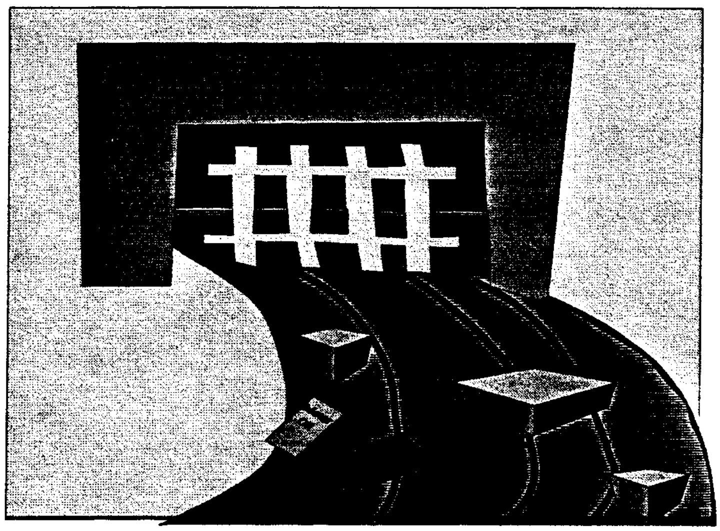
Auto Recycler and Dismantler Facilities:

Environmental Analysis of the Industry with a Focus on Storm Water Pollution



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Auto Recycler and Dismantler Facilities: Environmental Analysis of the Industry with a Focus on Storm Water Pollution

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Environmental Science and Engineering

by

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This dissertation is dedicated to

my parents S. Swamikannu and Rosary Swamikannu

for their personal sacrifices and commitment to my education

my wife Laveeza Bhatti

for her academic and professional achievements which inspire my own

and

the American people

for a wonderful nation that so freely proffers the opportunity to excel

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ABSTRACT OF THE DISSERTATION

Auto Recycler and Dismantler Facilities: Environmental Analysis of the Industry

with a

Focus on Storm Water Pollution

by

Xavier Swamikannu

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Professor Michael K. Stenstrom, Chair

Auto recycler and dismantler facilities, synonymous with auto wrecking yards or junkyards, perform a useful environmental benefit by collecting out-of-service motor vehicles, recycling scrap metal, and supplying replacement auto components. Storm water or nonpoint source pollution has been identified as the largest uncontrolled source of pollutants to surface waters in the United States. Current operational and material handling practices render auto recycler facilities a potential source of significant quantities of conventional pollutants, and toxic pollutants especially heavy metals and certain hydrocarbons, in storm water.

Federal regulations issued pursuant to the 1987 amendments to the Clean Water Act require that the auto recycler industry be regulated for storm water runoff with an emphasis on pollution prevention and waste minimization practices. Current permit requirements proposed by the USEPA appear to be both too broad because they impose an unreasonable burden on many small operators, and achieve too little because they do not emphasize toxic pollutant reduction.

This dissertation discusses the operational characteristics and recycling practices of the auto recycler industry, summarizes recent data on conventional and toxic pollutants in storm water runoff, reviews possible sources for storm water contaminants, and comments on cost factors associated with the economics of auto recycling. In addition, it presents an overview of best management practices and treatment methods to prevent or control storm water pollution from auto recycler facilities. The observations and findings from two studies conducted on the industry focussing on storm water pollutant characteristics, pollutant trends, toxicity characteristics, and storm water treatment are reported.

It is suggested that a tiered storm water regulatory requirement based on vehicle throughput or facility size, and which includes toxic pollutant monitoring for large operators, may be more suitable. The auto recycling industry is an environmentally valuable industry. Public efforts to improve the environmental management of auto

recycler facilities and motor vehicle recycling processes are likely to succeed only with the active involvement of auto manufacturers, automotive material suppliers, and other partners in the automotive business.

INTRODUCTION

This study represents an in-depth investigation of the auto-recycling industry from a water quality perspective with a focus on storm water pollution. The auto recycling industry plays a significant role in the automotive aftermarket, estimated in 1989 at 103 billion dollars (Howard 1990). The industry performs three valuable functions in its business: it (i) collects abandoned, out-of-service and wrecked cars in confined yards; (ii) recycles used or rebuilt parts in the automotive aftermarket; and (iii) provides scrap to processors to reclaim recyclable metals including, iron, lead, copper, zinc and aluminum, and more recently some plastics (USBM 1985, Ness 1984, USDOT 1977, USEPA 1973A). To ensure the continued benefits from the industry, these functions must be conducted in a manner which has minimal adverse environmental impact during the process of motor vehicle recycling. It is intended that this study will increase the understanding of sources and pollutants from auto recycling facilities that affect surface water quality, and identify pollutant sources, feasible technologies and changes in practices to minimize such impacts.

Previous reports on the industry have focussed on locational policies (Suitts 1985; OCPC 1965), highway beautification (FHWA 1979; FHWA 1976, Miller Jr. 1971), scrappage and recycling (USBM 1985, USDOT 1977, USBM 1967), solid waste disposal (FHWA 1975; USEPA 1973A, USEPA 1973B; USBM 1967), and business characteristics (ADRA 1983). The few discussions of the industry's impact on liquid waste generation and recycling have been limited to overviews of automotive-related service industries (USEPA 1991A, CDHS 1988B, CDHS 1988C, CDHS 1987). Interest in the industry from an air pollution perspective has lessened since open burning of auto bodies was made illegal in the 1970s. Air quality management districts now require auto recycler facilities to capture residual chlorofluorocarbons (CFCs) from air-conditioner units. The auto recycler industry also appears to have been recently affected by vehicle buy-back policies being implemented by Air Quality Management Districts to take polluting vehicles off roadways (SCAQMD 1993).

Environmental impacts of automobiles that generated national interest include: (i) abandoned vehicles due to unprocessed inventories at auto-wreckers (USDOT 1977, FHWA 1975, USEPA 1973B); (ii) solid waste generation (USEPA 1973B, USBM 1967); and (iii) material recycling (USBM 1985, Niemczewski 1984, Purcell 1978, Compton 1978, USEPA 1977A). The significant contribution of automobile emissions to non-attainment of air quality standards in major metropolitan areas is also well documented (OECD 1986, USEPA 1991C).

Controlling storm water pollution from previously unregulated industries, such as the auto recycler industry, has become a national priority under the 1987 amendments to the Clean Water Act. Little information, however, has been compiled to assist public agencies in environmental surveillance of the industry to minimize their potential to pollute surface waters. In addition, auto recycler facility operators have been genuinely confused about their compliance duties and responsibilities when pollutants, pollution sources, appropriate monitoring and mitigation measures have not been clearly identified. It is the intent of this dissertation to examine the relevant characteristics of the industry to facilitate such an understanding, to investigate its potential for the contamination of storm water, and to explore mitigative measures that can be undertaken by auto recycler operators.

Of concern are procedures to capture automotive fluids during the dismantling process, and parts removal, auto body storage, and compaction practices. The magnitude of potential contamination, however, differs significantly from facility to facility and depends on factors such as **facility size**, which may range from less than half an acre to several hundred acres; **vehicle throughput**, which could range from less than five vehicles a month to more than a thousand; and the **type of facility**, whether primarily self-service yards where employees prepare vehicles and customers remove parts, or central dismantling facilities where employees perform both dismantling and parts removal.

Early surveys by governmental agencies of the environmental impacts of the industry erroneously concluded that since vehicle dismantling did not consume process water,

water pollution was not an associated problem (USEPA 1973A). In 1990, however, the United States Environmental Protection Agency (USEPA) in its rule-making under the 1987 amendments to the Clean Water Act (USEPA 1990), identified the industry (SIC code 5015) as a category to be regulated for storm water discharges associated with industrial activity. This SIC 5015 industry code describes facilities that primarily dismantle motor vehicles for the sale of used parts. Further, in 1992 and 1993, the USEPA prescribed pollutant parameters, for mandatory monitoring, for the industry in its Federal Register notice (USEPA 1993, USEPA 1992A). The industry was one of twenty-six selected for special monitoring conditions from a list of more than fifty industrial categories developed by the USEPA.

Facilities that dismantle or recycle motor vehicles are progressively beginning to receive much attention because of their potential to contaminate storm water runoff and contribute to nonpoint source pollution (USEPA 1993, USEPA 1992, NCDEHNR 1992, SCVNPSCP 1992, SSP 1992, ADEM 1992A, ODEQ 1991). It is estimated that more than 20,000 auto recycler (synonymous with auto dismantler, auto salvage, car breaker, auto wrecker, and auto junkyard) facilities exist in the U.S. today, where approximately 11 million vehicles are "scrapped" annually (R.L. Polk & Co. 1992, MWCOG 1991). These facilities, while serving the useful function of recycling motor vehicle parts and material, are often poorly managed, and represent a significant but yet unquantified and uncharacterized source of pollutants to surface waters.

The objectives of this dissertation are to (i) review the industrial profile of the auto recycling industry, (ii) research its potential for nonpoint source pollution, (iii) characterize storm water pollution and common pollutants attributable to the industry, and (iv) recommend regulatory approaches and environmental practices that could minimize the pollution potential without endangering the industry. The first two Sections in the dissertation review the auto recycling process and the characteristics of the industry. The third Section summarizes the potential for storm water contamination that exists in the industry based on waste quantities generated, pollutant sources, and storm water quality data. Section 4.0 provides a review of structural and treatment control measures or best management practices that are available to the industry to mitigate the potential for storm water contamination.

Sections 5.0 and 6.0 describe two studies that were conducted on auto recycler facilities to establish the nature of storm water pollution, its potential toxicity to the aquatic environment, and to evaluate selected treatment measures. Section 7.0 provides an overview of policy issues that affect the industry as government agencies take a more comprehensive approach towards addressing environmental pollution. The Conclusions Section summarizes avenues to support recycling benefits provided by the industry while also ensuring that the objectives of environmental regulatory efforts, such as the control of storm water pollution, are achieved without decimating auto recycler operators.

SECTION 1.0 THE AUTO RECYCLING PROCESS

CURRENT RECYCLING PRACTICE

The automobile salvage industry is a major conduit for the flow of automobile scrap to the scrap recycling industry. The recycling of an automobile begins when the vehicle owner determines that the vehicle can no longer be economically maintained or repaired for transportation. It is then towed to a collecting agency or insurance agency, disposed at an auction agency, or driven to a wrecker or dismantler. Few vehicles are abandoned on streets and highways because of the value of the auto body to the scrap industry (FHWA 1976). If this happens, local municipal agencies can be called upon to remove the vehicle under abandoned vehicle abatement programs. Most vehicles are disposed when they are seven to eleven years old, although some are retired sooner as a result of accidents (Ness 1984, USDOT 1977).

The major function of auto recycler facilities in the recycling process is to remove useful parts from retired automobiles, and sell retail or wholesale replacement parts to dealers, service facilities, and individuals. The process of motor vehicle recycling as it occurs today and possible future changes are illustrated in Figure 1.

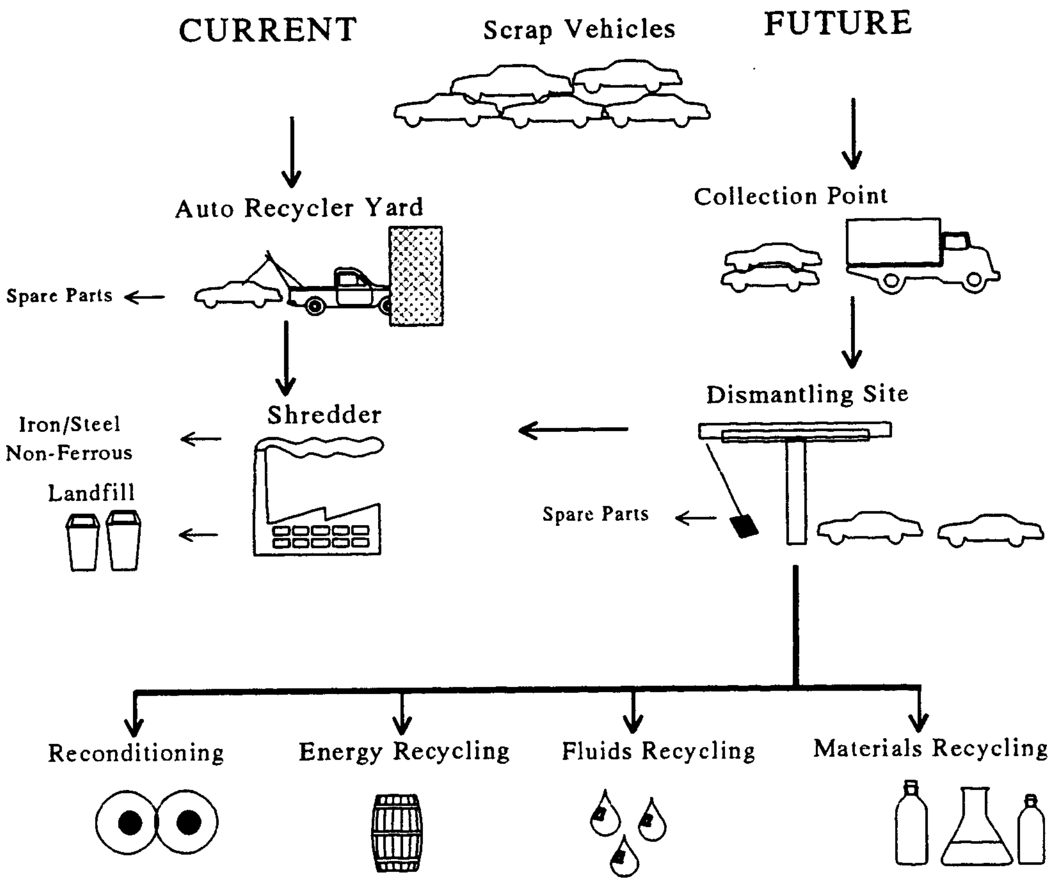

Figure 1. Schematic of the principal stages involved in the recycling of automobiles today and potential future changes. Recycling at present is restricted to ferrous and non ferrous metals, and spare parts. The future envisions new markets for plastics, glass, automotive fluids, tires, and other automotive waste materials.

Batteries, copper radiators, and catalytic converters are stripped from the vehicles, stockpiled, and sold to non-ferrous metal dealers. Other parts with high inherent scrap value such as trim and carburetors (zinc and stainless steel), and catalytic convertors (platinum, palladium, and rhodium) may also be removed for separate sale. Seventy-five percent of the income to auto recyclers is derived from the sale of replacements parts and only 4.3% from the sale of scrap (ADRA 1983). If the auto recycler facility has its own transportation trucks, the residual auto body is sold directly to the shredder. More commonly, the residual auto body is sold to a collector who flattens the body, and then transports 18 to 20 units at a time on flatbed trucks to a shredding facility. Gas tanks, mufflers, catalytic converters, and tires are removed before transfer as a standard practice.

At the shredding facility, the auto body is baled, by a hydraulic compression process to facilitate handling (Ness 1984). A hydraulic shear then cuts the bales to a predetermined size. The sheared bales are then fragmentized and sorted into ferrous and non-ferrous fractions in the shredder. The metallic fraction is transported to a storage bin before being shipped to a mill or foundry. The non-ferrous fraction is further processed by a water elutriator or an air classifier for metals recovery. The shredder waste is then disposed of at a landfill (CDHS 1989, USBM 1986). It is estimated that such recycling of vehicle scrap reduces the volume to be disposed in landfills by nearly 97% (Holusha 1991).

ENVIRONMENTALLY SAFE RECYCLING

Strict environmental recovery laws in European nations, declining landfill space, and the absence of a reasonably efficient dismantling industry have compelled automakers to look at alternative approaches to private dismantling (VW 1991; Brooke *et al.* 1990). The global impetus to improve the recyclability of motor vehicles may be attributed to the German Waste Management Act of 1986 (*Gesetz zür Vermeidung und Entsorgung von Abfällen*), which is still in the implementation phase (BUNR 1990A, BUNR 1990B). Salient features of this law include: (i) assigning responsibility for minimizing waste generation to manufacturers and distributors of products, (ii) promoting waste reuse over waste disposal, (iii) conferring broad authority on the federal government to establish regulations for waste management, including elimination or reduction of hazardous substances, and (iv) incorporating waste oil management provisions to ensure proper recycling, reuse, and disposal (BUNR 1987, BRD 1986).

Auto manufacturers are currently evaluating several options to improve and increase the recyclability of vehicles. The key to environmentally safe recycling of motor vehicles appears to be the establishment of a mechanism to ensure delivery of scrap motor vehicles to the auto recycler, and the establishment of proper disassembly and safe materials separation procedures.

Some of these measures have been tried with some success in the past although not with an integrated approach to vehicle recycling. In the U.S., a one-time surcharge on vehicle registration fees was used to create a fund to reimburse the shredder or an auto recycler for every vehicle collected. This largely solved the abandoned vehicle problem of the 1960s and 1970s (FHWA 1976). In Sweden, a scrapping premium, which includes charges for recycling, is presently collected from the vehicle purchaser. The fee is partially refunded to the final owner of the car in the form of a tax deduction after showing proof of legal disposal (Nobile 1991, Volvo 1991). The value of used parts has largely eliminated the importance of the scrap vehicle reimbursement incentive to auto recyclers in the U.S. However, in the absence of tangible incentives and with the increasing costs of recycling wastes and recovering recyclable materials, proper disassembly, safe materials separation, and waste recycling are often not practiced by many small operators.

