to estimate the levels of seven heavy metals that may be contained in various ASR components found in automobiles. Those heavy metals are: lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), zinc (Zn), nickel (Ni), and copper (Cu). The data was evaluated and used to make recommendations about reducing ASR toxicity and volume. Automobiles that were ten years old or less were selected for testing because the majority of vehicles being salvaged today, fall into this category. Automobiles older than ten years were not selected for sampling because they do not reflect the bulk of automobile hulks now being processed. The sampling of heavy metals in automobile components was conducted at a salvage yard south of the Twin Cities.

Next, we chose the sampling method. Simple random sampling was the method used in the analysis of the salvage yard samples. This sampling method was chosen because it most accurately represents the mode of extraction of the vehicles prior to sampling. Automobiles were pulled from a holding pen (where they are kept until they are processed for parts) in no particular order. By sampling vehicles in this way, we believe we received a random, representative sample of the various vehicle components.

Next, salvage yard employees brought in seven vehicles. Five vehicles were selected for sampling. Two of the cars were disregarded because they were older than ten years. From the five vehicles selected, 103 samples were collected. Each sample was coded with a letter and number designator. The letter (A-E) denoted which vehicle the sample came from, and the number (1-24) denoted what the component part was.

Since our goal when taking samples was to determine the levels of heavy metals in automobile components, we decided to compare the salvage yard data with data from new automobile components. In this way, we would find out how the cars being manufactured today compare with cars manufactured more than ten years ago. This comparison was intended to help answer questions such as: Are new car components more toxic than older cars?, What specific new components contain higher or lower levels of heavy metals? and, If higher levels of heavy metals are found in new car components, would easier dismantling procedures aid in lowering the toxicity of ASR?

One important piece of knowledge that came from this sampling effort is information we learned when this data was compared with data from Phase Two of the sampling effort. Total composition analysis information was compared between Phase One and Phase Two. This helped to show trends in the automobile industry. Analysis specifically helped concerning the discovery of any significant changes in automobile component composition. This is important because we could compare components of the past to components of the present. The following is a summary of our salvage yard sample data, accompanied by our data sheets.

## Phase One Study Data and Results

### *Laboratory Analysis*

Prior to data collection, arrangements were made to have our samples analyzed at Braun Intertec Laboratory. Braun Intertec Laboratory is one of the laboratories under contract to Minnesota state agencies. The decision to use this laboratory was based on three main factors:

- 1) ability to analyze samples for heavy metal content and accurately report findings;
- 2) timeliness in analyzing data and reporting results; and
- 3) cost of sampling procedure.

After selecting the laboratory for sample analysis, sampling was conducted at a local salvage yard facility. Samples from the five vehicles were collected by a field researcher.

When samples were collected, they were put into containers, coded, and photographed for future reference. The samples were sent to Braun Intertec Laboratory for analysis of the seven targeted heavy metals. The last of the samples was delivered to Braun Intertec Laboratory by the middle of February 1995 and results were obtained on March 20, 1995. The following is an examination of those results and a discussion of their implications regarding potential toxicity of ASR.

### *Testing Method*

All of the initial 113 samples were tested for total composition. To help determine the quality and accuracy of the results we received from the laboratory, two spiked\* samples were sent to the laboratory, along with the other samples. These two samples were automotive oils that contained known amounts of cadmium, lead, and chromium. The laboratory had no knowledge of the spiked samples (which were similar to the other samples of oils we sent to them). The results of the total composition analysis of the spiked samples were at the expected levels. All of the initial samples that were sent to Braun Intertec Laboratory for analysis were tested using total composition testing rather than TCLP (which analyzes a sample for its leaching potential).

The Total Composition test was done in Phase One instead of TCLP for three primary reasons:

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\* The spiked sample is used to test the credibility of the laboratory results by comparing the laboratory's analysis with the predetermined composition of the spiked sample.



- 1) Total composition testing is inexpensive. Therefore, we decided to begin by learning what each automobile component contained as a total composite and then target the components with higher levels of heavy metals for future TCLP testing.
- 2) We did not know what each sample component contained. In testing components for total composition, we were able to determine which components may pose the highest risk of heavy metal contamination.
- 3) The EPA method for TCLP allows for total analysis testing to eliminate samples of a TCLP if the total composition level is less than the regulatory level that is stated in the TCLP regulations.

The standards used to determine if the composition of a component might be high enough to warrant concern, are based upon EPA calculations and values taken from a study conducted by the California Department of Health Services Toxic Substances Control Division (see Table 4) (18, 28). These standards are considered by some to be too high; however, they help to define what levels of heavy metals may pose a threat to the environment. The values are not meant to show that a substance is necessarily hazardous, but that the potential to be hazardous is there. The EPA based heavy metal chart was used to determine which components might have high levels of heavy metals so that we could target them for TCLP testing in Phase Two of the study.

**Table 4**

**EPA Potential Hazardous Limits For Total Composition of Heavy Metals**

<u>Metal Type</u>	<u>Potential Hazardous Limit (based on EPA calculations- values are in mg/kg)</u>
Lead	1000
Cadmium	100
Chromium	500
Mercury	20
Nickel	2000
Zinc	5000
Copper	2500

*Total Composition Testing Method*

Total composition testing is a relatively simple process. First, samples are shaved or broken down into small particles for digestion. Predetermined weights of these sample pieces are put into containers for digestion. Next, the samples are digested, or dissolved, by using varying concentrations of nitric acid, peroxide and hydrochloric acid. Increasing

concentrations of acid are added until the sample is fully digested. The digested sample is then analyzed for the various heavy metals of concern.

This is a simplified breakdown of the testing procedure for total composition sampling. Our intent is to give you an idea of the how the testing process is conducted, so that the sampling process is as clear as possible and the results are better understood. The following is an examination of each of the initial seven heavy metals of concern.

### *Heavy Metal Levels Found in Auto Component Samples*

All of the salvage yard samples were analyzed for seven heavy metals: lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), zinc (Zn), nickel (Ni), and copper (Cu). Mercury levels were tested separately using a cold vapor generation process while the other six metals were tested together using an Inductively Coupled Argon Plasma (ICP) method of analysis. Analysis of the seven heavy metals revealed varied results. Each of the seven heavy metals is examined below by individual metal type. The results of the testing procedure and explanations concerning toxicological effects, are as follows:

#### *Lead*

Testing for lead concentration in the various samples generated a variety of results. Some of the results were expected while others were surprising. We believed that lead concentration would be highest in samples that contained red pigments. Experience has shown us that objects that contain red pigment often times contain higher amounts of lead and chromium (among other things) than other colors used to paint automobiles. Red paint is a good example of a "classic" lead-containing item. The actual results from our paint samples were somewhat surprising. Not only did the red paint samples have high levels of lead in them, but the other paint samples did as well. The other colors of paint that exhibited higher lead levels were gray and blue. Three of the top four "hits"\* for lead occurred in samples that were not red. The results for lead and the other six heavy metals, can be seen in Table 5.

The other "hits" for lead were most frequent in samples from a gray colored vehicle. The samples that contained high lead levels included: wiring, dashboard, "ding" guard protective stripping, and paint. Because of the high levels [measured in milligrams per kilogram (mg/kg)] of lead in these samples, we decided to focus our next sampling effort on the four primary lead bearing samples.

Most of the lead in the environment that humans come in contact with comes from a variety of human activities (24). Vehicle emissions from leaded gasoline have accounted for the largest portion of lead contamination in the environment. People may come into contact with lead in a variety of ways. Exposure may occur in one of three primary ways. Eating foods like seafood, can expose people to high amounts of lead (24). Lead can also

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\* A hit indicates a heavy metal value that is very close to or above the EPA based levels

enter your body by inhaling lead dust and fumes or by drinking liquids that contain lead. The other route of exposure typically occurs in children. Children can be exposed to lead through the ingestion of soil or dust that is contaminated with lead. One of the leading sources of lead contamination in children comes from lead based paint chips (24). Old homes that contain these paints can have high concentrations of lead in the surrounding soils. Also, children may eat the paint chips directly.

Lead at hazardous levels can have the following adverse effects (24):

- 1) increase the chances of SIDS (Sudden Infant Death Syndrome);
- 2) encephalopathy-disease that effects general brain function;
- 3) general developmental effects in children; and
- 4) learning and behavior problems in children. (Symptoms usually do not occur immediately. Symptoms typically occur when they are in their teens.)

### *Mercury*

The highest level of mercury was contained in a sample of blue headliner material that measured 4.6 milligram per kilogram (mg/kg). All other samples were well below the EPA based 20 mg/kg level for mercury (see Table 6). The fact that mercury was present in many of the automobile components that were analyzed, is disturbing. Although the levels of mercury in the analyzed components were well below the EPA based limit for mercury, the MPCA's strategy concerning the addition of mercury to products is very clear. Any mercury that is added to a company's product, that is not later recycled by that same company, is too much. Levels in the components we analyzed should not exceed .01 mg/kg of mercury (.01 mg/kg is considered a background level for mercury) (20).

Mercury is a naturally occurring metal found in the environment from normal breakdown of the earth's crust as well as from a variety of human activities (25). Many different forms of mercury exist in the environment. Metallic mercury (found in mercury switches) can easily evaporate into the air and move great distances before being deposited back into the soil or water through rain or snow. Organic mercury is produced from metallic mercury through the action of some microorganisms. This form of mercury can remain in sources of water for great lengths of time.

Mercury can enter a human body through a variety of pathways. Respiration, ingestion, and skin contact are the three primary routes of exposure (25). Once inside a person, organic mercury can change to inorganic mercury in the brain and remain there for a long time. Exposure to mercury can come from dust, water, food, etc. Exposure can occur in a workplace where mercury is used; however, the most common source of contamination is from mercury contaminated fish.

Mercury has no known benefit to human health. Damage to the nervous system, kidneys, and respiratory system can occur when exposure to mercury is on a long-term basis (25). Full recovery is more likely after short-term exposures.

Mercury at hazardous levels can have the following adverse effects (25):

- 1) damage to the central nervous system;
- 2) dizziness;
- 3) respiratory problems;
- 4) kidney damage; and
- 5) damage to a developing fetus.

### *Cadmium*

Cadmium levels occurred in samples second only to zinc. Ten of the 113 samples contained levels at or above the recommended EPA limit for cadmium. Cadmium is used as a stabilizer in many automotive plastics (11). Samples containing high levels of cadmium include: dashboards, steering wheels, headliner, and wiring. Like the other samples, these four were targeted for sampling in Phase Two.

Cadmium is typically ingested by humans through the air or food. Cigarette smoke contains cadmium. Smokers absorb approximately 1-3 mg per day from cigarettes alone (21). Cadmium can also enter the body through the ingestion of water. People who work with cadmium (such as soldering and welding activities) may be exposed to high levels of cadmium.

Cadmium has no known positive effects on human health (21). Severe lung damage can occur from breathing in high amounts of cadmium. Cadmium levels build up in the kidneys and slowly leave a person's system. In addition to general exposure through the air, water, or food, people living near landfills or hazardous waste sites may run a higher risk of being exposed to cadmium.

Cadmium at hazardous levels can have the following adverse effects (21):

- 1) respiratory problems (lung damage);
- 2) emphysema;
- 3) high incidence of kidney disorders; and
- 4) death from high inhalation levels.

### *Chromium*

Although there were four sample types that contained high levels of chromium, the only sample type above the hazardous level was paint. These paint samples were red and blue. Several paint samples were targeted for Phase Two of the sampling effort. This confirmed our suspicion that certain automotive paints contain high levels of chromium.

Although chromium can be ingested through air and water particles, this is not the route of greatest exposure (22). Chromium exposure tends to come from industrial operations and by ingesting food. Chromium levels do not accumulate to any great extent in fish. Chromium is a necessary element for humans because it aids in the processing of sugar.

High exposure to chromium tends to occur around industrial sites and landfills (22). Also, busy roadways and waterways (with high industrial discharge) can contribute to high chromium concentrations in the environment. Skin contact with chromium has almost no impact on a person. Typically, chromium that is ingested or inhaled in some way, leaves the body through the kidney in a short period of time.

Chromium at hazardous levels can have the following adverse effects (22):

- 1) general lung and respiratory problems;
- 2) liver damage;
- 3) general reproductive problems; and
- 4) increased risk of respiratory cancer.

### *Zinc*

Zinc "hits" occurred in 14 out of the 103 samples that were taken from the five vehicles. Phase Two of the sampling effort (sampling of the same parts tested in Phase One, but in 1993 vehicles or newer) targeted four key samples to compare zinc levels with Phase One (salvage yard samples).

Zinc occurs as a result of both natural processes and human activities (27). Zinc typically enters the body through the air, water, or food. Very little zinc can be taken in through skin contact. Zinc is a necessary element for the body. Zinc exposure (at high levels) can occur from industrial operations such as mining and smelting. Zinc is typically inhaled in these operations. Other routes of general exposure include food ingestion and drinking water (27). These levels of zinc are typically very low.

Zinc at hazardous levels can have the following adverse effects (27):

- 1) vomiting and nausea;
- 2) increased chance of still births; and
- 3) can promote decreased levels of hemoglobin.

### *Nickel*

Nickel was not found at levels of concern. This was not an element of great concern for our study, but testing did confirm our assumption that nickel concentrations were not a major concern in ASR toxicity.

Nickel is a naturally occurring element in the environment (26). Nickel is essential to maintain health in animals and may be essential for humans. High levels of nickel exposure can have damaging effects upon the human body. High levels of nickel exposure typically come from inhalation or ingestion of nickel from industrial processes.