Presently, an auto recycler can maximize profits from resale of parts and sale of metal scrap without any attention to good recycling practices because there are no incentives, financial or otherwise. Further, many auto recycler operators have paid scarce attention to compliance with environmental regulations. The deterrent that exists, which is the threat of facility shutdown for non-compliance with environmental laws, is seldom enforced. Consequently, one is likely to find many noncompliant risk takers, and illegal disposal practices are common. For example, in the U.S., only about 25% of the 300 million tires generated annually are recycled (Brooke *et al.* 1990). The remainder are sent to landfills or stockpiled, mostly illegally. Similarly, in Sweden, only 10% of the four million scrapped tires each year are recycled. However in Germany, 97% of the 47 million tires scrapped each year are recycled because of high dumping charges coupled with a vigorously practiced recycling program (VW 1991, Volvo 1991).

Efforts in the United States

The U.S. Bureau of Mines conducted research on separation and recovery of useful materials from scrapped motor vehicles between 1965 and 1983. This research, largely targeted resource recovery and centralized disassembly operations, did not evaluate environmentally safe disassembly practices and small scale vehicle dismantling activities from an environmental protection perspective (USBM 1985, USBM 1967).

American motor vehicle manufacturers were not a part of this effort and were inattentive to the fate of their products. However, with declining landfill space, broader classification of hazardous wastes, and apprehension over potential legislative fixes, U.S. manufacturers have become more sensitive to improving the recyclability of motor vehicles. Chrysler, General Motors, and Ford, in partnership with auto recycler associations, have formed a consortium to research methods for improving motor vehicle recyclability and to establish guidelines for proper vehicle disassembly (Murphy 1993, CIWMB 1993A, Rouse 1991). The German automaker BMW has initiated a pilot program with the Auto Recyclers Association (formerly the Auto Dismantlers and Recyclers Association) to study the feasibility of establishing a network of BMW recycling centers in the U.S. (BMW 1992). In addition, the Society of Automobile Engineers, working with U.S. automakers, has established a coding standard on the basis of chemical content to facilitate reuse and recycling of plastics (Rouse 1991, Brooke *et al.* 1990, McCosh 1990).

Efforts in Europe

The Swedish auto manufacturer Volvo has initiated a pilot project with a Swedish auto recycler to study current costs and preferred methods of vehicle dismantling and to determine if economic incentives are necessary to sustain better recycling (Volvo 1991). Results from the project will be used to develop a guidance manual for environmentally safe vehicle disassembly and dismantling for use by auto recyclers. German automakers Volkswagen and BMW have established pilot plants to study recycling of scrapped motor vehicles and to develop viable recycling methods for independent private firms and to provide employee training (VW 1991, BMW 1991).

Volkswagen is promoting a market approach which avoids requiring the manufacturer to accept 'returns' (VW 1991). Vehicles will be turned in by the last owner to private recycling facilities which have the expertise and authorization to accept them. The owner is issued a certificate of legal disposal which is then used to deregister the vehicle.

The recycler facility removes fluids and useable components to maximize recovery and to minimize waste generated at the shredder. The first step at the auto recycler facility is the drainage of fluids and lubricating oils to minimize contamination of shredder waste. The fluids and oils are collected in special containers by type, as fuel, engine oil, gear box and differential oil, shock absorber oil, hydraulic fluid, brake fluid, coolant, and refrigerant. Some of the fluids may be reconditioned at processing facilities to achieve the quality of new liquids. The next step involves the dismantling of drive units including engines and gear boxes according to specifications. Suitable units are reconditioned and unsuitable units are drained, freed of plastics and shredded. Similarly from the battery unit, the lead is reclaimed, the propylene from the battery casing is reconstituted, and the sulfuric acid reconditioned. Catalytic converters are reclaimed for precious metals like platinum and rhodium.

Glass panes are removed separately and collected according to type of glass. Rubber in gaskets, seals, and tires is reconditioned or reused as special fuel or filler material. Plastics will be reconditioned or collected for refabrication as fuel tanks and bumpers, and upholstery reclaimed for alternative uses. Metals are largely recovered at the shredder.

BMW espouses a similar approach to motor vehicle recycling but instead of a fixed residual value, supports a freely negotiated value between the last owner and the auto recycler facility authorized to accept BMW vehicles (BMW 1991). BMW believes that such an approach: (i) encourages the last owner to be responsible in delivering the vehicle; (ii) induces the manufacturer to develop a recycling-friendly vehicle that will enhance its residual value, and; (iii) compels the auto recycling facility to work with maximum efficiency for better business.

The Recycling Process in the Future

In the future, the motor vehicle recycling process is likely to be more systematic than at present if the trend in Europe is indicative (Figure 1). Retired vehicles will be returned and dismantled in a multiple stage process that will reduce the vehicle to individual assemblies and subassemblies (McCosh 1990). In the first step, all fluids in the cars will be drained. Then, sequential processes will remove doors, hoods and deck lids, then the interior, followed by disassembly of the trunk, exterior panels, engine compartment, and undercarriage. The engine, motors and pumps will be reconditioned for resale, and the bare body shredded and sent to a steel mill. Residuals like plastics, glass, motor fluids, rubber, cables, electronic components, and tires will be separated into similar elements which are then sent to raw material producers for reuse. European auto manufacturers have already begun labelling plastic parts according to recommendations of the Association of German Auto Manufacturers, and Nissan has established a coding system in Japan (Link 1991, Nobile 1991, Harrell 1991).

SUMMARY

This section discussed current processes involved in the recycling of automobiles, and reviewed new developments, especially in Europe, to render the activity environmentally safe. It is expected that these changes will impel the auto recycling industry in the U.S. to take a more systematic approach in conducting their business and develop partnerships with vehicle manufacturers in their efforts to implement pollution reduction measures. Governmental efforts to minimize environmental impacts from auto recycling activities, including storm water pollution, are likely to succeed only if a more integrated approach is taken towards understanding current problems in auto recycling and possible solutions.

SECTION 2.0 THE AUTO RECYCLING INDUSTRY

OPERATIONAL CHARACTERISTICS

Motor vehicles received by auto recyclers fall into two categories; - those that are uneconomical for transportation and those that are uneconomical to repair from damage in accidents. Vehicles that are more than ten years old have primarily scrap value while those that are newer have significant spare parts value (Ness 1985, USDOT 1977). Scrap prices paid to auto recyclers can range from $65 a metric ton for car bodies to $1,250 a metric ton for copper-rich radiators (Howard 1990). Most auto recyclers will take any out-of-service vehicle for parts salvage. However, some operators specialize their business exclusively to imported vehicles, domestic makes, pick-up trucks, and luxury name brands to attract specialized customers. From a customer's perspective, purchasing recycled parts often constitutes cost savings of between 100% and 400% when compared to new parts.

There are two distinct types of auto recycler facilities; one that is operated as a self-service facility, and the other as a service-counter facility. In between these two classes, some minor variations exist. These variations are largely determined by facility size, the need for storage space, the volume of business, and number of employees.

Large facilities in both classes often conduct auxiliary practices which may be additional sources of pollutants. These include compaction of vehicles (crushing) to increase the number of vehicles for transport on flatbed trucks, and compaction of the auto hulk into a bundle (baling) for delivery to the shredder. The crushed auto bodies, vehicle bale, or the stripped vehicles (cores) are delivered for metal recovery to approximately 220 shredders nationwide, including eight in California (Holusha 1991, CDHS 1989).

The Self-service Type Facility

At the self-service recycler facility, purchased vehicles are drained of most fluids including gasoline; gas tanks, catalytic convertors, batteries and radiators are also removed. The vehicle is then displayed in an open area on jacks, hubs, or some other device that provides elevation. Such facilities are often large, greater than 8.1×10^{-3} km^2 (>2Ac), because of the need for open display space. The customer is charged a nominal entrance fee and allowed to remove parts of interest using a personal or rented tool box. One pays only for the parts that one wishes to carry away. Self-service facilities, generally appear to have poor housekeeping practices and require better environmental management because of extensive customer involvement in parts removal with little attention to good dismantling practices (this observation was apparent from several site visits). Some facilities collect an environmental tax to pay for waste disposal. The vehicle remains on display for about a month before being sent to a shredder. The sources of pollutants from self-service auto recycler facilities are employee-directed vehicle dismantling practices, material storage practices, and auxiliary activities if any.

The Service-counter Facility

At the service-counter facility, purchased vehicles are drained of fluids and gasoline, and have the gas tanks, catalytic convertors, radiators and batteries removed. The vehicle is then disassembled by employees for readily saleable parts (20 to 30 components) which are inventoried and stored in bins or on shelves under a cover. These parts are cleaned and tested before warehousing. The vehicle with less saleable parts is stored in an open area. The customer is served over-the-counter for the purchase of desired parts. Occasionally, if a part on a vehicle is desired, the customer is escorted to make the selection and the part is then removed by an employee. Larger facilities of this type primarily deal in wholesale and serve repair shops, car dealers, parts rebuilders, and insurance companies, while smaller facilities have a greater proportion of walk-in customers. Vehicles remain on storage display between 1 to 2 months before removal to a shredder, although smaller facilities tend to hold them for much longer periods. Large service-counter facilities are generally better maintained and managed than facilities where the customer is involved in parts removal. At facilities of this type, the auto recycler operator has greater control over the manner in which auto parts are removed. Small size facilities, however, often appear poorly kept due to a lack of environmental awareness. The primary sources of pollutants at service-counter facilities are from employer-directed parts removal, material storage practices, and auxiliary activities if any.

AUTOMOBILE USE AND SCRAPPAGE

Global and the United States

Motor vehicles are the primary mode of surface transportation in industrialized societies. In the United States, the total number of registered motor vehicles has grown from 33.5 million in 1946 to nearly 200 million today (R.L. Polk & Co. 1993). Global estimates report that there are approximately 600 million motor vehicles in use for both public and private transportation (Nauss 1994, Renner 1988). The worldwide vehicle scrappage rate is approximately 30 million vehicles per year. Recent motor vehicle census figures provided by the Federal Highway Administration show that the United States has more than 188 million registered vehicles (FHWA 1992). In the U.S., the total number of motor vehicles scrapped has increased considerably in the last half century, from less than half a million vehicles in 1946 to about eleven million vehicles in 1991 (Figure 2). In contrast, in the largest European auto market Germany (which has a population one-third of the U.S.), only about 2 million or a fifth as many vehicles are scrapped annually (Brown 1994, VW 1991).

California

In California, the largest U.S. auto market, more than 22 million motor vehicles were registered in 1992 while an estimated 1.6 million vehicles were scrapped (CIWMB 1993A). Estimates performed for this dissertation indicate that the actual number of scrapped vehicles may be as high as 2.5 million. As an example, a study commissioned by the California Integrated Waste Management Board estimated 477 million scrapped vehicles in Los Angeles County for 1991, while the California Department of Motor Vehicles recorded 840,000 vehicle de-registrations the preceding year (CIWMB 1993A, CDMV 1991). The large discrepancy between the two numbers cannot be simply explained by out-of-state vehicle re-registrations.

U.S. States

Estimates of vehicle scrappage for other U.S. States were determined using motor vehicle registration data (FHWA 1992). These are presented in the Appendix in Table A-1. Seven populous states including California, Florida, Illinois, Michigan, New York, Pennsylvania, and Texas accounted for nearly 45% of vehicles registered in the U.S. in 1992, and an equivalent percent of vehicles scrapped (Figure 3).

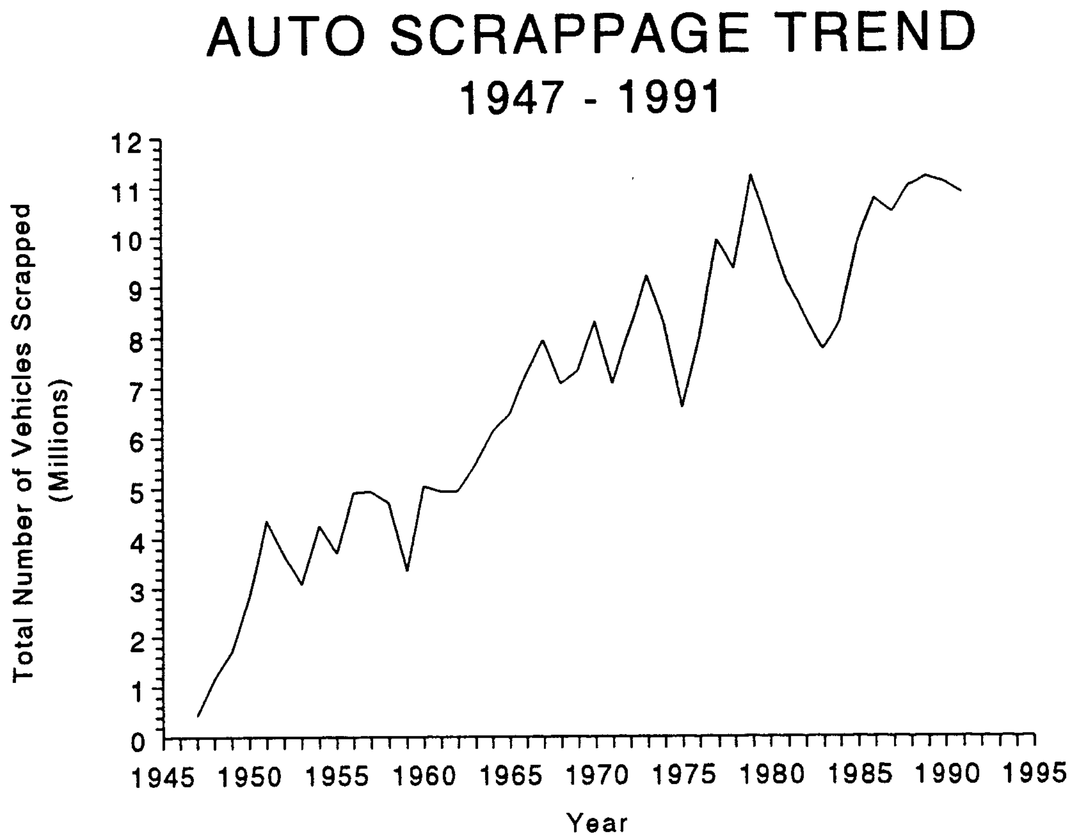

Figure 2. Trends in the scrappage of motor vehicles in the United States between 1947 and 1991. Data on vehicle scrappage for individual years were obtained from statistics compiled by R. L. Polk and Co., Detroit, MI.

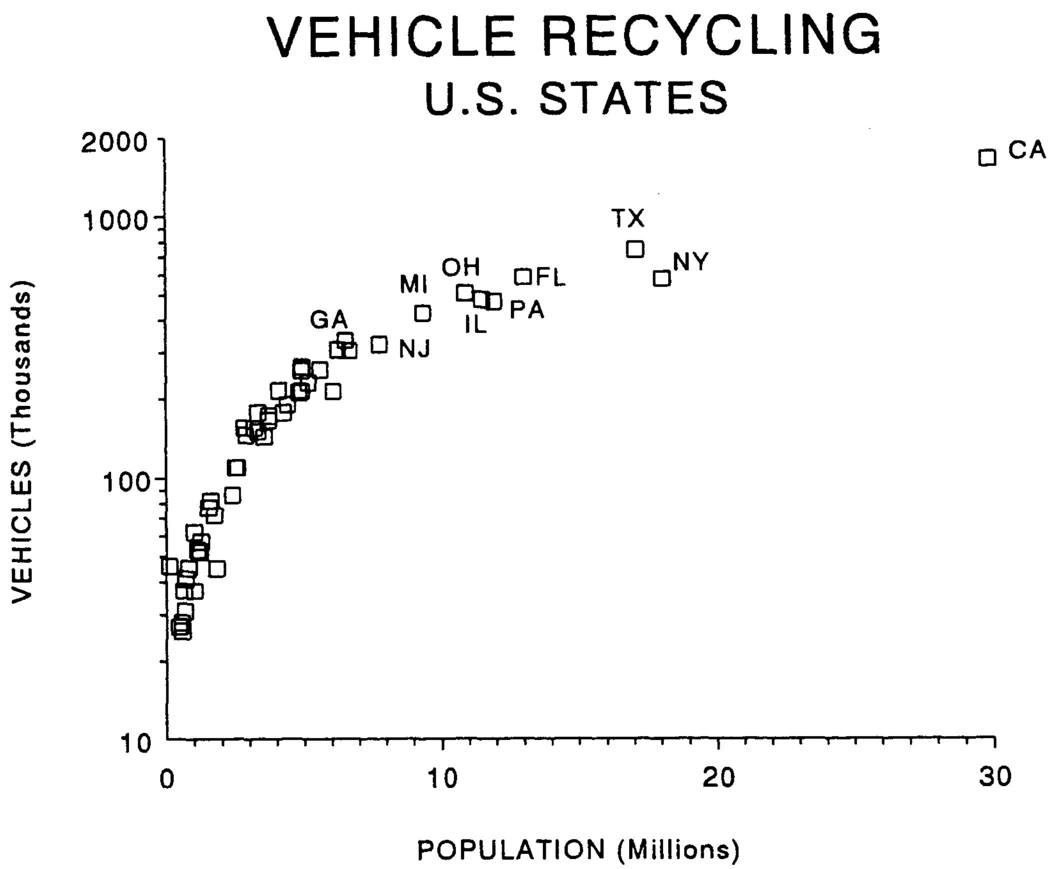

Figure 3. The relationship between estimated number of motor vehicles recycled and the populations of U.S. states. Only states with the highest volume of recycled vehicles are labelled. Data for the other states are listed in the Appendix in Table A-1. U.S. Census Bureau data for 1990 and FHWA motor vehicle statistics for 1991 were used to plot data points.