Nickel at hazardous levels can have the following adverse effects (26):

- 1) lung cancer;
- 2) general allergic reactions;
- 3) damage to the heart; and
- 4) damage to the kidney.

### *Copper*

Copper concentrations were similar to nickel concentrations. They were low. We were not as concerned with copper levels, but were interested in what levels were present in the samples. The two "hits" of importance with regard to copper concentration were found in the wiring and paint samples. Because of the "hits" in these two samples by other heavy metals of interest, we targeted these two component types for Phase Two of the sampling effort.

Copper is another naturally occurring element that is an essential element for humans (23). Exposure to high levels of copper can come from drinking water, air (dust), and food. Industrial operations such as mining and welding can create higher copper concentrations. It is not known if concentrations and exposure risk to copper is higher around industrial landfills and hazardous waste sites. This is because it is difficult to tell how high the copper levels are above natural background levels.

Copper at hazardous levels can have the following adverse effects (23):

- 1) liver damage in infants;
- 2) vomiting and stomach cramps;
- 3) general respiratory problems; and
- 4) sexual impotence.

All of the above adverse effects can result from exposure to each heavy metal either through ingestion of food or water, respiration, and skin contact. The severity of exposure can be highly dependent upon factors such as level of exposure, exposure duration, route of exposure, etc. By listing some of the risks of exposure to these heavy metals, we hope to show the potential problems that may be associated with the toxic nature of ASR. In most of the above cases, exposure risk is higher in areas around or near landfills. However, this is not the only area that exposure can occur at significant levels. Most of these elements can move through the water, soil, and air in such a way that contamination and exposure can come far from the initial source (for example, a landfill). This makes the issue of reducing ASR toxicity more important to the general public because it is not just a localized problem.

Table 5

## Auto Components Containing Close to or Above the EPA Hazardous Limits For Heavy Metals

## Total Composition Analysis

Note: All values are in mg/kg. Values in the Over/Under column represent how much above (bold faced value) or below (negative) the heavy metals are compared to the potential hazardous limit.

<b>LEAD</b>						
<u>Sample Code</u>	<u>Part Description</u>	<u>Metal</u>	<u>Sample Level (mg/kg)</u>	<u>Proposed Limit (mg/kg)</u>	<u>Over/Under (+/-) the EPA Limit (mg/kg)</u>	
A17	WIRING	Pb	600	1000	-400	
B8	DASHBOARD	Pb	740	1000	-260	
B17	WIRING	Pb	5200	1000	<b>4200</b>	
B20	GLASS	Pb	670	1000	-330	
B16	DING GUARD	Pb	7800	1000	<b>6800</b>	
D8	DASHBOARD	Pb	1100	1000	<b>100</b>	
D19	PAINT	Pb	510	1000	-490	
E17	WIRING	Pb	720	1000	-280	
E19	PAINT	Pb	6700	1000	<b>5700</b>	
<b>CADMIUM</b>						
<u>Sample Code</u>	<u>Part Description</u>	<u>Metal</u>	<u>Sample Level (mg/kg)</u>	<u>Proposed Limit (mg/kg)</u>	<u>Over/Under (+/-) the EPA Limit (mg/kg)</u>	
B8	DASHBOARD	Cd	280	100	<b>180</b>	
B26	HUBCAP-PLASTIC	Cd	82	100	-18	
C8	DASHBOARD	Cd	680	100	<b>580</b>	
C9	STEERING WHEEL	Cd	160	100	<b>60</b>	
C13	BODY PANELS	Cd	800	100	<b>700</b>	
D8	DASHBOARD	Cd	420	100	<b>320</b>	
D9	STEERING WHEEL	Cd	190	100	<b>90</b>	
D16	DING GUARD	Cd	98	100	-2	
D17	WIRING	Cd	130	100	<b>30</b>	
D22	HEADLINER	Cd	58	100	<b>42</b>	
<b>CHROMIUM</b>						
<u>Sample Code</u>	<u>Part Description</u>	<u>Metal</u>	<u>Sample Level (mg/kg)</u>	<u>Proposed Limit (mg/kg)</u>	<u>Over/Under (+/-) the EPA Limit (mg/kg)</u>	
B8	DASHBOARD	Cr	220	500	-280	
C9	STEERING WHEEL	Cr	330	500	-170	
C19	PAINT	Cr	1300	500	<b>800</b>	
D8	DASHBOARD	Cr	370	500	-130	
D19	PAINT	Cr	1100	500	<b>600</b>	
D24	AIR CLEANER	Cr	390	500	-110	



<b>ZINC</b>						
<u>Sample Code</u>	<u>Part Description</u>	<u>Metal</u>	<u>Sample Level (mg/kg)</u>	<u>Proposed Limit (mg/kg)</u>	<u>Over/Under (+/-) the EPA Limit (mg/kg)</u>	
A18	FAN BELT	Zn	19,000	5000	<b>14,000</b>	
A25	RADIATOR HOSE	Zn	7900	5000	<b>2900</b>	
B18	FAN BELT	Zn	15,000	5000	<b>10,000</b>	
B25	RADIATOR HOSE	Zn	6200	5000	<b>1200</b>	
B26	HUBCAP-PLASTIC	Zn	2900	5000	-2100	
C17	WIRING	Zn	2500	5000	-2500	
C18	FAN BELT	Zn	26,000	5000	<b>21,000</b>	
D8	DASHBOARD	Zn	4000	5000	-1000	
D13	BODY PANEL	Zn	8900	5000	<b>3900</b>	
D17	WIRING	Zn	2300	5000	-2700	
D18	FAN BELT	Zn	19,000	5000	<b>14,000</b>	
D25	RADIATOR HOSE	Zn	5900	5000	<b>900</b>	
E8	DASHBOARD	Zn	9800	5000	<b>4800</b>	
E17	WIRING	Zn	6200	5000	<b>1200</b>	
<b>COPPER</b>						
<u>Sample Code</u>	<u>Part Description</u>	<u>Metal</u>	<u>Sample Level (mg/kg)</u>	<u>Proposed Limit (mg/kg)</u>	<u>Over/Under (+/-) the EPA Limit (mg/kg)</u>	
B17	WIRING	Cu	2800	2500	<b>300</b>	
D17	WIRING	Cu	1800	2500	-700	
D19	PAINT	Cu	1700	2500	<b>800</b>	

**Table 6****Phase One Samples Exhibiting Mercury Levels Above Background Levels**

<b>Part Code</b>	<b>Part Description</b>	<b>Mercury Level (mg/kg)</b>
A10	SEATBELT MATERIAL	0.06
A19	PAINT FLAKES	0.1
A22	HEADLINER	0.03
B11	CARPETING	0.04
B19	PAINT SHAVINGS	0.04
C8	DASHBOARD	0.03
C10	SEATBELT MATERIAL	0.05
C11	CARPETING	0.03
C12	SEAT FOAM	0.03
C13	BODY PANELS	1.0
C19	PAINT SHAVINGS	0.04
C22	HEADLINER	1.8
D1	BRAKE FLUID	0.03
D10	SEATBELT MATERIAL	0.1
D12	SEAT FOAM	0.03
D19	PAINT SHAVINGS	0.04
D22	HEADLINER	2.3
E9	STEERING WHEEL	0.04
E10	SEATBELT MATERIAL	0.06
E11	CARPETING	0.04
E19	PAINT SHAVINGS	0.04
E22	HEADLINER	0.05
F7	BUMPER	0.04

*Interpretation of Study Results and General Conclusions*

The results of this portion of the study gave us a couple key pieces of information. First, from the data received, we were able to narrow the focus of the study. Learning which of the 24 components contained high levels of heavy metals, helped to target potentially problematic components for closer examination. Specifically, we found eight components that exhibited the highest levels of heavy metals. Those components are (in descending order from the sample that had the most "hits" associated with it, to the sample type with the least):

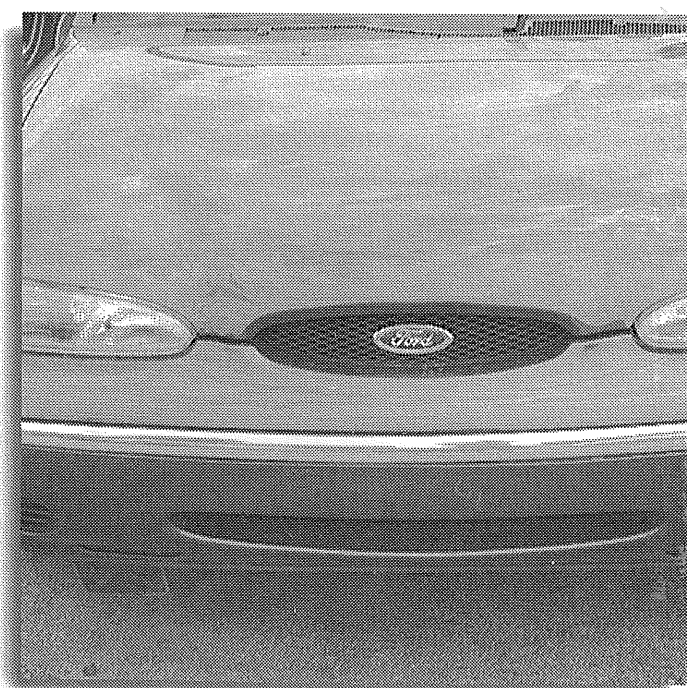
- 1) wiring;
- 2) dashboard material;
- 3) fanbelts;
- 4) paint;
- 5) radiator hose;
- 6) steering wheel;
- 7) body panel; and
- 8) "ding" guard stripping.

These eight components contained varying levels (at or above the recommended EPA level) for lead, cadmium, chromium, zinc, and copper. Mercury levels were found below the recommended EPA level; however, the presence of additional mercury in the ASR components goes against the MPCA's strategy of not using mercury in products. Nickel was not found at levels of concern.

Second, these results helped provide a benchmark for how potentially hazardous these components could be. These specific samples are analyzed in Phase Two via a TCLP test to determine if these higher levels of heavy metals could pose a threat to the environment. The TCLP test is used to ascertain the level of leaching that may occur when the components are landfilled. Basically, these results helped give us a better understanding of the composition of the various automobile components.

These general conclusions are a summary of Phase One of the sampling effort. They will be discussed later in the report in conjunction with our other findings and presented in our final recommendations and conclusions section. This next section examines Phase Two of our sampling effort.

# PHASE TWO : NEW VEHICLE COMPONENT COMPOSITION STUDY



## **Phase Two: New Vehicle Component Composition Study**

After a thorough examination of the individual results of the seven targeted heavy metals, we began Phase Two of the sampling effort. This phase of sampling targeted eight of the sample types that registered high for levels of heavy metals. This time, the sampling took place on vehicles that were three years old or newer. New vehicles were sampled to provide us with data for comparison. We wanted to know how "new" vehicles might compare (with regard to heavy metal composition) to the older vehicles found in salvage yards today. This comparison helped determine trends and similarities in the toxicity of plastic automobile components. Finally, this gave us a chance to "retest" our results. In this way we were able to get a better idea of how reliable our original total composition results were. For example, did we find similar levels of metals in the new samples or did the results differ in some way?

This next section describes Phase Two of the sampling effort, what we learned, and how it compares with our initial sampling data. After the salvage yard data was completed and analyzed, specific new components were targeted for "retesting" based upon several criteria:

- 1) levels of heavy metals found in similar samples taken from the salvage yard sampling effort (samples that were found to have half the hazardous limit or more were targeted for resampling);
- 2) availability of new samples for analysis; and
- 3) cost of additional sampling.

Thirty-five new samples were collected from several local automobile dealers. In each case, parts warranty rooms were used as the sample population. These rooms were used because they contain a variety of automobile components (including all 24 types of sample components taken from the salvage yards). The majority of these components are three years old or newer, and there was no cost for using these samples. The general sample design was the same for the new component composition study as for the old component composition study. Simple random sampling was used because it best represents the mode of extraction of the samples. Two dealers were randomly selected from a group of six and samples of the eight components that were targeted from Phase One, were taken at each facility. Samples were recorded, photographed, and sent to the laboratory for analysis of their heavy metal content and potential leachability.

## Phase Two Study Data and Results

### *Laboratory Analysis*

Samples were sent to Braun Intertec Laboratory. This decision was based upon the same evaluation criteria used in Phase One of the sampling effort. Braun Intertec Laboratory gave us the best price, quality, and timeliness for laboratory testing.

Samples were collected, put into containers, coded, and photographed for future reference. Five of the original seven heavy metals (lead, mercury, cadmium, chromium, and zinc) were examined. The other two metals (nickel and copper) were left out because they were not considered an important contributor to heavy metal contamination in ASR. The removal of these metals from the testing parameters reduced the cost for laboratory analysis. These samples were delivered to Braun Intertec Laboratory on April 7, 1995. The following is an examination of our results and a discussion of the implications of new components on the potential toxicity of ASR.

### *Testing Method*

As with the salvage yard samples, all of the new component samples were tested for total composition. In addition, the new component samples were also tested using the TCLP method. This was done for several reasons. First, we knew which samples contained higher levels of the heavy metals from Phase One. We wanted to target those samples and determine their leaching potential. Second, we only had 25 samples that required TCLP testing. Therefore, the cost was much lower than it would have been if we had done TCLP testing on the original 113 samples. Third, we wanted to compare the relationship between leaching potential of automobile component samples and their total composition. For example, if we found that our new samples of paint contained 100 parts per million (PPM) of lead and that half of it would leach over time, we would have some idea about the amount of lead that might similarly leach from other types of paint.