The availability of motor vehicles for recycling appears largely to be a function of regional populations, and may be an indicator of the growth or consolidation of auto recycler operations.

California Counties

A similar estimate of vehicles scrapped was conducted for the 58 counties in California. These are listed in the Appendix in Table A-2. As in the case of U.S. states, the more populous California counties of Los Angeles, San Diego, San Bernardino, Santa Clara, Riverside, Alameda, and Sacramento, which make up about sixty percent of California's population, accounted for nearly an equal percentage of vehicles scrapped (Table 1). Wide differences in the number of motor vehicles scrapped were also observed among watersheds, and among locations within a single county. Such distributions in urbanized areas are probably determined by availability of space and zoning policies.

In Los Angeles County, vehicle scrappage in the Los Angeles River and the San Gabriel River watersheds accounted for more than 99% of vehicles scrapped, although these basins made up only 81% of the surface area in the county (Table 2). For the year 1990, just three locations (Santa Fe Springs, Sun Valley and Wilmington) of more than 200 locations on record accounted for 53% of all vehicles scrapped in the county area (CDMV 1991).

Table 1. Auto recycler facilities environmental impact and vehicle recycling summary for populous counties in California. Data for other California counties are listed in the Appendix in Table A-2.

COUNTY	POPULATION	NUMBER OF RECYLERS (ESTIMATE)*	IMPACTED LAND AREA COEFFICENT ($x10^{-2}$)	IMPACTED WATER AREA COEFFICIENT (x^{10-3})	MOTOR VEHICLES REGISTERED	VEHICLES TO RECYCLER RATIO	VEHICLES RECYCLED (ESTIMATE)*
Los Angeles	9,087,400	355	4.43	93.09	5,824,169	16,406	477,461
San Diego	2,602,200	88	2.32	38.55	1,786,413	20,300	136,722
San Bernardino	1,530,600	83	0.13	7.86	990,008	11,918	80,419
Sacramento	1,099,100	78	7.41	22.56	763,626	9,790	57,748
Santa Clara	1,531,800	52	1.34	12.50	1,167,020	22,433	80,482
Kern	584,100	47	0.68	30.09	393,686	8,376	30,689
Riverside	1,289,700	41	0.38	4.14	840,221	20,493	67,762
Alameda	1,313,100	40	3.22	2.56	916,564	22,194	69,002
Contra Costa	836,900	36	5.18	5.95	645,153	17,921	43,972
Fresno	713,700	32	0.50	8.70	469,120	14,660	37,499
STATE TOTAL	30,989,040	1,286			22,210,417		1,628,195

(References: CIWMB 1993, CDMV 1993, CDMV 1992)
Dismantler estimates are based on CDMV data corrected for auxilliary facilities.
Dismantled vehicles estimate is based on a CIWMB report of 1,628,195 vehicle units scrapped and tonnage broken down by county.

Table 2. Auto recycler facilities summary for the three principal watersheds in Los Angeles County. Number in parentheses indicates the percent of vehicles dismantled in that area. Data for the table were compiled from reference CDMV 1991.

WATERSHED	AREA (km^2)	NUMBER OF FACILITIES	NUMBER OF VEHICLES DISMANTLED	PRINCIPAL LOCATIONS (PERCENT)
LOS ANGELES RIVER	2,155	237	446,258	Sun Valley (11) Wilmington (11) N. Holywood (8) Downtown L.A. (7)
SAN GABRIEL RIVER	1,663	118	387,171	Santa Fe Spring (31) Monrovia (5)
SANTA MONICA BAY	912.5	NR	6,555	Santa Monica (0.2)
TOTAL	4,730.5	355	839,984	

NR = None recorded

Such concentrations of auto recycler facilities are, no doubt, are direct result of local zoning ordinances. The above observations appear to have some implications for regulatory efforts to control storm water pollution. It is apparent that some watersheds, when compared with others, are at a greater risk from impairment of water quality as a result of auto recycling activities. Targeting pollution prevention and regulatory actions at a limited number of areas within such a watershed can be a very efficient method to reduce nonpoint source pollution.

DISTRIBUTION, SIZE AND PRACTICES

Historical Surveys

Past surveys and current information on the size and vehicle processing characteristics of the auto recycling industry in the U.S. are scarce. A report by the U.S. Department of Commerce in 1968 estimated 33,000 facilities engaged in automobile dismantling (USEPA 1973A). This survey included 74 firms in 4 cities which were selected to represent urban and rural areas, different population levels, and geographic locations using the U.S. Bureau of Census nomenclature. The number of employees at these facilities ranged from one to more than ten, with 64% of facilities having three or less people. The survey established an average size of 3×10^{-1} km^2 (7.4 Ac) and a median size of 1.6 x 10^{-2} km^2 (4 Ac) for a typical facility. The mean annual throughput of vehicles was estimated at 439 vehicles per facility.

The Automobile Dismantlers and Recyclers Association (the largest national auto recycler association) in a survey in 1982, reported an estimate of 11,200 recycler facilities. The business profile survey listed a median size of 1.2 x 10^{-2} km^2 (3 Ac) and a median annual throughput of 350 vehicles (ADRA 1982).

In California, a survey by the city of Oakland of 24 auto recyclers in 1965 found a mean size of 2.4 x 10^{-3} km^2 (0.6 Ac) (OCPC 1965). A survey in San Diego County in 1985 reported 70 facilities, 25 of which were in the City of San Diego and had a mean size of 1.2 x 10^{-2} km^2 (3 Ac). The same report estimated that there were 2,302 auto recycler facilities in California (Suitts 1985).

New Analysis

This sub-section describes the results of a new estimate of the number of auto recycler facilities in the U.S. based and currently available data.

<u>Methodology</u>

This estimate of the number of auto recyclers is based on extrapolations of the number of facilities in national groups (2,009 facilities) that participated in the

USEPA's group application for storm water discharges; the number of California facilities (140 facilities) that sought group monitoring privileges in the State's permit program in 1991; and the proportion that this number was of the total number of facilities (1,738) registered as licensed dismantlers with the California Department of Motor Vehicles, with a correction for auxiliary operations like auto repair shops and towing companies that also carry a dismantlers license (26%).

For example,

No. of facilities in USEPA groups for State S = Y

Then, the estimate of the number of facilities in State S is given by,

No. in State S = [(Number of registered dismantlers in CA) x (correction factor for non auto recyclers) x (Number in USEPA group storm water applications)] / (Number of auto recyclers in CA group)

or

$$\text{No. in State S} = \left[\frac{(1738 \times 0.74)}{140} \times Y\right] \qquad (1)$$

U.S. States

Analysis performed for this dissertation produced an estimate of 22,095 auto recycler facilities for the U.S., and a mean annual vehicle throughput of 513 vehicles per facility. The States of Texas, California, Georgia, Indiana, Kansas, Kentucky, Minnesota, North Carolina, and New York accounted for 47% of the national total of auto recycler facilities (Table 3 and Figure 4). U.S. states where the highest volume of vehicle recycling occurs are not necessarily those with the largest number of auto recyclers (Cf. Figures 3 and 4). One possible explanation is that this apparent incongruity reflects differences in the auto recycling market among states. Other explanations include that (i) the regulatory nature of the data source predisposes these numbers to reflect he extent of compliance with federal storm water regulations and not actual facilities in operation, (ii) zoning restrictions in states with large metropolitan areas and limited land area lowers the number of auto recycler operations, (iii) across-state movement of retired vehicles for recycling is more prevalent in some regions of the U.S. than in others, and (iv) the auto recycler census is biased against states with older metropolitan areas, especially in the East and the Mid-west, where auto recycler facilities connected to combined sewer systems (CSOs) are not subject to the federal storm water regulations; the baseline computation , however, included auto recycler facilities connected to CSOs in California.

Auto recycler facility size information obtained from auto recycler associations indicate that the national mean size for a facility is 4.7×10^{-2} km^2 (11.7 Ac), with the mean size for U.S. states ranging from 2 x 10-2 km^2 (5 Ac) for California to 10.1×10^{-2} km^2 (25 Ac) for Delaware.

Table 3. Auto recycler and motor vehicle registration summary for U.S. states with the highest number of auto recycling facilities. Data for other U.S. states are listed in the Appendix in Table A-1. Estimates are based on FHWA 1991 motor vehicle statistics and USEPA 1991 storm water regulatory data (USEPA 1993, FHWA 1992, ADRA 1992).

STATE	NUMBER OF RECYCLERS (ESTIMATED)	POPULATION (1990)	NUMBER OF REGISTERED VEHICLES	NUMBER OF VEHICLES DISMANTLED (ESTIMATED)	REGISTERED VEHICLES TO RECYCLER RATIO (x 10^3)
TEXAS	1,506	17,059,805	12,696,540	741,416	8.43
CALIFORNIA	1,286	29,839,250	22,252,741	1,628,195	17.30
GEORGIA	1,258	6,508,419	5,714,189	333,681	4.54
MINNESOTA	1,148	4,387,029	3,273,153	191,136	2.85
NORTH CAROLINA	1,111	6,657,630	5,216,177	304,599	4.70
KANSAS	1,065	2,485,600	1,879,442	109,750	1.77
KENTUCKY	1,065	3,698,969	2,962,763	173,011	2.78
INDIANA	1,038	5,564,228	4,413,624	257,734	4.25
OHIO	955	10,887,325	8,684,599	507,138	9.09
NEW YORK	937	18,044,505	9,771,437	570,604	10.43
OREGON	863	2,853,733	2,506,950	146,394	2.91
U.S. TOTAL	22,095	248,004,783	188,371,935	11,328,744	8.5

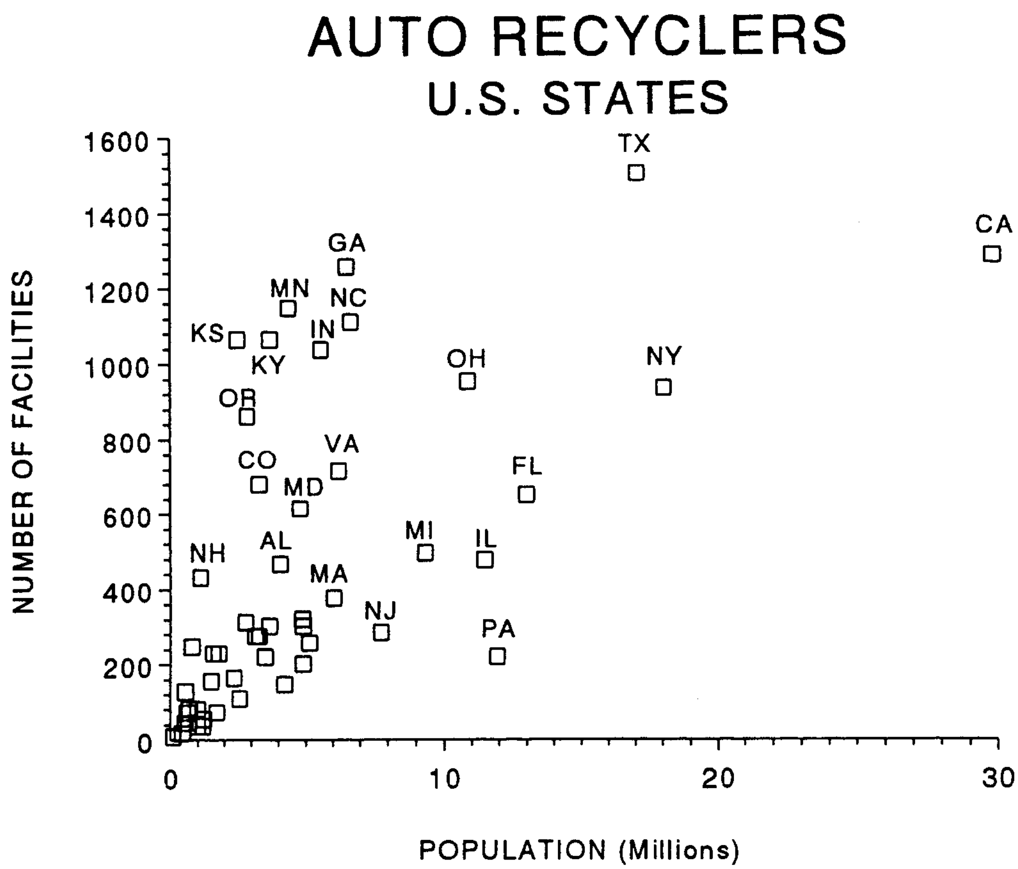

Figure 4. The relationship between the number of auto recycler facilities in U.S. states and their populations. Only states with the highest number of auto recycling facilities are labelled. Data for individual states are listed in the Appendix in Table A-1.

Individual facility sizes ranged from less than 2×10^{-3} km^2 (<0.5 Ac) to 8.1×10^{-1} km^2 (200 Ac). The size distribution of U.S. auto recycler facilities is illustrated in Figure 5. The national median facility size is 20.24×10^{-3} km^2 (5 Ac), and ninety percent of U.S. facilities are less than 82.6×10^{-3} km^2 (20.4 Ac). These facility size summaries were computed from size information provided by 1,270 facilities that were independents or members of auto recycler associations.

California

For California, the estimate of the number of facilities is 1,286 (CDMV 1992). Ten of 58 counties account for 66% of this total (Table 1). This estimate projects a mean annual vehicle throughput range for California between 1,266 vehicles (based on reference CIWMB 1993A) to 1,944 vehicles (based on this dissertation estimate using references, CDMV 1991 and CDMV 1990). This number is considerably higher than the national mean vehicle throughput and may seem to indicate a trend towards consolidation to fewer and more efficiently run operations because of market forces. The median facility size in California is 8.1×10^{-3} km^2 (2 Ac) and 90% of auto recycler facilities are less than 36.4×10^{-3} km^2 (9 Ac) (Figure 6).

Twenty-eight percent of facilities in California are located in just one county, and two-thirds of the number of facilities in this county are in the highly urbanized Los Angeles River basin (Table 2).

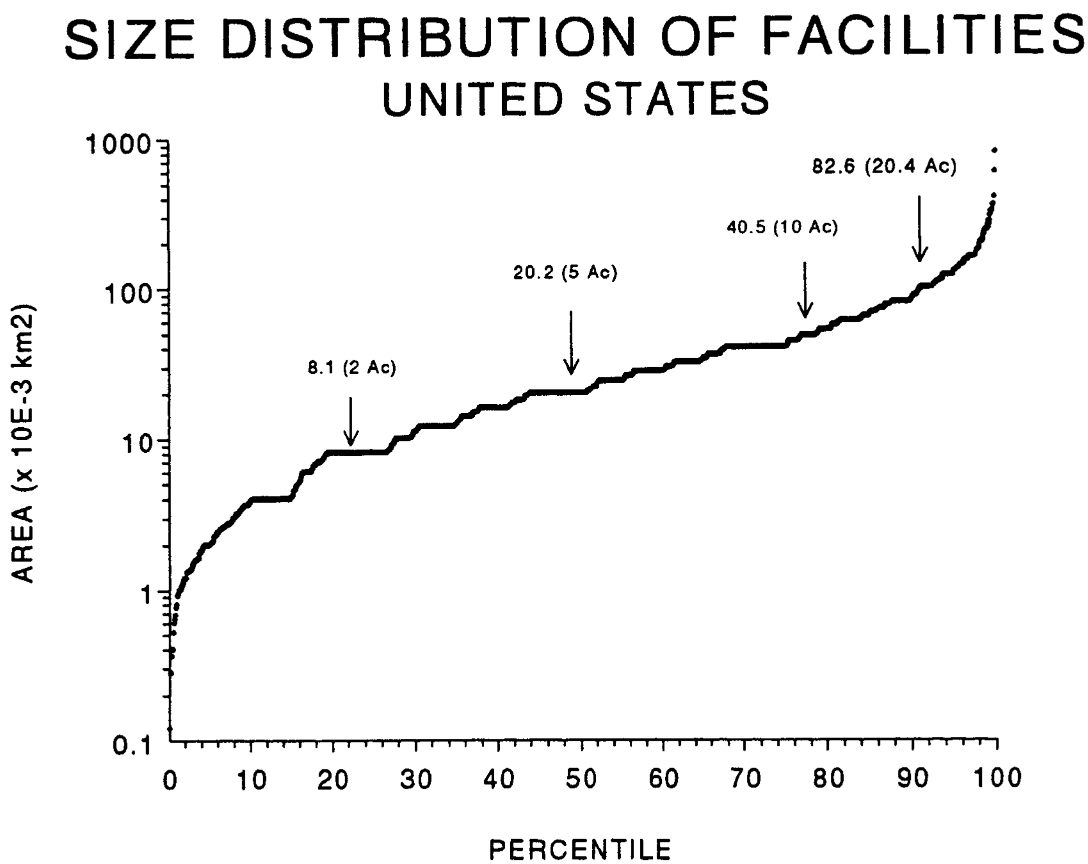

Figure 5. Distribution by size of auto recycler facilities in the U.S. The arrows indicate (from left to right) the 25th percentile, the 50th percentile (median), the 75th percentile and the 90th percentile values for facility size. Facility size data from 1,270 auto recyclers in the U.S. were used to develop the distribution.

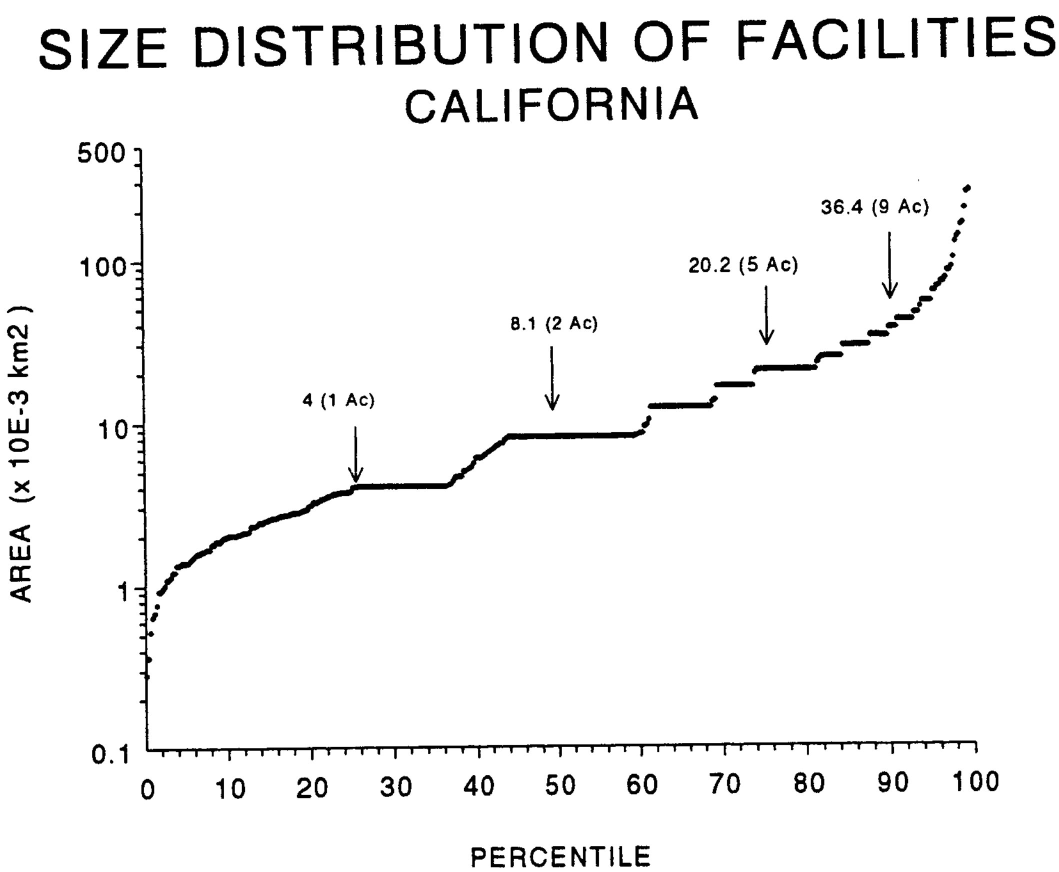

Figure 6. Distribution by size of auto recycler facilities in California. The arrows indicate (from left to right) the 25th percentile, the 50th percentile (median), the 75th percentile and the 90th percentile values for facility size. Facility size data from 399 auto recyclers in California were used to develop the distribution.

Within Los Angeles County, the mean facility size is 1.3 x 10^{-2} km^2 (3.24 Ac) and the median size is 4 x 10^{-3} km^2 (1 Ac). Auto recycler facilities located in rural areas are generally larger in size. Unlike facilities in urban areas, facility sizes in rural areas are not constrained by the relatively high cost of land. For example, San Joaquin, a rural county, has a mean facility size of 5.1 x 10^{-2} km^2 (12.7 Ac) and a median size of 3.6 x 10^{-2} km^2 (9 Ac).

Vehicle Processing to Facility Size Relationship

It might be expected that auto recycler facility size would strongly correlate with the annual mean vehicle throughput at a facility. The auto recycler facility size could determine its annual vehicle processing capacity (vehicle throughput) and predict indirectly the quantity of solid and liquid wastes generated and pollutants discharged in storm water. The USEPA has used the 'vehicle throughput to pollutants generated' rationale to institute monitoring requirements for facilities processing over 100 vehicle units per year under its general permit requirements for storm water (USEPA 1992).

In order to test this relationship between facility size and vehicle throughput in urbanized regions, annual vehicle throughput information for nine facilities, ranging in size from 1.6 x 10^{-3} km^2 (0.4 Ac) to 109.3 x 10^{-3} km^2 (27 Ac), in Los Angeles County was compiled for the year 1992. These facilities were considered to be representative of the range of auto recycler operators in a metropolitan area. A linear regression analysis conducted with vehicle throughput as the dependent variable and facility size as the independent variable, produced the linear fit,

$$\text{Log } y = 1.678 + 1.361 \log x \qquad (2)$$

where,

y is the annual vehicle throughput in number per year, and

x is the facility size in km^2

and a coefficient of determination $r^2 = 0.97$ (Figure 7). Although the reliability of the regression equation is weakened by the lack of vehicle throughput data for intermediate size facilities (between 5 and 30 x 10^{-3} km^2), the example serves to illustrate the invalidity of a current professional judgement criterion. When this equation is tested on the USEPA threshold to trigger special monitoring conditions, an annual throughput of 100 vehicle units corresponds to a facility size of 1.72 (0.4 Ac). This suggests that the 100 unit threshold selected by the USEPA for sampling requirements may be too burdensome for small auto recycler operators in industrialized states, where a large number of facilities are less than 4 x 10^{-3} km^2 (1 Ac) in size. Such facilities often have fewer than four employees and sampling requirements may pose a considerable financial burden on small operators.

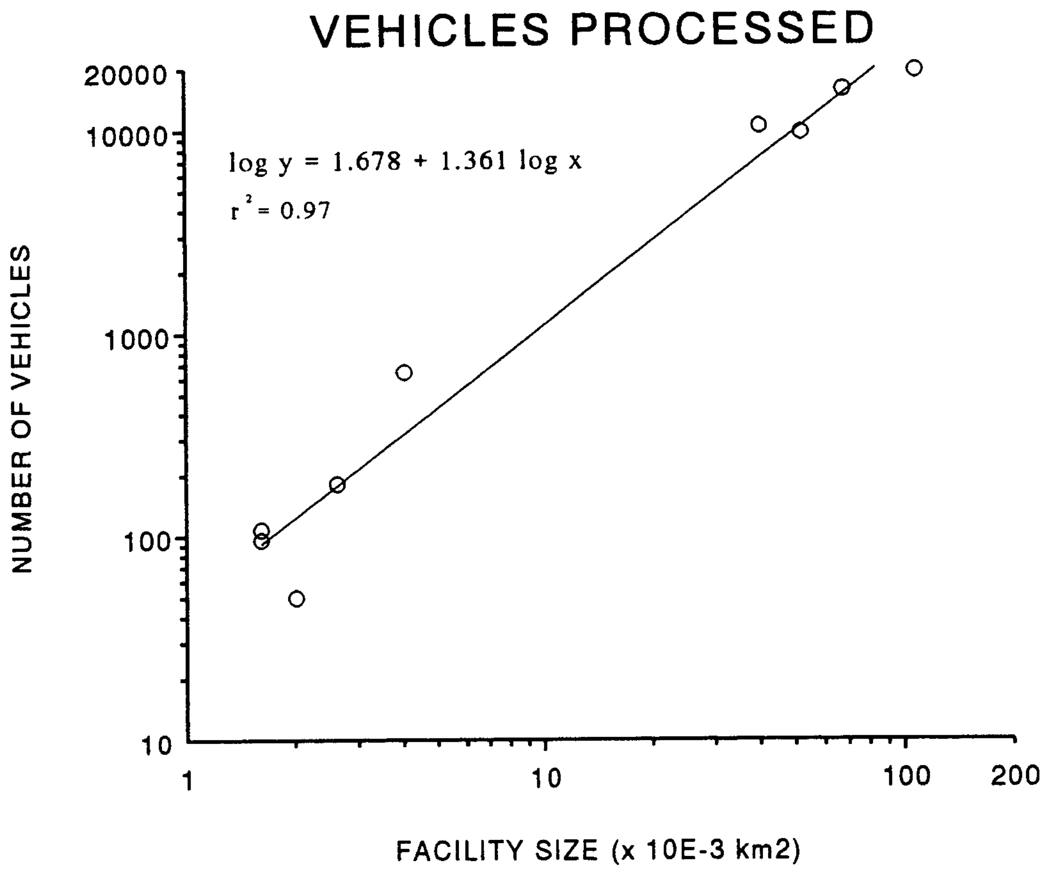

Figure 7. The relationship between facility size and vehicle throughput. Information for the analysis was provided by nine auto recyclers in Los Angeles. Note that data for intermediate size facilities, if had been available, would have strengthened the regression relationship.

At these small facilities, the limited financial resources may be better spent on the implementation of best management practices to reduce storm water contamination as opposed to sampling. A more appropriate threshold to trigger sampling requirements commensurate with the environmental risk posed may be the first quartile, 8.1×10^{-3} km^2 (2 Ac) and the equivalent 1,000 vehicle units per year (rounded off); or the median size of 20.2×10^{-3} km^2 (5 Ac) and the corresponding 3,000 vehicle units per year.

Pollution Threat in California

Analyses were performed using landuse information to identify California counties where the greatest threat of regional storm water contamination exists. Coefficients related to surface area occupied by auto recycler facilities, and water area impacted were computed (See Appendix Table A-2). Land and surface water area data were obtained from the California County Fact Book, and auto recycler facilities data were compiled from state agency databases (CSWRCB 1993A, CDMV 1993, CDMV 1992, CSAC 1989).

The Impacted Water Area Coefficient (IWAC) is a measure of the proportion of land area occupied by all auto recycler facilities in a county to the total area occupied by surface waters. Among the more populous counties, Los Angeles County had the highest value (IWAC = 93.09×10^{-3}) and Alameda County the least (IWAC = 2.56

x 10^{-3}). The Impacted Land Area Coefficient (ILAC) is the ratio of total land area occupied by auto recycler facilities to the total land area of the county. Among the more populous counties, Sacramento County had the highest value (ILAC = 7.41 x 10^{-2}) in comparison to San Bernardino County which had the lowest (ILAC = 0.13 x 10^{-2}). A higher value for both coefficients indicates the potential for a relatively greater water quality impact from auto recycler activities. In combination, these two coefficients may serve to identify counties where there appears to be the greatest need to target environmental programs in order to minimize surface water and ground water impacts from the auto recycling industry. The IWAC is probably a better indicator of potential water quality threat because it is indicative of the significance of the industry relative to available water resources.

BUSINESS AND REGULATORY HISTORY

Business Practice

Auto recycler operators then as now did business by one of three methods: (i) parked vehicles in their yards with employees stripping parts as required; (ii) stripped the vehicles to the bare hulk and placed the parts in storage racks and bins, or immediately sold parts to rebuilders or wholesale outlets; then disposed of the stripped body; or (iii) parked the vehicles in their yards and let the customer remove the desired parts (USDOT 1977, USBM 1967). Rural locations were less preferred because of the distance from supply sources and potential customers. Urban and suburban locations had the advantages of proximity to supplies of out-of-service vehicles and the auto-parts market, but the disadvantages of high overhead (from land values) and zoning controls (fencing requirements and burning restrictions). Community pressures sometimes offset such advantages. Approximately 38% of supply of vehicles came from individuals, 26% from new and used car dealers, 21% from insurance companies, 12% from public agencies, and 3% from other sources. When no significant value remained for the parts, auto bodies were either allowed to accumulate or prepared for delivery to a scrap processor for recycling. Transportation rates were negotiated between the auto recycler operator and the trucker.

Local Government Policies

State regulations in the early 1960s preempted the regulation of auto recycler facilities by local jurisdictions, leaving them with only zoning controls (OCPC 1968). In California, State Law required auto recycler operators to be licensed annually by the California Department of Motor Vehicles (USBM 1967). Consequently, attention during the 1960s on activities of auto recycler facilities was directed at their impact on neighboring properties.

Cities set minimum operational standards such as height and quality of fencing, and general zoning restrictions. For example, in Los Angeles county, auto recycler operators were required to obtain a business license, and zoning regulations were imposed limiting operations to heavy industrial zones, with a minimum distance of 91.4 m (300 ft.) from a public school or park, and tight fences no less than 2.4 m (8 ft.) high (USBM 1967).

Vehicle Abatement Programs

In the 1970s, the auto recycler industry gained much visibility because of the abandoned automobile problem. It was estimated at that time that 2.85 million motor vehicles were abandoned, many in rural areas because of impediments such as title irregularities, transportation costs, and excess parts inventories at salvage facilities (USEPA 1973B). Policy recommendations were made by governmental agencies to ease the problem. These included the transfer of salvage rights to auto recycler operators and a rural subsidy as the least expensive choices to remove abandoned automobiles. In addition, a disposal certification program was favored to prevent aesthetic deterioration of the environment. Some states created a special fund from vehicle registration and renewal fees, to pay auto recycler facilities for receiving and promptly disposing of inoperable motor vehicles (USDOT 1977).

Environmental Protection Laws

Auto recycler facilities were also slightly affected in the 1980s by the USEPA's regulations on waste motor oil disposal and recycling practices under the Resource Conservation and Recovery Act (RCRA). This action was taken to stem the improper disposal of large quantities of waste oil in the environment, estimated in 1972 to be about 340 million gallons, or 31% of waste oil generated from automotive, industrial, aviation and other uses (FHWA 1976).

SUMMARY

This section provided an overview of operational characteristics of auto recycler facilities in the U.S. and in California. A rough method was developed to quantify potential threat to water quality in California counties from the industry. Also included were a brief discussion on the history of auto recycler activities and the evolution of governmental regulations that have impacted the industry.

SECTION 3.0 STORM WATER POLLUTION

WASTE GENERATION

Auto recycler facilities are the termini for the accumulation of residual automotive wastes from retired motor vehicles. The wastes generated come from the stripped body, auto components, motor vehicle oils and fluids, and solvents used for parts cleaning. These wastes in turn are sources of conventional and toxic pollutants to storm water. Estimates of the quantity of various auto dismantling wastes generated at auto recycler facilities in the United States, California, and in Los Angeles County are presented in Table 4. The waste generation factor per vehicle was adapted from a waste quantification report prepared by the Metropolitan Washington Council of Governments (MWCOG 1991).

Auto Recycler Waste

More than 90% of retired motor vehicles are eventually recycled (CIWMB 1993A). Shredded metal scrap from motor vehicle bodies and components supplies the raw material for about 90% of steel output in the United States. The nation's auto recycler facilities generate approximately 81 million liters of antifreeze, much of which is not reclaimed.

Table 4. Estimates of the quantity of automotive wastes generated at auto recycler facilities. Waste generation factors were adapted from reference MWCOG 1991. Waste quantity estimates for California and Los Angeles County are presented as a range to account for differing estimates of total vehicles recycled.

WASTE	GENERATION FACTOR (Per Vehicle / Year)	UNITS (per Year)	UNITED STATES	CALIFORNIA	LOS ANGELES COUNTY
Vehicles		X 10^6	11.3	1.6 - 2.4	0.47 - 0.84
Tires	5	X 10^6	56.6	8.1 - 12.1	2.4 - 4.2
Batteries	1	X 10^6	11.3	1.6 - 2.4	0.47 - 0.84
Antifreeze	7.12 L	X 10^6 L	80.6	11.6 - 17.2	3.4 - 6.0
CFCs	0.22 Kg	Tons	2,466	355 - 526	104 - 183
Waste Oil	2.84 L	X 10^6 L	32.2	4.6 - 6.9	1.4 - 2.4
Hydraulic Fluid	4.2 L	X 10^6 L	47.6	6.8 - 10.1	2.0 - 3.5
Oil Filters	1	X 10^6	11.3	1.6 - 2.4	0.47 - 0.84
Air Filters	1	X 10^6	11.3	1.6 - 2.4	0.47 - 0.84
Fuel / Transmission Filters	1	X 10^6	11.3	1.6 - 2.4	0.47 - 0.84
Brake Material	1	X 10^6	11.3	1.6 - 2.4	0.47 - 0.84
Steel	0.81 Tons	X 10^6	9.1	1.3 - 2.0	0.39 - 0.68
Iron	0.21 Tons	X 10^6	2.4	0.3 - 0.5	0.10 - 0.18
Other Metals	0.07 Tons	X 10^6	0.8	0.12 - 0.18	0.03 - 0.06
Plastic	0.1 Tons	X 10^6	1.1	0.16 - 0.23	0.05 - 0.08
Glass	0.04 Tons	X 10^6	0.4	0.06 - 0.09	0.02 - 0.03
Other Fluff	0.23 Tons	X 10^6	2.6	0.4 - 0.6	0.11 - 0.19

Of the 30 to 50 million liters of waste oil and hydraulic fluids that are generated at auto recycler facilities, recovery for recycling is estimated to be only between 20% to 40% because of the disincentive associated with the cost of licensed collection. These facilities also generate 33 million vehicle filters which carry oil, fuel, fluids, and metallic waste which are deposited in landfills. In addition, nearly eleven million waste brake pads and linings are produced. Also disposed in landfills are automotive plastic debris and fluff which account for nearly 27% of a shredded vehicle by weight (Brooke *et al.* 1990). Most of the nearly half a million ton of automotive glass generated at recycler facilities, although fully recyclable, is rarely recycled because of non-profitability and the absence of a glass recycling system. Tires generated at auto recycler facilities account for approximately 19% of scrap tires in the United States most of which are sent to landfills improperly (Brook *et al.* 1990).