### *TCLP Testing Method*

TCLP testing is done to simulate the leaching that would occur to objects in a landfill setting. The basic method for TCLP testing is to place a predetermined weight of the sample in a container with an acid solution and agitate the mixture in a tumbler for approximately 18 hours. After this procedure, the fluid is removed, filtered, and the solution is analyzed for heavy metals. The concentration of the acid solution along with the vigorous tumbling of the sample is an attempt to simulate the leaching that may occur in a landfill over time. As with the description of total composition sampling, this is a simplified breakdown of the TCLP testing method and is not intended as a thorough explanation of the testing process. Appendix C provides the general guidelines that are used in TCLP testing.

*Heavy Metal Levels Found in Auto Component Samples*

All of the new sample components were analyzed for five heavy metals: lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), and zinc (Zn). The following is an individual breakdown of our findings by heavy metal type. Some of the results of the TCLP testing are included in Table 7. These results are a summary of the samples that contained close to or above the hazardous waste limit for the heavy metals of concern.

**Table 7**

**TCLP Test Data For Samples Composed of High Levels of Heavy Metals**

<u>Sample ID</u>	<u>Sample Description</u>	<u>Metal</u>	<u>TCLP Reading (ug/L)</u>	<u>EPA limit (ug/L)</u>	<u>Over/Under(+/-) the EPA Limit (ug/L)</u>
S1	Dashboard Material	Cd	800	1000	-200
S5	Steering Wheel	Cr	1600	5000	-3400
SA1	Dashboard Material	Cd	810	1000	-190
SB1	Dashboard Material	Pb	2100	5000	-2900
N12	Wiring	Pb	4200	5000	-800
P1	Paint	Pb	4800	5000	-200
P3	Paint	Cr	86000	5000	<b>81000</b>

*Lead*

Three samples contained high levels of lead. Wiring, dashboard material, and red automobile paint, all contained high total concentrations of lead. High leach rates were also recorded after conducting the TCLP phase of testing. The highest recorded value came from the red sample of paint. The reading was just below the proposed hazardous leach rate for lead-containing items. The wiring sample was next highest with a TCLP value of 4200 micrograms per liter (ug/L). This level is approximately 800 ug/L lower than the EPA limit. The third and final sample that contained high lead readings was found in dashboard material. TCLP analysis of this sample revealed levels approximately half the proposed EPA limit. Lead, cadmium, and chromium were the three elements that were the most prevalent in the analysis of the TCLP phase of testing.

*Cadmium*

TCLP testing of the eight sample types gave us only one sample with high cadmium levels. Two samples of dashboard material and one sample of a body panel had high leach rates (high TCLP levels). The samples were taken from both salvaged and new vehicles.

### *Chromium*

Chromium is the third element that had high TCLP readings. Chromium occurred in two sample types; paint and steering wheel cover material. The highest readings came from the paint samples. The paint sample with the highest reading was the black primer. The steering wheel sample indicated that around one-third of the total concentration of the sample would leach. Although this is not as high as the paint sample, it is a significant amount.

### *Zinc*

Zinc TCLP levels did not occur at any significant levels. Although total concentration of zinc in many samples was high, the TCLP test indicated a low leach potential.

### *Mercury*

The results for mercury for Phase Two were consistently low when applying the EPA's standard TCLP regulatory levels. This may be somewhat misleading; however, because TCLP testing does not necessarily give an accurate assessment of the amount of mercury that will be released into the environment through routes other than leaching (such as volatilization). TCLP levels for mercury were all less than 0.2 ug/L with some of the total values reaching 0.06 mg/kg.

### *Interpretation of Study Results and General Conclusions*

The results of this phase of testing provided us with several key pieces of information. First of all, the total composition results for Phase Two were similar to our results from Phase One. This helped to reassure us that our results were accurate. Also, this gave us an idea about the relationship between some of the samples total composition of heavy metals and their potential to leach in a landfill. There is no definite correlation between the total composition of a component and its leaching potential; however, our results give us some idea of a component's tendency to leach. In some of our samples that tested high for levels of heavy metals, there was also a high rate of leaching (as indicated by the TCLP test) that tended to occur. With that in mind, those components should be targeted for removal or reprocessing to help reduce the overall toxic level of the ASR that is being landfilled. The third main piece of information that resulted from this phase of the study was a better idea of the nature of ASR's toxic components. After completion of the second sampling effort, we are able to rank ASR components (with some degree of confidence) in order of their total concentrations and potential leachability. The top three components from the most potentially hazardous to the least are: paint, dashboard material, and wire casing. If the top three toxic ASR components are targeted for removal and considered for recycling research, salvage yards would be able to separate them prior to shredding.



Overall, the TCLP testing showed us that a variety of ASR components have toxic levels of heavy metals in them. Although a few of these components are toxic enough to be noticed individually, the main point is that the combined effect of the heavy metals in ASR components is significant. By properly understanding which ASR components are the most toxic and more likely to leach, we can be more efficient in our removal of parts to help reduce overall toxicity.

As mentioned earlier, the purpose of this report is not only to examine components of ASR for composition and potential leachability, but also to get a better understanding of how to deal with this material. This next section discusses where automobile technology is moving in the future and how we might find ways of reducing the amount of ASR being put into landfills.

## Impacts of New Technology

New methods of car manufacturing are bringing about change in design of today's automobile. Two of the biggest changes are the increase in the amount of plastic and aluminum used in automobile (6, 8). Due to these changes, ferrous metal use is declining and is being replaced by lighter (and sometimes more durable) plastic and aluminum. The fact that metal use in automobiles is on the decline and plastic use is on the rise only heightens the urgency regarding "what to do with the growing volumes of ASR?"

New technology is being explored by the automobile industry to make vehicles easier to disassemble. Traditionally, vehicles have been manufactured for the most efficient assembly possible. Today, most automobile manufacturers are looking at disassembly because of increased pressure from governmental and environmental organizations. Additional cost savings through recycling are another reason to explore disassembly. If vehicles could be dismantled more easily when they are salvaged, less waste would be going into landfills and more would be recycled. Work is currently being done by the MPCA and North Star Steel Company to find out how removing the majority of the plastic portion of an automobile affects the volume and toxicity of ASR. The study is also examining the time and cost associated with dismantling vehicles to find out if partial or complete dismantling efforts would help reduce the volume and cost of disposing of ASR.

New technology has been introduced by the American Plastic Council that can identify the various types of plastics that are used in automobiles (17). This new method of plastic identification uses an infrared plastic "fingerprinting" method to scan and identify up to 25 different automobile plastics. The identification process takes only five seconds. This portable computerized machine is considered to be "...key to continued advancements in automotive plastics recycling." The actual device is manufactured by Bruker Instruments Inc. of Billerica, Massachusetts.

With so much research and focus on ASR, one question still remains the same. What do we do with the ASR that is currently being produced? One potential solution comes from Argonne National Laboratory. As mentioned earlier, Argonne National Laboratory has been working on methods for recovering and recycling plastics from ASR. The next section outlines the "Argonne method" and discusses its benefits and drawbacks.