The recycling of batteries is similarly inadequate. For example, in California, it has been estimated that nearly 2.4 million batteries, or as many as are generated at auto recycler facilities in the State, are unaccounted for and presumed to have been improperly disposed. This illicit disposal could potentially expose 232,000 metric tons (210,000 tons) of lead and ten million liters (3 million gallons) of sulfuric acid to the environment (CIWMB 1990B). Similarly CFCs, which are air pollutants, are seldom recovered during the vehicle dismantling process. This practice is likely to change as the termination of CFC manufacture creates a demand for CFCs to operate freon-based cooling systems.

Barriers to Waste Management

There are presently several reasons for the minimal waste recycling and waste minimization practices conducted at auto recycler facilities. Many of these reasons are related to economics and linked to the absence of an efficient recycling infrastructure. A good illustration of the situation is the case of vehicle tires, which auto recyclers consider a liability (Rolph 1991). Tires take up space, do not convert readily into profit, consume both cash and person-hours for processing, constitute a fire hazard, and create regulatory problems. Despite the desire of auto recyclers to move unsalable tires quickly out of their facilities without incurring huge costs, few options are currently available.

Another situation where economics significantly increases the potential for pollution at auto recycler facilities is waste oil recycling. Waste oil is often stockpiled by auto recyclers in order to accumulate a full truck load. Waste oil management regulations have increased processing costs, and what was once bought or hauled away free is now charged by the truck load. Thus, an evaluation of auto recycler facilities may find poorly run facilities more common than efficient ones (Brook *et al.* 1990).

STORM WATER POLLUTANT SOURCES

In order to control the release of pollutants in storm water, the sources of pollutants that commonly contaminate storm water must be known. Table 5 summarizes specific sources of the most common conventional and toxic pollutants that contaminate storm water runoff at auto recycler facilities. Practices that enhance the management, isolation, and containment of these pollutant sources will greatly reduce their release to storm water.

Chemical Oxygen Demand (COD) is a measure of the total amount of oxygen necessary for oxidation of wastes, and is indicative of organic chemicals. Sources of COD at auto recycler facilities include waste motor oils (hydraulic, crankcase and gear), hydraulic fluids (brake, automatic, power steering, and shock absorber), antifreeze, gasoline, diesel, and parts-cleaning solvents.

Total Kjeldahl Nitrogen (TKN) and Nitrate + Nitrite Nitrogen ($N - NO_3 + NO_2$) are measures of organic and inorganic nitrogen which are aquatic nutrients. Likely sources of nitrogen at auto recycler facilities include waste motor oil and hydraulic fluids. The nitrogen content of waste motor oil has been reported to be between 50 mg/kg and 180 mg/kg (Vaquez-Duhalt 1989).

Table 5. Summary of principal sources of conventional and toxic pollutants at auto recycler facilities which may contaminate storm water runoff. Automotive sources and associated pollutants were compiled from numerous publications which are cited in the text.

	COD	TKN	N-NO_3 + NO_2	O&G	pH	P	TSS	TDS	Al	Fe	Pb	Cu	Zn	Cd	Ni	Cr	Et-OH	HC	PAHs	NaN_3
Waste Oil	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•		•	•	
Hydraulic Fluids	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•		•	•	
Antifreeze	•				•		•	•			•	•					•			
Gas / Diesel	•			•							•							•	•	
Parts Cleaner	•			•														•	•	
Tires / Wheel							•			•	•		•							
Body / Paint							•		•	•	•			•	•	•				
Radiator							•				•	•								
Carburettor / Engine / Transmission									•	•			•					•	•	
Mufflers							•			•	•									
Catalytic Convertors							•			•	•								•	
Batteries							•	•			•									
Air Bags										•		•								•
Brake Pads / Liners							•				•	•	•							

Oil and Grease (O & G) is a measure of extractable and heavy hydrocarbons that have the potential to damage aquatic life and environment aesthetics. At auto recycler facilities, the pollutant is associated with waste oils, hydraulic fluids, gasoline, diesel, parts-cleaning solvents, and as residue on motor vehicle parts, for example oil filters, crankcase, and the engine (CWC 1990A). Oil and grease is a very visible and common pollutant in storm water runoff from auto recycler facilities.

pH is a measure of the acidity or alkalinity of the storm water runoff from auto recycler facilities. pH values that are markedly different from the receiving aquatic environment adversely affect the biotic community. Extreme pH values in runoff likely result from contact of storm water with battery acids, antifreeze, and air bag residue (CIWMB 1993A, CDTSC 1991, CIWMB 1990A, CIWMB 1990B). Antifreeze has been reported to have an approximate pH of ten (CDTSC 1991).

Total Phosphorus (P), which is another aquatic nutrient, principally comes from waste motor oil, hydraulic fluids, and some detergents. Waste motor oil may contain up to 32 mg/g of P (Vaquez-Duhalt 1989).

Total Suspended Solids (TSS) at auto recycler facilities are associated with the unpaved facility surface, and particulates derived from waste motor oils, hydraulic fluids, wear and tear of parts, and auto body corrosion. Heavy metals and organics are often transported as TSS. In addition to the toxicity of such constituents, high turbidity which is caused by suspended solids adversely affects the receiving aquatic environment.

Total Dissolved Solids (TDS) measures dissolved constituents and inorganic additives that come from waste motor oils, hydraulic fluids, and antifreeze. TDS can adversely affect the salinity of freshwater receiving environments and their resident biotic communities.

Aluminum (Al) comes from waste oil, hydraulic fluids, aluminum parts, auto body, and unpaved surface particulates. Next to iron, it is the most abundant metal in a motor vehicle. Its use in motor vehicles is projected to increase as auto manufacturers progress in their efforts to improve vehicle efficiency (McCosh 1990, Niemczewski 1984).

Iron (Fe), which is about seventy percent by weight of a motor vehicle, is the most abundant metal associated with storm water runoff from auto recycler facilities (ADRA 1993, SSP 1992). It comes from unpaved surface particulates, waste oils, hydraulic fluids, vehicle parts wear, auto body corrosion, and air bag generants. In excessive quantities, it leads to discoloration of the aquatic environment.

Lead (Pb) is a toxic pollutant that bioaccumulates in aquatic organisms and poses human health risks. Most of the lead in vehicles is in batteries and battery cable clamps. It also occurs in waste oils, hydraulic fluids, lead based paints, leaded and unleaded gasoline, exhaust systems, wheel balance weights, radiators, heater core, body filler, electric solder, brake pads, and brake linings (SCVNPSCP 1994, CIWMB 1993A, SCVNPSCP 1992, Brooke *et al.* 1990, Vaquez-Duhalt 1989, Ness 1985).

Copper (Cu) is a pollutant that causes acute and chronic toxicity to aquatic organisms. More than half the copper in motor vehicles occurs in the radiator, with lesser amounts in heater cores, wiring, cables, clamps, starter, waste oils, hydraulic fluids, air bag generant, brake pads and brake liners (SCVNPSCP 1994, CIWMB 1993A, SCVNPSCP 1992, Vaquez-Duhalt 1989, Ness 1985).

Zinc (Zn) is a pollutant that is toxic to aquatic organisms. Zinc is present in waste oils, hydraulic fluids, tires, brake pads, brake linings, and as an alloy in carburetors, engine block, fuel pump, and trim (SCVNPSCP 1994, SCVNPSCP 1992, Brooke *et al.* 1990, Vaquez-Duhalt 1989, Ness 1985).

Cadmium (Cd) is a human carcinogen and is also toxic to aquatic life. It is used in bright pigments and paint, as underbody fasteners, and occurs in small amounts in waste oil and hydraulic fluids (Brooke *et al.* 1990,Vaquez-Duhalt 1989).

Nickel (Ni) is a toxic pollutant to aquatic organisms and affects human health. It occurs in waste oils, hydraulic fluids, pigments, and in body alloys (Vaquez-Duhalt 1989).

Chromium (Cr) is toxic to aquatic life. It is found in waste oils, hydraulic fluids, bumpers, trims, and body alloy (Brooke *et al.* 1990, Vaquez-Duhalt 1989).

Ethylene and propylene glycol (Et-OH) are the primary constituents in antifreeze. They are acutely toxic to aquatic life and humans (CDTSC 1991).

Petroleum hydrocarbons (HC) such as benzene, toluene, ethylbenzene, xylenes, and cleaning solvents are toxic to aquatic life and carcinogenic to humans. They are present in waste oil, hydraulic fluids, gasoline, diesel, motor component residues, and parts cleaners (CDHS 1987).

Polynuclear aromatic hydrocarbons (PAHs) are human mutagens and carcinogens (Menzie *et al.* 1992, Pasquini and Monarco 1983). PAHs accumulate progressively with vehicle operating time from a concentration of less than 5 $\mu g/g$ to more than 11,000 $\mu g/g$ in crankcase oil (Vaquez-Duhalt 1989, Pruell and Quinn 1988). The PAH most often detected in storm water runoff from auto recycler facilities is the low molecular weight naphthalene which also occurs in cleaning solvents, gasoline and diesel. It is likely that storm water is also contaminated by the more potent high molecular weight PAHs.

Sodium azide (NaN_3) is the principal chemical used to deploy air bags. It is toxic and explosive when it comes in contact with water. Inflator residue is caustic and can raise runoff pH (CIWMB 1993A).

Other Pollutants which occur in small quantities may be associated with specific components in motor vehicles. For example, silver occurs in the heating element of the rear windows. Traces of arsenic, inorganic additives and non-metals are found in waste motor oil. Mercury is contained in some electrical switches.

STORM WATER POLLUTANT CONCENTRATIONS

Storm water pollutant data from auto recycling facilities have been generally scarce because the industry was never specifically regulated for water pollution under the Clean Water Act such as mining activities, asphalt manufacturers and refineries. In some instances in the past, a few auto recycler facilities have been issued permits with numerical limitations for the discharge of storm water (CRWQCB-LA 1994, CRWQCB-SA 1994). More recently, data on pollutant discharges in storm water have become available under USEPA group application and general permit requirements (ADRA 1993, USEPA 1993, SCADA 1993). These data mainly characterize conventional pollutants in storm water from auto recycler facilities and are fairly reliable because they were collected in conformance with USEPA guidelines (USEPA 1992B).

Auto Recycler Storm Water Data Review

Table 6 summarizes data from several sources for both conventional and toxic pollutants in storm water discharges from auto recycler facilities. Listed in the Table are data from two individual facilities, and four facility groups which include one regional, one statewide and two national surveys.

Individual Facility Reports

The Los Angeles facility operates under an individual NPDES permit and directs storm water through oil-water separators (OW separators) prior to discharge (CRWQCB-LA 1994). Data for the facility are summarized for 45 discharge events that were sampled for several parameters between 1984 and 1992 and analyzed at the same laboratory. Storm water discharge quality at the facility has considerably improved in recent years after facility modifications.

Data for the Sacramento facility were collected during a single storm event under a pilot study conducted by Sacramento-area municipalities in 1992 (SSP 1992). In addition to composite samples, grab samples were collected to determine pollutant concentrations in 'first flush' runoff.

Los Angeles Regional Survey

The Los Angeles Regional survey was conducted for the dissertation, during the 1991-1992 wet season, to complete a preliminary investigation of selected pollutants in storm water for a range of auto recycler facilities. Facilities sampled ranged in size from 2×10^{-3} km^2 to 41×10^{-3} km^2 (0.5 to 10 Ac). Analyses were conducted for three metals (Pb, Cu, Zn), two conventional pollutants (TSS and COD), PAHs, and PCBs. The preliminary study identified metals and the conventional pollutants as significant contaminants at auto recycler facilities. PAHs and PCBs were not below the detection limits used for the chemical analysis (see Section 5.0).

California Survey

Storm water data for the California Auto Dismantlers Association (SCADA) were collected from 17 facilities selected to represent 140 group participants statewide. Data represent results of sampling performed for the 1992-1993 wet season (SCADA 1993).

Table 6. Comparison of conventional and toxic pollutant concentrations in storm water from auto recycler facilities. Data were compiled from local, regional, and national surveys (concentrations are reported in mg/L). The benchmark values are from reference USEPA 1993; (n = No. of samples; N = No. of sites; G = Sampled as a grab; C = Composite sample; NA = Not analyzed; * = Best available technology standard).

POLLUTANT	LOS ANGELES FACILITY n = 38-45 1984-1992			SACRAMENTO FACILITY n = 1 1992	LOS ANGELES AREA SURVEY N = 3 1991 / 1992			SCADA GROUP (CALIFORNIA) N = 17 1992 / 1993			NON-ARA GROUP (NATIONAL) N = 13 - 30 1992 / 1993			ARA GROUP (NATIONAL) N = 58 1992 / 1993			USEPA BENCH MARK
	Mean	Median	95tile	Mean	Mean	Median	Max	Mean	Median	95tile	Mean	Median	95tile	Mean	Median	95tile	
BOD (G)				140	N/A	N/A	N/A	15	6	49	7	6	16	16	7	77	9
(C)	93	74	270	120							13	6.5	48	11	6	43	
COD (G)	N/A	N/A	N/A	670	291	332	480	118	72	320	135	61	250	139	80	518	65
(C)				370							66	60	155	77	54	196	
TKN (G)	n=1	N/A	N/A	4.4	N/A	N/A	N/A	1.3	0.9	2.9	2.2	1.9	4.9	3.3	2.0	10.2	1.5
(C)	0.12			3.2							2.3	1.8	6.6	2.0	1.0	5.8	
T-N (G)	n=1	N/A	N/A	0.49	N/A	N/A	N/A	N/A	N/A	N/A	1.70	0.83	5.65	1.27	0.59	5.53	0.68
(C)	2.4			0.28							1.62	1.32	4.87	2.63	0.58	20.83	
O&G (G)	25	21	55	38	N/A	N/A	N/A	6	2	16	5	3	32	6	3	28	15*
(C)				190													
pH (G)	5.8	7.3	9.5	7.1	N/A	N/A	N/A	6.1	6.4	7.6	6.4	7.5	8.3	5.2	7.6	9.1	6-9
	(min)		(max)					(min)		(max)	(min)		(max)	(min)		(max)	
T-P (G)	n=1	N/A	N/A	1	N/A	N/A	N/A	0.49	0.40	1.50	0.19	0.05	1.08	0.48	0.12	2.89	0.33
(C)	0.56			0.64							3.05	0.26	15.7	0.23	0.11	1.0	
TSS (G)	n=3	N/A	N/A	420	963	110	2,740	179	50	330	474	183	2,300	569	202	2,634	100
(C)	108			130							839	226	5,100	335	140	1,914	
TDS (G)	n=3	N/A	N/A	N/A	N/A	N/A	N/A	121	93	260	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(C)	913																
PHENOLS				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
(C)	0.05	0.03	0.13														10.2

(CONTINUED)

POLLUTANT	LOS ANGELES FACILITY n = 38-45 1984-1992			SACRAMENTO FACILITY n = 1 1992	LOS ANGELES AREA SURVEY N = 3 1991 / 1992			SCADA GROUP (CALIFORNIA) N = 17 1992 / 1993			NON-ARA GROUP (NATIONAL) N = 13 - 30 1992 / 1993			ARA GROUP (NATIONAL) N = 58 1992 / 1993			USEPA BENCH MARK
	Mean	Median	95tile	Mean	Mean	Median	Max	Mean	Median	95tile	Mean	Median	95tile	Mean	Median	95tile	
Al (G)	n=1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.49	8.50	59.63	0.75
(C)	1.73													11.10	5.30	41.64	
Fe (G)	N/A	N/A	N/A	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19.95	8.85	77.83	0.3
(C)				5.8										13.42	5.15	57.23	
Pb (G)				0.590	0.234	0.170	0.428	N/A	N/A	N/A	N/A	N/A	N/A	0.240	0.100	1.000	0.034
(C)	0.182	0.110	0.510	0.290										0.160	0.100	0.500	
Cu (G)				0.240	0.106	0.114	0.159	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.009
(C)	0.104	0.090	0.210	0.130													
Zn (G)				0.980	0.724	0.639	1.086	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.065
(C)	0.522	0.430	1.350	0.540													
Cd (G)				0.016	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.002
(C)	0.009	0.005	0.200	0.013													
Ni (G)				0.054	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.788
(C)	0.048	0.030	0.100	0.030													
Cr (G)				0.038	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(C)	0.020	0.007	0.040	0.011													
As (G)				0.010	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00002
(C)	0.004	0.003	0.010	0.005													
Benzene (G)	n=1	N/A	N/A	0.0003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.3
(C)	0.007			0.0003													
EtBenzene (G)	n=1	N/A	N/A	0.0003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32
(C)	0.002			0.0003													
Toluene (G)	n=1	N/A	N/A	0.0003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17.5
(C)	0.024			0.0003													
Xylenes (G)	n=1	N/A	N/A	0.0003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(C)	0.041			0.0003													

National Surveys

Storm water data for national auto recycler groups were collected pursuant to USEPA Part 2 Group application requirements (ADRA 1993, USEPA 1993). The storm water data was provided by 30 facilities representing state or regional associations (Non-ARA group), and 58 representing the national association (ARA group). USEPA benchmarks listed for purposes of comparison of storm water quality are taken from the USEPA multi-sector general permit notice (USEPA 1993). The benchmark value noted for oil and grease did not appear in this notice but is a common best available technology standard that is widely used in the NPDES program.

Storm Water Pollutant Data Overview

A review of the existing data on storm water quality from auto recycler facilities for conventional pollutants (Table 6) indicates that mean concentration values for biochemical oxygen demand, chemical oxygen demand, total kjeldahl nitrogen, total nitrogen, oil and grease, total phosphorus, and total suspended solids frequently exceed the USEPA benchmark, sometimes by more than an order of magnitude. The USEPA benchmarks are storm water quality criteria that have been proposed as guidance measures to evaluate the effectiveness of pollution prevention plans and best management practices (USEPA 1993). This observation signifies that storm water runoff at auto recycler facilities is being contaminated by conventional pollutants at levels much above urban runoff background concentrations, and could be a major contributor to surface water quality impairment. The pattern of exceedance of these criteria appears to be similar for mean concentration values for most metals including iron, lead, copper, zinc, cadmium, and arsenic, with the exception of nickel. In the case of metals, values above the USEPA benchmark signify that the storm water amy be considered to cause acute toxicity effects in receiving water-bodies.

Median values for conventional pollutants, however, appear to be closer to or below the USEPA benchmark, unlike median values for metals which are considerably higher than the measure. Proximity of the median values to the USEPA benchmark may be used as a measure of progress of efforts towards achieving storm water pollution control for the industry as a whole.

Petroleum hydrocarbons appear to be less of a problem, although they could be a concern where storm water infiltration practices predominate as a runoff mitigation measure. Pollutant concentrations in grab samples, which are usually collected during the early portion of a storm event, are about two times as high as in event composite samples or event mean concentrations (EMCs) (USEPA 1992B).

The compiled data summary appears to validate the supposition that auto recycler facilities have a substantial potential for releasing both conventional and toxic pollutants in storm water. These facilities should be able to reduce this potential by adopting proper material and waste handling practices, and by taking measures to minimize the exposure of their vehicle dismantling activities to storm water runoff.

SUMMARY

This Section provided a quantification of automotive wastes generated by the auto recycler industry. It discussed the sources of common conventional and toxic pollutants during auto dismantling processes, and summarized data from literature on pollutant concentrations in storm water from auto recycler facilities

SECTION 4.0 STORM WATER BEST MANAGEMENT PRACTICES AND TREATMENT CONTROLS

Pollutants in storm water discharges from auto recycler facilities primarily result from the exposure of materials, wastes and dismantling activity to rainfall runoff. The most cost-effective approach for minimizing pollutants in storm water discharges from such facilities is to focus on exposure minimization practices. Treatment controls may be considered a final step when non-structural Best Management Practices (BMPs) are fully implemented and water quality standards or performance standards continue to be exceeded.

CURRENT PRACTICES

The Auto Recyclers Association conducted a survey among its 1,478 members between 1991 and 1992 for its group storm water application to the USEPA. This survey found that only 34% of facilities conducted loading and unloading operations inside buildings, and 13% performed the activity under a roofed area (USEPA 1993, ADRA 1992). A common sense management practice, the draining of fluids prior to vehicle storage, was conducted at less than 20% of facilities. Less than six percent of the auto recycler facilities utilized waste containment practices, such as diking around material storage areas.

Storm water runoff treatment measures were rare with only one percent of facilities piping process areas to a wastewater treatment plant, and ten percent of facilities utilizing lined grassy swales. Historically, storm water at auto recycler facilities has not been treated to remove pollutants, with the exception of a few facilities. Effective BMPs for auto recycler facilities must target the two principal sources of storm water pollutants: (i) liquid wastes generated during vehicle dismantling and storage of parts; and (ii) corrosion and wear particles generated during dismantling, and body and parts storage.

POTENTIAL BEST MANAGEMENT PRACTICES

Auto recycler operators appear to have general difficulty in identifying appropriate storm water pollution prevention and control practices for their facility to improve storm water quality. This subsection presents a compilation of best management practices that may be considered by the industry to reduce storm water pollution (Table 7).

Table 7. List of best management practices (BMPs) for auto recycler facilities. The BMPs are categorized by activity type. BMPs were selected from a review of several documents which are cited in the text.

ACTIVITY	PURPOSE	BEST MANAGEMENT PRACTICES
Vehicle Dismantling Antifreeze / Coolant	Eliminate exposure	Drain prior to dismantling and resell or recycle.
Batteries	Minimize exposure	Remove and place in covered storage area, on a paved surface that is bermed, or in plastic containers with lids.
Brake fluid	Eliminate exposure	Drain using suction. Remove and drain parts with fluids. Store in holding tanks and recycle.
Refrigerant	Minimize air pollution	Evacuate prior to dismantling and when part is removed.
Gasoline/Diesel	Eliminate exposure	Drain prior to vehicle storage. Filter, pump into holding tanks. Sell or reuse.
Motor oil	Eliminate exposure	Drain prior to dismantling and parts removal. Store in holding tanks and recycle.
Transmission oil	Eliminate exposure	Drain prior to dismantling and parts removal. Store in holding tanks and recycle.
Tires	Minimize exposure	Remove and store in semi-trailer, indoors, or covered area. Sell or recycle.
Oil filters	Eliminate exposure	Drain oil and properly dispose or recycle.
Vehicle parts	Eliminate exposure	Wash or clean in contained area. Store in plastic containers, covered area, or indoors.
Parts cleaner	Eliminate exposure	Recover and recycle.
Air bags	Eliminate exposure	Deploy airbags per guidelines or remove intact airbags for reuse and store under cover.

(CONTINUED)

ACTIVITY	PURPOSE	BEST MANAGEMENT PRACTICES
Auto / Parts / Material Storage Display autos	Minimize exposure	Use drip pans under stored vehicle. Replace hoods after parts removal. Reduce holding time for scrap disposal. Minimize inventory during wet season.
Burnt autos	Minimize exposure	Cover with plastic sheet, and remove for scrap disposal promptly.
Separated components	Eliminate exposure	Confine to designated area. Store under temporary or permanent cover. Curb, berm, or dike if necessary.
Auto body	Minimize exposure	Replace hoods after parts removal. Reduce holding time for scrap disposal. Minimize inventory during wet season.
Scrap parts	Eliminate exposure	Store under cover and dispose off to scrap collector promptly.
Material and liquid wastes	Improve materials management	Keep separate and label. Track recycling. Dispose properly.
Site Management Spills	Contain / cleanup pollutants	Prepare for and clean up spills. Use rags/adsorbents to clean, and adsorbent snakes to contain. Dispose off properly.
Site grading	Minimize exposure	Repave area to direct flows away from storage and waste areas.
Dismantling area	Minimize exposure	Roof or cover to eliminate rain-in. Berm to eliminate storm water run-on.
Waste and liquids	Good maintenance	Inspect to ensure integrity of tanks, containers, pipings and valves. Install safeguards against accidental releases.
Washwaters	Waste minimization	Recycle and reuse or release to sanitary sewer.
Employee training	Waste minimization	Train employees regularly on proper and environmentally safe practices.
Customer education	Waste minimization	Inform and require customers who remove parts to do so properly and appropriately dispose wastes.
Materials inventory	Good management	Maintain proper inventories of vehicles processed, materials stored, and wastes recycled or disposed.

(CONTINUED)

ACTIVITY	PURPOSE	BEST MANAGEMENT PRACTICES
Storm Water Treatment Flow dissipation	 Remove pollutants	 Direct flow discharge over coarse gravel or cobblestones to facilitate settling out of particulates and sediment.
Vegetative belts	Remove pollutants	Direct flow discharge over vegetative belts or biofilters to enhance pollutant removal.
Sand / gravel filters	Remove pollutants	Allow storm water from open parts storage areas to pass through sand-gravel filter with drain holes. Sand layer must be periodically replaced.
Detention ponds	Remove pollutants	Capture storm water runoff from high activity areas. Skim off surface oil and remove bottom sediment. Reuse or evaporate runoff water.
Oil-grit / oil-water separators	Remove pollutants	Direct flows from high activity areas through OW separators. Off-line separators to bypass large storms are preferable. Maintain regularly.
Flotation / coagulation	Remove pollutants	Store runoff flows, equalize, and provide flotation / coagulation. High operation and maintenance costs. Inappropriate if used only intermittently.
Industrial sewer piping	Remove pollutants offsite	Pretreat as required and pipe to sanitary sewer if allowed.

The BMP list has been classified according to four general activity descriptors. The selection of effective and appropriate BMPs from the list in Table 7 for a particular facility will depend on site specific considerations. These may include facility size, facility layout, geographic location, climate, operational characteristics, hydrology, and volume of storm water discharge.

BMPs identified under 'Dismantling Activity' target specific wastes generated in the dismantling process. BMPs listed under 'Auto/Parts /Materials Storage' identify specific practices that can be instituted to minimize storm water pollution from storage activities. BMPs identified under 'Site Management' are more general in applicability and emphasize facility and personnel management actions that can be undertaken to minimize pollutant releases to storm water. BMPs listed under 'Storm Water Treatment' are more costly to implement and involve structural modifications to remove pollutants in storm water runoff.

Many of the BMPs that are listed for waste management and storage practices have been recommended generically for the automotive service industry (PARWQCP 1994, PARWQCP 1993, CSWRD 1993, SCVNPSCP 1992, USEPA 1991A, BSSWU 1990, SCVNPSCP 1990, CDHS 1988B, CDHS 1987). Specific treatment BMPs recommended were compiled from an array of sources and from personal insights (WDEC 1994, MWCOG 1993, CSWQTF 1993, ADEM 1992B, Silverman *et al.*

1986). Also reviewed for this list were BMPs recommended in special reports on recycling and management of automotive waste discards (CIWMB 1993B).

SUMMARY

This Section discussed current pollution prevention practices at auto recycler facilities. It also reviewed potential best management practices that merit consideration for implementation at these facilities to reduce storm water contamination. The review considered treatment options in addition to source control and waste minimization measures.

SECTION 5.0 STORM WATER CHARACTERIZATION AND TREATMENT

INTRODUCTION

Motor vehicles incorporate metals, non-metals, and alloys in their structure. For normal operation, vehicles use gasoline and freon; and transmission, hydraulic, brake and crankcase fluids. Waste motor oil (which is a collective term for transmission, hydraulic, brake and crankcase oils) is a significant source of heavy metals and polycyclic aromatic hydrocarbons to the environment (Vazquez-Duhalt 1989, CDHS 1988A). Pollutants released into storm water runoff from auto recycler facilities are produced by, (i) the corrosion of the body and parts, (ii) leakage of motor fluids, and (iii) dismantling and disassembly operations (USEPA 1993, SCVNPSCP 1992, Cayless 1974, Svenson 1974). The limited studies on storm water runoff from auto recycler facilities performed to date have identified heavy metals including arsenic, cadmium, copper, iron, lead, nickel, zinc, chromium, as well as oil and grease (Bain 1993, SCADA 1993, SSP 1992, ADEM 1992A).

The following study was a first foray into understanding the auto recycler industry and its role in storm water pollution. It included site visits to several facilities, developing a cooperative relationship with auto recycler operators for research purposes, and learning about related industrial activities such as auto shredding. The purpose of this study, which was conducted between January 1991 and April 1992, was to identify pollutant parameters and indicators considered the most significant for monitoring nonpoint source pollution from auto recycler facilities, and to evaluate in a limited manner existing treatment methods. This section presents results from a preliminary multi-site storm water pollutant characterization survey (Phase I), and a more detailed investigation of the effectiveness of storm water treatment methods at one site (Phase II). The second investigation site allowed for observations on the performance of oil-water separators (OW separators) and an aeration-flocculation process (AF treatment system) in pollutant removal.

METHODS AND MATERIALS

Site Characteristics

Phase I Study Sites. Three sites were studied. The 40×10^{-3} km^2 (10 Ac) Monterey Park site (MP site) is a self-service facility and is located about 21 km east of downtown Los Angeles on a closed landfill. Monthly vehicle throughput in 1990 was 893 units. The downtown Los Angeles facility (LA site) of 2×10^{-3} km^2 (0.5 Ac), and the 8.1 x 10^{-3} km^2 (2 Ac) Alameda facility (AL site), 9 km south of Los Angeles, are in areas zoned for heavy industrial use and are paved sites where vehicles are dismantled and parts sold in retail. Motor vehicle fluids were collected in containers but no additional treatment of storm runoff was practiced at these sites.

Phase II Site. The Rialto auto recycler facility (RL site) is 52.6 x 10^{-3} km^2 (13 Ac) in size and situated in San Bernardino County, about 85 km east of Los Angeles. The RL site is fully paved and is a self-service facility. Motor fluids are drained directly into tanks and containers in a work area before vehicles are put on display for customers. Mean monthly vehicle throughput was 815 units in 1991. Mean monthly recovery of gasoline was 23 m^3. Mean monthly volumes of 4.8 m^3 of waste motor oil and 598 liters of antifreeze were hauled away.

Drainage from 75% of the site, including areas utilized for dismantling, storage and display, is directed to a series of OW separators and then to six storage tanks with a total storage capacity of 227 m^3. Storm water from the remaining vehicle storage area flows directly to an on-site catch basin. Storm water collected in the storage tanks is pumped to the AF treatment system (Figure 8). The treatment system consists of an equalization tank, a mixer, a clarifier settling tank, and an air aerator. Rotating rubber blades distribute the sludge onto a belt press (Balboa/Pacific Corp., Santa Fe Springs, CA).

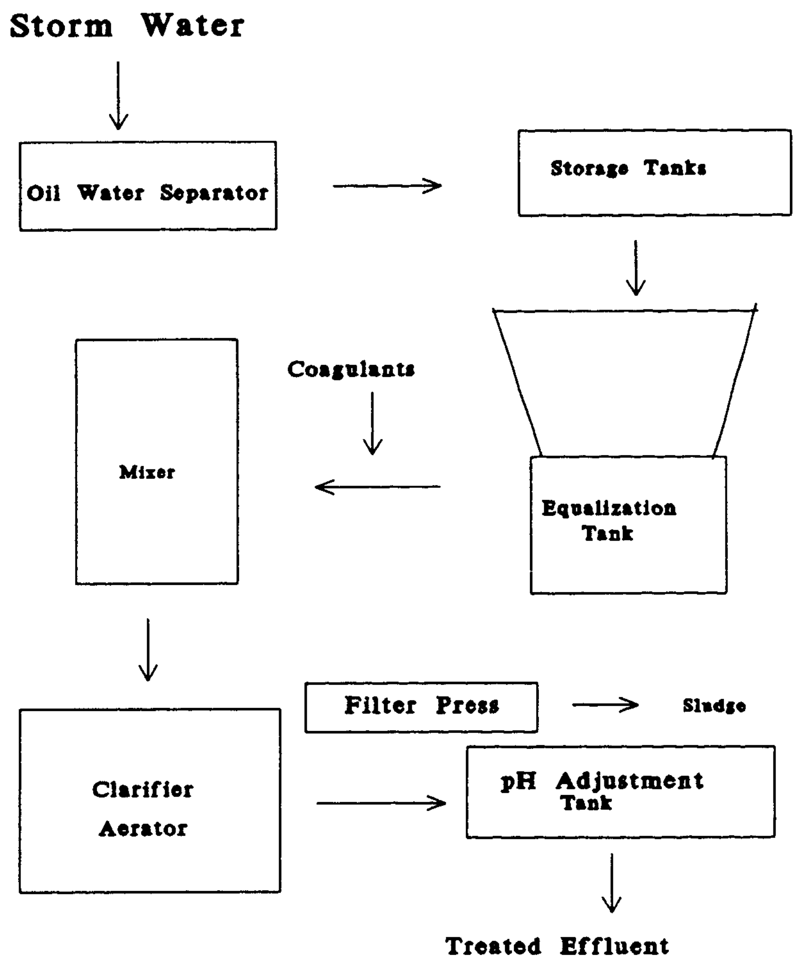

Figure 8. Schematic of storm water treatment at the Rialto facility. The treatment system includes oil-water separators and an aeration-flocculation (AF) process.