### The Argonne Method

Argonne National Laboratories has developed a three-step process to recover thermoplastics: physical separation, solvent treatment, and solvent regeneration. Physical separation begins by running the ASR through a multi-deck vibrating screen separator. This separates the materials into three product streams: iron fines, PUF, and a plastic-rich stream. The iron fines make up roughly 30-40 percent of the total stream's weight and are less than a quarter inch in diameter. PUF is about 15-20 percent of the total ASR weight and a mixture of polyvinyl

chloride (PVC) and acrylonitrile-butadiene-styrene (ABS), accounts for the remaining 50 percent (1, 2, 3, 7, 8).

The second step in the process is solvent treatment. This is handled differently for each of the three product streams. After the initial separation, the iron fines are again separated by using magnets that end up removing 30-40 percent of the materials (primarily iron oxides or rust) and leaves behind the remainder of the ASR which is glass, soil, and miscellaneous automotive fluids (oils, radiator fluid, etc.). The contaminated PUF is initially collected via a vacuum system. First, the PUF is washed with solvents (i.e., acetone and hexane) and rewashed with water and other detergents. Second, the solvents are recovered, leaving a third of the PUF's weight in the automotive fluids. Once cleaned, the foam no longer contains any contaminants and does not give off any offensive odors. When the plastic rich stream (PRS) is first recovered from the initial separator, it is inspected by hand for large metal chunks, which are subsequently removed. At this point, the PRS is washed with boiling acetone to remove oily materials using an extraction system. The acetone is then regenerated but oils and dissolved plastics (like polystyrene) remain. Next, the cleaned PRS is treated again in the same extraction system, but this time using different solutions (i.e., tetrahydrofuran or ethylene dichloride) to dissolve thermoplastics, specifically, PVC and ABS. Finally, the PVC and ABS is treated with a boiling xylene bath to dissolve the remaining thermoplastics polypropylene (PP) and polyethylene (PE), again. The third step, solvent regeneration, is simply a distillation of the solvents. After distillation, the plastics in the solution are left behind to solidify and be collected (2).

The Argonne process appears to be a successful method of recycling ASR. Current research by Argonne shows the potential to reduce plastic ASR volume by up to 75 percent. Projections for recovery of long-term costs and implementation of the complete Argonne process are currently estimated to take 3 - 3 1/2 years. Some portions of the recovery process are much quicker than others (in terms of the turnaround time for recovery costs it would take to break even on the cost of implementing the process). For example, by applying the PUF recovery portion of the three-step process, businesses can reduce their landfill requirements by 20 percent. This would cut their landfill costs by one-fifth and turnaround time for recovery costs is around 1 1/2 years. In addition to the reduction in landfill costs, businesses implementing the PUF recovery process would be able to sell their foam on the market for around 40-60 cents per pound. Implementation of the complete Argonne method could reduce landfill costs by 75 percent and increase profits from recycling portions of the plastic ASR stream.

The MPCA is considering the Argonne process as a potential way of reducing ASR volumes in Minnesota. Among the reasons for this consideration are: the high amount of ASR volume reduction possible via the Argonne process, reasonable turnaround time for profit, and Argonne's willingness to share information and work with interested parties.

Another problem with completely recycling ASR concerns the other main ASR component, glass. Automobile glass poses unique recycling problems and at this point is not considered to be cost effective in terms of recycling. The problems with recycling automobile glass are discussed in the next section along with some relatively "new" potential methods for recycling automobile glass.

### Recovering Glass From ASR

Currently, the majority of automobile glass is left in salvaged vehicles when they are sent to a crusher. After vehicles are crushed and shredded, the glass that is contained in them is landfilled along with the rest of the ASR (9). Some automobile glass blows out the side of the vehicle as it is crushed and may remain near the crusher. One reason that automobile glass is left in the vehicle and eventually landfilled is because of the lack of alternative recycling methods for automobile glass.

Automobile windshield glass is made by adhering a vinyl coating between two pieces of windshield glass (11). This is primarily done to prevent glass from shattering (in the case of an accident) and injuring the occupants of the vehicle. The vinyl coating holds the broken pieces of glass together in one piece. Finding a method of removing the vinyl coating and a good method for recovering the glass before shredding are the two main barriers facing automobile glass recycling.

### *Glass Recycling Techniques and Current Technology*

There are several methods being explored concerning glass recycling. The following summaries are taken from work being done at the Clean Washington Center in Seattle, Washington, along with a brief description of work being done by a Minnesota based group [Glass Aggregate Manufacturing and Engineering, Inc.(GAME)]. These brief descriptions concerning applications for glass recycling are intended to show the potential usefulness of glass recycling in the automotive industry. It is our hope that some of these processes will be investigated further.

#### Project 1: Glass as a construction aggregate

##### Work to date:

- 1) Glass Feedstock Study by Dames and Moore Engineers, July, 1993. Developed test data based on ASTM protocols to demonstrate efficacy of glass as a construction aggregate.
- 2) WSDOT specifications allow glass as an aggregate up to 15 percent in any aggregate applications, and up to 100 percent in specific non-fluctuating load applications.

This process of using glass as a construction aggregate has shown to be successful. Some potential barriers to this method are:

- a) enormous demand of the aggregate market;
- b) new users not wanting to "be the first" to utilize; and

- c) keeping the cost of aggregate low enough to make it a worthwhile alternative.

#### Project 2: Glass in slow sand municipal water treatment

##### Work to date:

A twelve month bench flow test comparing glass with five sands for a planned municipal water treatment system in central Washington to end in March 1995. Work shows positive feedback when using glass in this type of application. Some of the potential barriers to this market are:

- a) glass is an effective medium for this type of operation, but not necessarily the best; and
- b) volumes needed for single municipal water treatment installations may make that application impractical. However, the results may help to open up the use of glass in other recirculating filtration applications (e.g., pools, aquariums, etc.).

#### Project 3: Glass with Portland Cement

##### Work to date:

In this case, glass is used as a fine or course aggregate in making cement or concrete products. Trials have been done with cement panel casters, cement planter makers, and a plaster contractor. One of the potential barriers to this market is glass will not substitute for natural aggregate in concrete manufacturing. It may be used in non-structural products.

#### Project 4: Grit for industrial flooring

##### Work to date:

Trials are being conducted with three installers. The material works fine with resin binders used in wheelchair ramps, coefficient of friction floors, etc. One of the potential barriers to this market is the availability of competitively priced, graded material.

#### Project 5: Glass used as a decorative tile

##### Work to date:

GAME is testing a glass tile for structural integrity. Initial reports show improvement over concrete blocks due to increased drainage and an increase in strength.

One of the barriers to this market is further market development needs to be explored before this option may be considered. Testing needs to be completed on structural integrity.

These five glass recycling alternatives are only a few of the possibilities being explored by industry. Some other alternatives include:

- 1) glass as a hydroponic growth medium;
- 2) glass as a blasting grit;
- 3) glass as an elastomeric roof coating; and
- 4) glass as a septic treatment filtration medium.