Lime, ferric sulphate, and a polymer binder are added to the mixer. Treated storm water from the AF treatment system is discharged directly to a culvert.

The RL facility was chosen for the study because it offered several advantages, including, (i) cooperative operators, (ii) size typical of large facilities, (iii) convenient composite sampling by collection of storm water runoff in storage tanks, (iv) additional sampling by the operator and the California Regional Water Quality Control Board, Santa Ana (CRWQCB-SA), and (iv) a secondary storm water treatment system (AF treatment system).

Sample Collection and Analysis

Phase I Study. Grab samples of storm water runoff (total volume of 3.5 L) flowing from each site were collected during the early part of storm events in January 1991. Each sample was apportioned in the field into 200 ml prewashed glass bottles for metals analysis (Cu, Pb, Zn); and 400 ml plastic bottles for analyses of conventional pollutant parameters (total suspended solids, chemical oxygen demand), and glass bottles for polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Sample bottles were ice-cooled and transported for chemical analyses at the Southern California Laboratory, California Department of Health Services, Los Angeles, CA.

Phase II Study. Three storm events, about a month apart, were sampled between January and April 1992. Storm water samples were collected from each of six storage tanks from a depth of 15 cm from the bottom with a hand operated guzzler pump (Cole-Parmer Instrument Co., Chicago, IL) fitted with a chemical resistant polymer hose). Samples were composited for a total volume of 19 liters. The sample for oil and grease was collected from the surface and made up to 3.8 liters in a glass bottle. Each composited 19 liter sample was apportioned in the field into 200 ml prewashed and pretreated glass bottles for metals analysis (Al, Ba, Cr, Cd, Cu, Fe, Mn, Mo, Ni, Pb, Zn, Sn, Hg), total organic carbon and ethylene glycol. Prewashed and pretreated 400 ml plastic bottles were used for conventional parameters (B, Cl^-, SO_4^{2-} , Cr^{6+}, total suspended solids, total dissolved solids, specific conductance, pH, total phosphorous, and Kjeldahl nitrogen); prewashed and pretreated 400 ml plastic bottles for polyaromatic hydrocarbons and polychlorinated biphenyls; and 50 ml clear vials for volatile organic compounds. Samples of treated storm water effluent from the discharge pipe of the AF treatment system were collected at the end of the first hour of discharge for similar analyses. Sample bottles were ice-cooled and transported for chemical analyses as in the Phase I study.

Laboratory Analyses. Analysis of total organic carbon (USEPA Method 415.2) and ethylene glycol (modified Method 8015) were conducted by the Environmental Toxicology Laboratory, County of Los Angeles, South Gate, CA. All analyses at the laboratory of the California Department of Health Services were conducted using standard USEPA methods; metals: USEPA Method 200.7, PCBs: USEPA Method 608, PAHs: USEPA Method 625, Hg: USEPA Method 245.1, and volatile organic compounds: USEPA Method 524.2 (APHA 1990). Lead, oil and grease, and total organic carbon samples collected by the facility operator and the CRWQCB-SA were analyzed by Associated Laboratories, Orange, CA. The analysis of the sludge sample from the AF treatment system was also conducted by the same laboratory.

Pollutant Load Estimates. Rough pollutant load estimates for metals (Pb, Cu, and Zn) and total suspended solids in storm water from auto recycler facilities were calculated using empirical load functions from mean concentrations of the pollutants (Marsalek and Ng 1989, Silverman *et al.* 1988). Storm water mean pollutant concentrations observed in the Phase I study were used as representative of the industry with minimal storm water pollution control practices. Assumptions made include the National Urban Runoff Program rainfall average of 101.6 cm (40 in) per year (USEPA 1983), and an auto recycler facility size of 20.24×10^{-3} km^2 (5 Ac), the national median size. The pollutant load estimate was generated as a general one for the U.S. Using isohyetal maps for determining rainfall averages would likely provided a better estimate of regional pollutant loads.

$$V = kAr \tag{3}$$

$$L = CV \tag{4}$$

where,

V is the runoff volume

k is the runoff coefficient for industrial sites (0.78)

r is the mean annual rainfall (40 in or 101.6 cm)

A is the facility area (5 Ac or 20.24×10^{-3} km^2)

L is the annual pollutant load

C is the mean pollutant concentration

RESULTS

Phase 1 Study

Pollutant Characterization

The analysis of storm water runoff from the three auto recycler sites in the Los Angeles area indicated significant contamination by organic constituents (chemical oxygen demand range of 63-480 mg/L) and metals (Cu range of 45-159 μg/L; Zn range 446-1,086 μg/L, and ; Pb range of 103-428 μg/L) (Table 8). In general, concentrations of metals and chemical oxygen demand (COD) were higher in storm water runoff from unpaved facilities than from concrete paved ones. Storm water from the unpaved sites also had the highest total suspended solids. Mercury was not detected at 1 μg/L. Polycyclic aromatic hydrocarbons (PAHs), which are present in waste motor oil and used crankcase oil, were not detected at 10 μg/L. Polychlorinated biphenyls (PCBs), which are often associated with fluff and non-metallic wastes at automobile shredder facilities, were not detected at 0.5 μg/L. Analysis for petroleum hydrocarbons was not performed.

Pollutant Loads

Rough estimates of pollutant loads per year from auto recycler facilities indicate that 13.3 metric tons (13.1 tons) of TSS, 2.2 metric tons (2.2 tons) of Cu, 12.6 metric tons (12.4 tons) of Zn, and 5.2 metric tons (5.1 tons) of Pb may be expected to be transported in storm water from a typical facility.

Table 8. Results of storm water runoff analyses from three auto recycler facilities in the vicinity of Los Angeles, CA. Runoff samples were collected as grab samples, at a discharge point where the runoff left the facilities, between January 3 - 10, 1991. PAHs were not detected at 10 μg/L and PCBs at 0.5 μg/L. First flush analysis results from a comparable site in Sacramento County (RC site) are provided for comparison.

SITE	SIZE (x 10^3 km^2)	RAINFALL cm	TSS mg/L	COD mg/L	Cu μg/L	Zn μg/L	Pb μg/L
LA Site (paved)	2	1	110	332	114	446	103
AL Site (paved)	3.2	0.8	40	63	45	639	170
RC Site (unpaved)	32.4	0.5	420	670	240	980	590
MP Site (unpaved)	40	1.4	2,740	480	159	1,086	428

Total Organic Carbon to Oil and Grease Correlation

A correlational analysis of total organic carbon (TOC) versus oil and grease was performed for storm water samples collected from different areas of the facility that had undergone different levels of treatment ($n=21$) (Figure 9). Total organic carbon measures [humic acids + hydrocarbons + oil and grease] while oil and grease is a measure of [hydrocarbons + oil and grease]. Total organic carbon was positively correlated with oil and grease concentration (Pearson's correlation $r=0.66$; $p<0.002$). However, the correlation was not robust enough to show significance on non-parametric testing (Spearman's correlation $r_s=0.4$, $p>0.05$; Kendall's $\Gamma=0.3$, $p>0.05$).

Pollutant Removal

At the RL facility, concentrations of lead and oil and grease in storm water at three locations were sampled. These were (i) the vehicle storage area, (ii) the dismantling area after passage through OW separators, and (iii) the AF treatment system effluent (Figure 10). Concentrations were noticeably different.

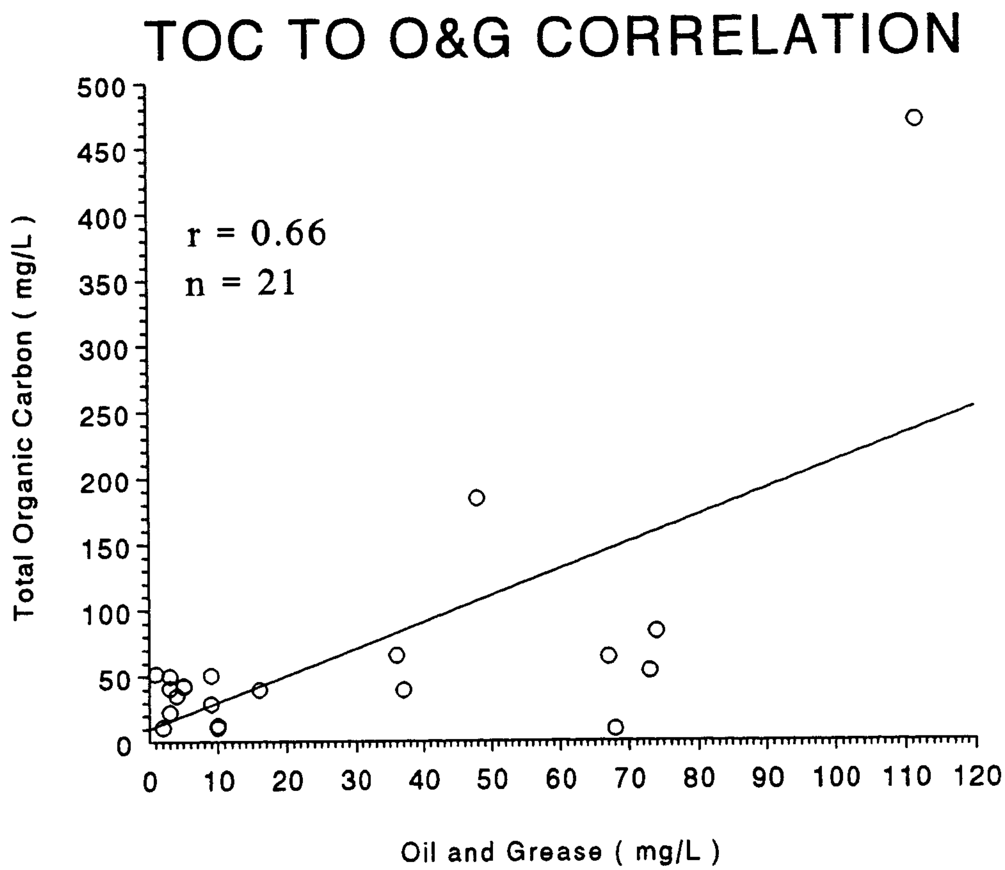

Figure 9. The correlation between total organic carbon and oil and grease measured in storm water at multiple locations at the Rialto facility. The correlation appears to have been influenced by outliers as is evident from the graph ($r = 0.66$; $n = 21$); ($r = 0.39$ when the extreme outlier value is removed from the data set).

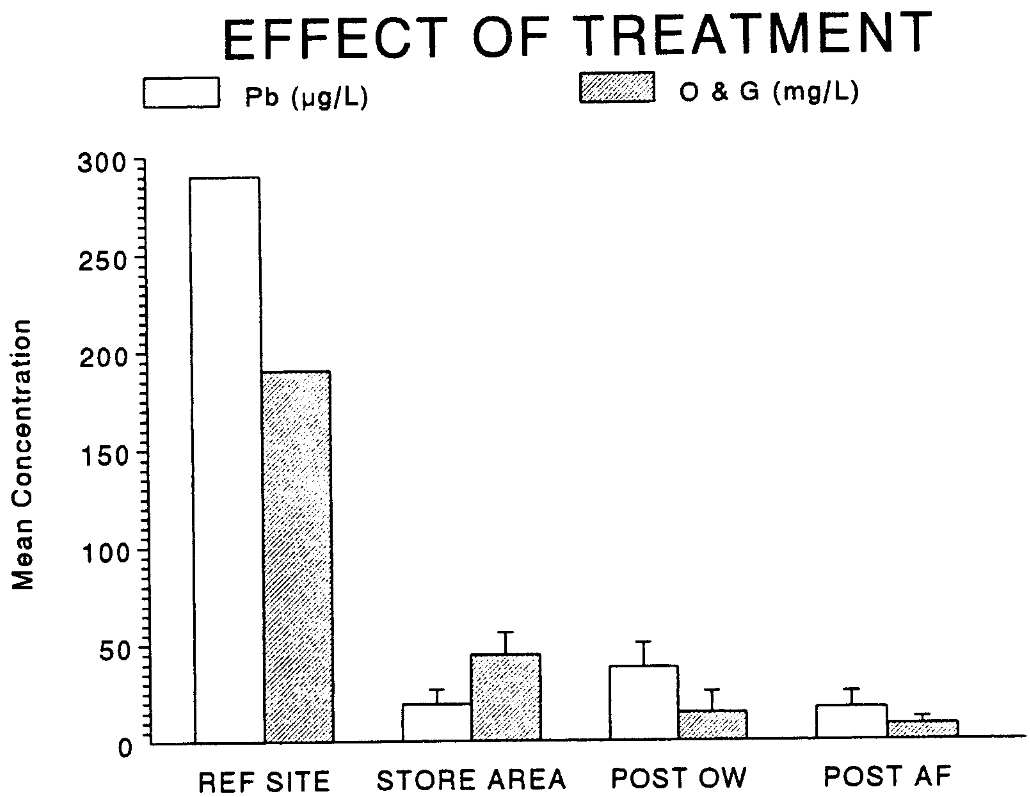

Figure 10. The effect of treatment on storm water concentrations of lead (Pb), and oil and grease (O & G). Data for the reference site, located in Sacramento, CA, was obtained from reference SSP 1992. Storm water from the vehicle storage area received no treatment. STORE AREA = storage area; OW = oil-water separator; AF = aeration-flocculation treatment system.

These results when compared with the reference site in Sacramento County (SSP 1992), which was similar in size but where storm water did not receive any treatment, showed Pb, and oil and grease concentrations that were lower by 87% and 92% respectively after passage through the OW separator. Additional treatment of storm water by the AF treatment system connected in series to the OW separator resulted in 97% lower lead, and 99% lower oil and grease concentrations when compared with the no-treatment baseline. Storage area storm water runoff was nearly three times as high in oil and grease as the effluent from the OW separators, while the concentration of lead was lower. It is possible that the resultant decreases may be attributable to other factors that were not controlled for the geographically separated sites. However, the concentrations of the two pollutants in storm water, observed in the Sacramento study, are not atypical (see Table 6).

Aeration Flocculation Process

Conventional Pollutants. AF treatment resulted in 65% mean removal of total phosphorous, and 87% mean removal of oil and grease in storm water effluent from the OW separators (Table 9). Influent and effluent to the AF treatment system were sampled. Removal of total Kjeldahl nitrogen (TKN) ranged from 0-15%. Increases, however, were observed for sulphate, total suspended solids (TSS), total dissolved solids (TDS), and conductivity.

Table 9. Comparison of conventional pollutant concentrations between storm water runoff (post oil water separator) and treated effluent (aeration-flocculation). Storm events occurred between January 2 and March 30, 1992, and were about a month apart (n= 3). (SEM = standard error of mean; NA = not analyzed).

CONVENTIONAL PARAMETER	STORM WATER RUNOFF	MEAN REMOVAL OBSERVED (PERCENT)
Chloride (mg/L)	15 ± SEM, 1.2	13
Sulphate (mg/L)	8.5 ± SEM, 4	0
Total Phosphorus (mg/L)	0.26 ± SEM, 0.13	65
Kjeldahl Nitrogen (mg/L)	1.82 ± SEM, 0.9	0
Ammonia Nitrogen (mg/L)	0.74 ± SEM, 0.43	86
Total Suspended Solids (mg/L)	35 ± SEM, 6	0
Total Dissolved Solids (mg/L)	234 ± SEM, 1	0
Conductivity (μS/cm)	311 ± SEM, 5	0
Total Organic Carbon (mg/L)	50 ± SEM, 8	34
Oil & Grease (mg/L)	15 ± SEM, 11	87
pH	6.3 - 6.8	NA

These increase in concentrations may have been related to ionic substitution mechanisms as well as caused by chemicals introduced in the AF treatment system.

Metals. A Waste Extraction Test (WET) analysis for 17 metals in sludge generated by the AF treatment system indicated that Zn, Pb, Ni, and Cu were the predominant metals removed (Figure 11). Low concentrations of Ag, Cd, As, Be, Cr, and Co were also identified. Antimony (< 10 mg/kg), Cr^{+6} (<0.01 mg/kg), Se (< 1 mg/kg), and Hg (<0.07 mg/kg) were not detected. The concentration of Zn was more than 40 times the concentration of the next highest metal Pb.

The removal of metals exceeded 90% for Al, Mn, and Fe (Table 10). Percentage removals for Zn and Pb were lower but could be explained by the computational limitations imposed by detection limits. Copper and Cr^{+6} were not detected in the effluent from the OW separators at 10 μg/L. Mo, Ni, and Sn were not detected at 20 μg/L; Hg was not detected at 1 μg/L.

Organics. Storm water effluent from the OW separators contained petroleum hydrocarbons as benzene, alkyl benzenes, and other benzene derivatives (Table 11). Total xylenes concentration was the highest at a mean concentration of 300 μg/L. The sole PAH observed above the detection limit of 10 μg/L was naphthalene at a mean concentration of 47 μg/L.