All but one of the above glass recycling alternatives used glass sources other than automobile windshield glass for their material base. Again, this is because of the vinyl coating that is put on the automobile glass surface. The decorative tile recycling method is the only one to use a unique process of stripping the vinyl off windshield glass and reusing it. GAME has developed a process that removes the vinyl coating from windshield glass. This process makes it possible to recycle automobile windshield glass and use it in various applications such as the above recycling alternatives. This process is relatively new and more needs to be done to explore the feasibility of removing automobile windshield glass prior to shredding. If this type of process were to be implemented by industry, a number of things would have to be done:

- 1) arrangements would need to be made with salvage yards to remove windshields prior to shredding;
- 2) windshield storage space and shipping costs would need to be explored;
- 3) a solid glass alternative market would need to be established so that the recycled windshields would be able to be used by industry;
- 4) cost for the entire process would need to be low enough so that recycling would be considered a viable option; and
- 5) more research would need to be conducted to study the benefits and drawbacks of using recycled automobile glass.

These barriers to successful implementation of automobile windshield glass recycling are not small. Automobile glass recycling may prove to be difficult, but it is one potential solution to the problem of recycling a material currently being wasted.

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- 22) US Department of Health and Human Services, "Toxicological Profile for Chromium," (1992) Atlanta, GA.
- 23) US Department of Health and Human Services, "Toxicological Profile for Copper," (1990) Atlanta, GA.
- 24) US Department of Health and Human Services, "Toxicological Profile for Lead," (1992) Atlanta, GA.
- 25) US Department of Health and Human Services, "Toxicological Profile for Mercury," (1992) Atlanta, GA.
- 26) US Department of Health and Human Services, "Toxicological Profile for Nickel," (1992) Atlanta, GA.
- 27) US Department of Health and Human Services, "Toxicological Profile for Zinc," (1993) Atlanta, GA.
- 28) US EPA, "Region 5 RCRA Permitting Branch Data Quality Levels," (1994).



**APPENDIX A**

**SHREDDER RESIDUE LEGISLATION**

# Minn Laws 1993, Chapter 172

Sec. Subd. 7. General Support 6,624,000 6,916,000

Summary by Fund		
General	1,762,000	1,762,000
Environmental	4,854,000	5,146,000
Metro Landfill		
Contingency	8,000	8,000

(b) \$150,000 is appropriated in each of fiscal years 1994 and 1995 to the commissioner of the pollution control agency from the motor vehicle transfer account in the environmental fund for the purpose of making grants for development of management alternatives for shredder residue under section 90. The unencumbered balance remaining in the first year does not cancel but is available for the second year and any amount of this appropriation not used to make grants under section 90 reverts to the motor vehicle transfer account on June 30, 1995.

(c) \$140,000 is appropriated to the commissioner of the pollution control agency from the motor vehicle transfer account in the environmental fund for the purpose of studying management of shredder residue from motor vehicles, appliances, and other sources of recyclable steel and administering the grants authorized under section 90.

(d) None of the money appropriated in paragraphs (b) and (c) may be spent unless the legislative commission on waste management has approved a work program prepared by the commissioner of the pollution control agency.

## Sec. 90. SHREDDER RESIDUE; GRANTS.

The commissioner of the pollution control agency may make a grant to a person engaged in the business of shredding and recycling motor vehicles, appliances, and other sources of recyclable steel for the purposes of studying the feasibility of alternative methods of managing shredder residue left over after the reusable and recyclable materials are removed. A person applying for a grant shall include in the application a list of the activities the person will undertake and reasonable estimates of the costs of those activities. The commissioner shall determine the amount of the grant, not to exceed \$300,000 or 50 percent of the total cost of the studies proposed in the grant application, whichever is less.

A person receiving a grant under this section may use the proceeds of the grant for the costs of:

(1) determining and testing methods of reducing the amount of shredder residue and the amount of hazardous constituents in the residue;

(2) periodic testing of shredder residue for hazardous constituents over a limited time period to be determined by the commissioner, but not less than six months;

(3) research and development of potential beneficial uses of the residue, including any preprocessing methods that may be applied to the residue to enable it to be beneficially used; and

(4) any necessary testing of alternative management technologies to determine the environmental and economic effects of the technologies.

## WASTE TIRES AND SHREDDER RESIDUE

### 115A.90 DEFINITIONS.

Subdivision 1. Applicability. The definitions in this section apply to sections 115A.90 to 115A.914.

Subd. 2. Collection site. "Collection site" means a permitted site, or a site exempted from permit, used for the storage of waste tires.

Subd. 3. Office. "Office" means the office of waste management.

Subd. 4. Repealed, 1988 c 685 s 44

Subd. 5. Person. "Person" has the meaning given in section 116.06, subdivision 17.

Subd. 6. Processing. "Processing" means producing or manufacturing usable materials, including fuel, from waste tires including necessary incidental temporary storage activity.

Subd. 6a. Shredder residue. "Shredder residue" means the residue generated by shredding a motor vehicle, an appliance, or other source of recyclable steel after removing the reusable and recyclable materials.

Subd. 7. Tire. "Tire" means a pneumatic tire or solid tire for motor vehicles as defined in section 169.01.

Subd. 8. Tire collector. "Tire collector" means a person who owns or operates a site used for the storage, collection, or deposit of more than 50 waste tires.

Subd. 9. Tire dump. "Tire dump" means an establishment, site, or place of business without a required tire collector or tire processor permit that is maintained, operated, used, or allowed to be used for storing, keeping, or depositing unprocessed waste tires.

Subd. 10. Tire processor. "Tire processor" means a person engaged in the processing of waste tires.

Subd. 11. Waste tire. "Waste tire" means a tire that is no longer suitable for its original intended purpose because of wear, damage, or defect.

HIST: 1984 c 654 art 2 s 92; 1988 c 685 s 45; 1989 c 335 art 1 s 269; 1993 c 172 s 58

### 115A.909 SHREDDER RESIDUE; MANAGEMENT.

The commissioner, in consultation with persons who are engaged in the business of shredding motor vehicles, appliances, and other sources of recyclable steel, shall study management of shredder residue. To the extent possible under state and federal law, the commissioner shall encourage reduction in the amount of residue generated, allow beneficial use of the residue, and minimize costs of management and disposal. The commissioner shall study all reasonably ascertainable alternatives for management of the residue, including use as cover material at solid waste disposal facilities, use in manufacture of refuse derived fuel, and any other resource recovery management technique.

HIST: 1993 c 172 s 61

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HIST: 1993 c 172 s 61

## **APPENDIX B**

# **SHREDDER RESIDUE SURVEY**

**Information Request Regarding Shredder Facility Regulation**

1. What state organization are you responding on behalf of? \_\_\_\_\_  
Please provide the name and telephone number of the main contact person for  
motor vehicle and appliance waste issues for your state.  
Name \_\_\_\_\_  
Telephone Number \_\_\_\_\_

2. Does your state have any facilities that shred the following?(Please circle)

- Motor Vehicles
- Appliances
- Both Motor Vehicles and Appliances
- None of the above

**If your answer was None of the above, stop filling out this survey and please return it in the postage-paid envelope. If your answer was motor vehicles, appliances, or motor vehicles and appliances, please fill out the rest of the survey.**

3. a. How many shredders that process only motor vehicles are located in your state? \_\_\_\_  
Please give name and address.

<u>Name of Facility</u>	<u>Address of Facility</u>
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

b. How many shredders that process only appliances are located in your state? \_\_\_\_  
Please give name and address.

<u>Name of Facility</u>	<u>Address of Facility</u>
_____	_____
_____	_____
_____	_____
_____	_____

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- c. How many shredders that process both motor vehicles and appliances are located in your state? \_\_\_\_\_  
Please give name and address.

**Name of Facility**

**Address of Facility**

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4. What quantity of shredder residue (material remaining that is not reused or recycled in shredding process) must be disposed of by the shredding facilities in your state, annually?

Please provide quantity in cubic yards or tons. \_\_\_\_\_

5. What percentage of shredder residue is disposed of through:

landfilling	-	___%
incineration	-	___%
other disposal method	-	___%

Please describe other disposal method: \_\_\_\_\_

6. What quantity of shredded material is recycled?

Please provide quantity in cubic yards or tons. \_\_\_\_\_

If shredder residue is recycled what is its use? \_\_\_\_\_

7. Have any organizations in your state found beneficial uses for shredder residue? Please give a brief description of any beneficial use found?

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## **APPENDIX C**

# **TOXICITY CHARACTERISTIC LEACHING PROCEDURE**

# Toxicity Characteristic Leaching Procedure

(New EPA-mandated toxicity test)

Major industries which are likely to be affected by the new test include:

- pulp and paper production
- wholesale petroleum marketing
- pharmaceutical production
- synthetic rubber manufacturing
- textile production
- lumber and wood product manufacturing
- petroleum, rubber, plastics and coal products manufacturing
- non-natural gas pipeline maintenance

The leather-processing industry, service stations and fiberglass manufacturers may also be affected.

Effective September 25, 1990, large quantity generators will be required by the U.S. Environmental Protection Agency (EPA) to document that their hazardous waste has been evaluated for toxicity using the new Toxicity Characteristic Leaching Procedure (TCLP). Small quantity generators (those generating less than 1,000 kilograms or 2,200 pounds of hazardous waste per month) must meet the same requirements by March 29, 1991.

The TCLP replaces the Extraction Procedure Toxicity (EP-Tox) test, used by the EPA to determine if certain metal- and pesticide-bearing wastes must be managed as hazardous waste. Both tests simulate the acidic conditions in landfills that can leach toxic metals and organics into ground water; however, the TCLP is significantly more sensitive and accurate than the EP-Tox. For example, TCLP test results for lead content may be five to ten times higher than they were using the EP-Tox test. This is one reason wastes which tested nonhazardous with the EP-Tox test may be considered hazardous with the TCLP.

Another reason a waste may now be considered hazardous is that the waste could contain any of 25 chemicals recently added to the toxicity list. The EPA's new regulations add 25 organic chemicals to the existing list of eight metals and six pesticides. If, after applying the TCLP to a waste sample, any of the 39 chemicals listed (see chart back page) are present in the leachate at or above regulatory levels, the waste is hazardous due to a toxicity characteristic. Generators will need to re-evaluate all wastes formerly considered nonhazardous and decide if the wastes should be retested using the TCLP.

Generators who have already notified the EPA that they generate hazardous waste and have obtained an EPA identification number for their business location are not required by the TC rule to renotify the EPA. They will, however, need to file an

*Text continued on back page* ⇨

**Minnesota Pollution Control Agency**

Hazardous Waste Division  
520 Lafayette Road, St. Paul, Minnesota 55155

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amended hazardous waste disclosure form with the Minnesota Pollution Control Agency (MPCA) if the TCLP reveals that their company's waste is now hazardous for toxicity.

The EPA is now in the process of determining regulatory treatment standards for the new chemicals listed at right. When established, they will be incorporated into the EPA's present land ban regulations which require that most hazardous waste be treated before being contained in a hazardous waste landfill. Until then, generators should manage their newly-defined hazardous waste according to present hazardous waste regulations, including proper on-site management and use of licensed hazardous waste transporters and permitted disposal facilities.

In the future, the EPA may amend the TCLP rule by adding 13 more chemicals to the present list. They must first

<b>EPA's Toxicity Characteristic Regulatory Levels</b>			
<b>Old Constituents (mg/l)</b>		<b>New Constituents (mg/l)</b>	
Arsenic	5.0	Benzene	0.5
Barium	100.0	Carbon tetrachloride	0.5
Cadmium	1.0	Chlordane	0.03
Chromium	5.0	Chlorobenzene	100.0
Lead	5.0	Chloroform	6.0
Mercury	0.2	o-Cresol	200.0
Selenium	1.0	m-Cresol	200.0
Silver	5.0	p-Cresol	200.0
Endrin	0.02	1,4-Dichlorobenzene	7.5
Lindane	0.4	1,2-Dichloroethane	0.5
Methoxychlor	10.0	1,1-Dichloroethylene	0.7
Toxaphene	0.5	2,4-Dinitrotoluene	0.13
2,4-Dichlorophen- oxyacetic acid	10.0	Heptachlor	0.008
2,4,5-Trichlorophen- oxypropionic acid	1.0	Hexachlorobenzene	0.13
		Hexachloro-1,3- butadiene	0.5
		Hexachloroethane	3.0
		Methyl ethyl ketone	200.0
		Nitrobenzene	2.0
		Pentachlorophenol	100.0
		Pyridine	5.0
		Tetrachloroethylene	0.7
		Trichloroethylene	0.5
		2,4,5-Trichlorophenol	400.0
		2,4,6-Trichlorophenol	2.0
		Vinyl chloride	0.2

establish regulatory concentration levels for these chemicals.

For information about industry-specific processes or constituents, contact the Resource Conservation and Recovery Act (RCRA) hotline at 800/424-9346. The hearing-impaired may call 800/553-7672.

**Minnesota Pollution Control Agency**

**APPENDIX D**

**CHARACTERISTICS OF  
HEAVY METALS**

**Minnesota Pollution Control Agency  
Ground Water and Solid Waste Division**

**General Characteristics of Certain Heavy Metals**

<b>Metal</b>	<b>Cadmium</b>	<b>Lead</b>	<b>Mercury</b>
<b>Target Organs</b>	Kidney	Nervous System	Nervous System
<b>Susceptible Population</b>	Smokers	Children	Children
<b>Portal of Entry</b>	Inhalation	Ingestion	Inhalation, Ingestion
<b>Source</b>	Tobacco, Dyes, Inks, Food	Lead-based Paint	Metallic, Food