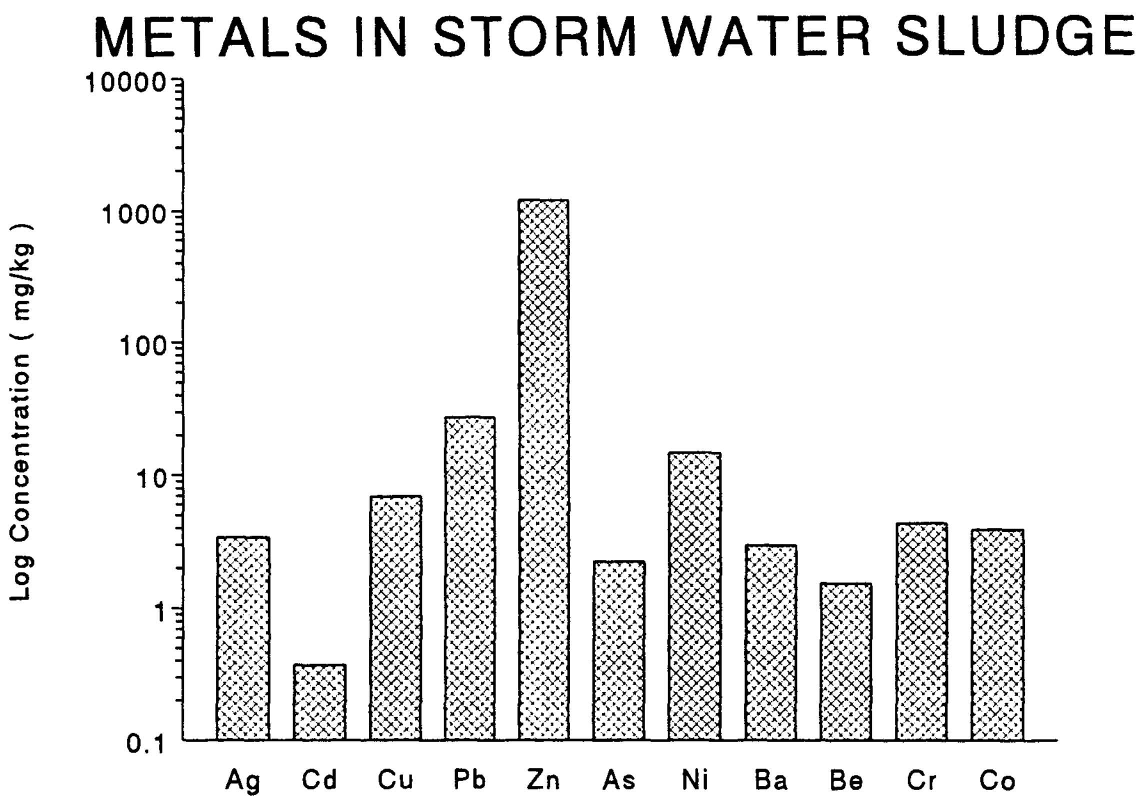

Figure 11. Concentration of metals in storm water sludge from the aeration-flocculation treatment system. The concentrations indicate the relative abundance of these metals in storm water at auto recycler facilities.

Table 10. Comparison of metal concentrations between storm water runoff (post oil-water separator) and treated effluent (post aeration-flocculation). Storm events occurred between January 2 and March 30, 1992, and were about a month apart (n= 3), (SEM = standard error of mean; NA = not analyzed). > indicates higher percent removal than the listed value but the exact percentage could not be computed because detection limits were reached.

METAL	STORM WATER RUNOFF (μg/L)	MAXIMUM REMOVAL OBSERVED (PERCENT)
Al	201 ± SEM, 139	97
Ba	73 ± SEM, 11	5
Fe	11,067 ± SEM, 2,105	99
Mn	414 ± SEM, 10	93
Pb	38 ± SEM, 13	>84
Zn	76 ± SEM, 4	>38

Table 11. Comparison of concentrations of organic compounds between storm water runoff (post oil water separator) and treated effluent (aeration-flocculation). Storm events occurred between January 2 and March 30, 1992, and were about a month apart (n= 3), (SEM = standard error of mean; NA = not analyzed).

SEMI / VOLATILE ORGANICS	STORM WATER RUNOFF ($\mu g/L$)	REMOVAL OBSERVED (PERCENT RANGE)
Benzene	15 ± SEM, 4	16-50
n-Butyl benzene	2.4 ± SEM, 1.6	61-95
Ethyl benzene	28 ± SEM, 5.8	45-71
Iso-Propyl benzene	0.6 ± SEM, 0.4	58
n-Propyl benzene	6.5 ± SEM, 2.5	32-98
1,2,4-Trimethyl benzene	99 ± SEM, 20	16-75
1,3,5-Trimethyl benzene	41 ± SEM, 7	26-77
Toluene	105 ± SEM, 21	15-56
m,p-Xylenes	184 ± SEM, 29	22-65
o-Xylene	116 ± SEM, 13	15-61
1,2-Dichloromethane	15 ± SEM, 15	100
Naphthalene	47 ± SEM, 19	15-77

The AF treatment system was moderately efficient at organic pollutant removal with maxima above 50% but also had percentages as low as 15-16% for toluene, benzene, 1,2,4 trimethyl benzene, and naphthalene. Higher removal percentages for organic constituents were associated with higher concentrations in the OW separator effluent indicating the presence of a limiting threshold.

DISCUSSION

The USEPA identified auto recycler facilities as an industrial category with a high potential for storm water contamination and prescribed special monitoring requirements for this category in federal permitting requirements (USEPA 1993, USEPA 1992, USEPA 1990). Very little technical documentation, however, has been available to support the regulatory action. The attention the industry has drawn because of nonpoint pollution concerns appears to be primarily based on a few reports, professional judgement, and observations in the field. A study on soil contamination in and around auto recycler facilities found metal contamination (Pb, Cu, Zn, Ni) distributed by vehicular movement and storm water runoff at concentrations 3 to 10 times higher than at control locations (Blake *et al.* 1987)

Industrial Pollutants

This study on storm water runoff from auto recycler facilities supports the findings of earlier reports that the principal contaminants in storm water runoff from such facilities are metals (Pb, Cu, Zn, Ni and Cd) and organic compounds (identified by indicators such as oil and grease, and chemical oxygen demand)(ADEM 1992A, SSP 1992). Aluminum and Fe, which may also be present in high concentrations in storm water runoff, are not normally considered pollutants of concern because they are ubiquitous. The observed metal and chemical oxygen demand concentrations at several auto recycler sites in this study are indicative of an industrial-type pollution. In addition, at the RL site, petroleum hydrocarbons (benzene and benzene derivatives) and one PAH (naphthalene) were detected, unlike in previous reports. The lack of detection of these compounds by others may be related to the relatively high concentrations necessary for detection and the volatility of these compounds.

Ethylene Glycol

Ethylene glycol, a major constituent of antifreeze, was an expected contaminant in storm water from auto recycler facilities, but its miscibility with water presented difficulties for chemical analysis. The analytical method used was unable to detect ethylene glycol at the rather high detection limit used (5 mg/L). However, ethylene glycol has a relatively high COD (1,400 g/L) (Evans and David 1974) and this may be indicative parameter. The influence of antifreeze on the value of COD may also partially explain the discrepancy of low oil and grease concentrations in the presence of high COD reported at other auto recycler sites (ADEM 1993A, CRWQCB-LA 1993, SCADA 1993, ADRA 1993, USEPA 1993). Chemical oxygen demand may thus serve as a good indicator of ethylene glycol and petroleum hydrocarbon contamination in storm water runoff from auto recycler facilities. Ethylene glycol has an aquatic toxicity LC_{50} of 53,000 mg/L to fathead minnows (*Pimephales promelas*) (CDTSC 1991). This value is not below the 500 mg/L threshold established by regulatory agencies for a chemical to be considered toxic or hazardous. However, ethylene glycol is considered orally lethal to humans at an LD_{LO} of 1560 mg/kg. It is also readily degradable in aquatic environments within three to eight days, and thus may cause depressed dissolved oxygen levels in sensitive waters (Evans and David 1974).

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are not normal constituents of waste motor oils but are often introduced carelessly by mixing degreasing solvents in waste oil drums and are often nondetectable (CDHS 1988A). They were not detected in storm water runoff from the preliminary sites (<0.1 μg/L). PCBs continue to contaminate non-metallic debris or 'fluff' generated by auto shredder facilities (Eaganhouse *et al.* 1990). In older motor vehicles, they were used primarily as pressure lubricants and in electrical equipment as insulators. However, they are less likely to be present in storm water runoff from auto recycler facilities because of the dissimilarity in processes between auto dismantling and vehicle shredding, and the phaseout of PCB manufacture and use.

Metals

Analysis of storm water runoff samples and the AF treatment system sludge showed higher concentrations of Fe, Zn, Pb, and lesser amounts of Cu, Ni (Figure 11). It is not surprising that the concentration of metals found in storm water comes from the two sources that characterize such facilities; automobile bodies, and waste motor oil. The average automobile weighs 1,145 kg (2,520 lbs) and has a typical composition, by weight of Fe 62-70%, Pb - 0.6%, Zn 1-1.5%, Cu 1-2%, Al 5-24%, Fluids 4% (Ness 1984, McCosh 1990, Bever 1978, USDOT 1977). However, some motor-vehicle components are rich in selected heavy metals: batteries and clamps (Pb); radiators, wires, and brake pads (Cu); and tires (Zn, Cd) (SCVNPSCP 1994, Ness 1984, Bever 1978). In addition, waste motor oil contains significant concentrations of heavy metals from piston blow-by, additives, and engine wear; Pb 1,200- >13,000 μg/g; Zn 1,200-2,500 μg/g; Cu 50 μg/g; Ni 5 μg/g; Cd 2 μg/g; Cr 3-30 μg/g; and As 5-25 μg/g (Vazquez-Duhalt 1989, CDHS 1988).

Iron is usually not of concern as a contaminant in storm water runoff. However, at auto recycler facilities, its concentration in runoff could be used as an indicator of heavy metal contamination from corrosion processes. Such an approach towards routine monitoring may serve to lower costs associated with the analysis of the full suite of priority toxic metals. Concentrations of Fe found in this and other studies have ranged from 7.8-54 mg/L (ADRA 1993, SSP 1992). Total suspended solids, which is used as an indicator for metals contamination, may be less reliable for auto recycler facilities because the indicator values are influenced to a greater extent, as when compared to Fe, by the erodability of the facility surface; namely, whether it is paved or unpaved.

Hydrocarbons

One PAH, the low molecular weight naphthalene, was detected in storm water. Naphthalene is abundant in waste motor oil and in gasoline, and thus readily contaminates auto recycler sites. The total PAH concentration in crankcase oil has been reported to increase 180 to 200 times of its initial concentration in a vehicle that is driven for several thousand miles (Vaquez-Duhalt 1989, Pruell and Quinn 1988). Other PAHs, may have been detected if lower detection limits (< 1 μg/L) were employed. PAHs such as naphthalene (100-1,400 μg/g), benzo(a)anthracene (10-50 μg/g), and benzo(a)pyrene (5-20 μg/g) are found in used motor oils and come from gasoline and motor oil combustion products (CDHS 1988A). Higher molecular weight PAHs like anthracenes, fluoranthenes and pyrenes are produced by incomplete combustion in the engine and increase progressively with mileage travelled (Vaquez-

Duhalt 1989, Pruell and Quinn 1988). These PAHs are preferentially bound in sediments and thus are not that easily detected in water column samples (MWCOG 1993).

Petroleum hydrocarbons such as benzene and its derivatives would not normally be expected to be present in storm water runoff because of their volatility. Other studies conducted have not found volatile or semi-volatile petroleum hydrocarbons in storm water from auto recycler facilities (SSP 1992, ADEM 1991A). Petroleum hydrocarbons, however, have been identified in runoff from automotive-related service facilities (MWCOG 1993, CSWRD 1993). This study found toluene and xylenes in the greater than 100 μg/L range and lesser mean concentrations of ethyl benzene and trimethyl benzenes. The detection of volatile petroleum hydrocarbons in storm water raises some concern since it indicates substantial loss of gasoline from spillage and poor dismantling practices at some auto recycler sites.

Other Observations

An evaluation of the relationship between total organic carbon and oil and grease in runoff from auto recycler facilities was conducted. These two measures, in some instances of environmental monitoring, have been used interchangeably as indicators (CSWRCB 1992). In this study, a positive correlation was observed, but the relationship was not strong and may have been influenced by outliers. One possible explanation is that the sample collection methods for the two parameters differ. While oil and grease is a surface sample, total organic carbon is obtained as a water column sample. It is likely that for storm water runoff from auto recycler facilities, gravimetrically different constituents are being measured, and the two parameters may not be interchangeable.

Storm Water Treatment

The comparison of two pollutant classes in storm water runoff, a metal (Pb), and an organic indicator (oil and grease), relative to a reference site from; (i) vehicle storage-display areas, (ii) post-OW separators, and (iii) post-AF treatment, indicated lower concentrations when control measures had been implemented. This observation may have a bearing on pollution control practices. Treatment of storm water runoff with OW separators (87-92% reduction), and AF treatment in series (incremental 7-10% reduction), may substantially reduce the concentration of the two pollutants in storm water. However, even in rare cases when storm water collection and treatment have been practiced by auto recyclers, the attention has often been focussed on high activity areas such as the dismantling perimeter. This study found that storm water runoff from storage-display areas could potentially contribute higher loads of some pollutants such as oil and grease, and should therefore not be neglected when implementing site management measures for pollution control.

Oil Water Separators

OW separators are an effective treatment process for removing oil and grease in storm water if concentrations of free oil are high. Their capacity to remove oil and grease may be as high as 92% for auto recycler facilities, although their efficiency for urban storm water is reportedly less (40-60%) (Eaganhouse and Kaplan 1981, Stenstrom *et al.* 1984). In contrast, petroleum hydrocarbons and light molecular weight PAHs, which may be mostly colloidal or in emulsion are not removed. The removal of metals such as Pb (87%), and to a lesser extent Cu, and Zn, which are associated with suspended solids, is largely a function of gravity settling and solids retention (Latimer *et al.* 1986). Recent studies of on-line OW separators have shown that they are not very effective in retaining trapped pollutants which may be flushed out even in minor storm events (MWCOG 1993). Off-line OW separator systems, which are designed for bypass by greater than design storms, may be more effective in pollutant removal and suspended solids retention.

Aeration-Flocculation Treatment

The AF treatment process when connected in series with the OW separators substantially augmented pollutant removal, with a few exceptions. TKN concentration was not effected. TSS, TDS, conductivity, and sulphate concentrations in treated effluent increased, as a result of chemicals introduced in the AF treatment process.

The AF treatment was effective in removing metals to levels less than 10 μg/L, which was about a 90% reduction in concentration when compared with the OW separator effluent . It was moderately effective in removing hydrocarbons (15-50%) to concentrations below 20 μg/L for benzene and naphthalene. The capital cost of the AF treatment system, however, is more than six times that of the OW separator. In addition, the high operation and maintenance costs at about $30 per hour for 24 hours per storm event to startup and run the system may appear prohibitive to most auto recyclers. Such costs could be partly recouped if the treated storm water is reused on site. This was not the case at the RL site.

The AF treatment system appears to be one alternative when numerical limitations for pollutants are being exceeded, and all other best management practices that emphasize source minimization and pollutant containment have been implemented. It is possible that more efficient storm water treatment systems will be developed for use at auto recycler facilities in the future.

SUMMARY

This Section presented the results of a preliminary study on the characterization of storm water pollution from auto recycler facilities, and observations on the effectiveness of storm water treatment methods on pollutant removal at a single facility. Rough estimates of annual pollutant loads for copper, lead, and zinc from typical auto recycler facilities were made. The findings of a detailed storm water pollutant characterization performed in the second study were discussed and two storm water treatment methods were evaluated. The weak correlation between two indicators, total organic carbon and oil and grease which are sometimes used interchangeably, was noted.

SECTION 6.0 TOXICITY AND LONG-TERM TRENDS IN POLLUTANT DISCHARGES: A CASE STUDY OF ONE FACILITY

INTRODUCTION

The discharge of storm water from industrial facilities, including auto recycler sites, was rarely regulated before the 1987 amendments to the Clean Water Act (CWA). Recently however, the USEPA has promulgated specific requirements for the auto recycler industry to manage storm water (USEPA 1993, USEPA 1992, USEPA 1990). These requirements call for the implementation of pollution prevention plans incorporating best management practices and storm water discharge monitoring to verify the effectiveness of such measures. The toxicity of storm water runoff in urban streams and industrial activity source areas has been previously established using bioassay screening techniques (SCCWRP 1990, Pitt and Field 1990, Cooke and Lee 1993). In addition, highway runoff which transports motor vehicle associated pollutants, has been found to cause lethal and sub-lethal effects in test organisms (Lord 1987). However, very little long-term data on pollutant discharges and runoff toxicity has been recorded for auto recycler facilities. The exceptions are a few facilities that were regulated for storm water before the 1987 CWA amendments (CRWQCB-LA 1994, CRWQCB-SA 1994). Studying these facilities may enable a better understanding of storm water runoff characteristics including toxicity. This section describes such a study conducted on one facility located in Los Angeles County.

Site Description

The auto recycler facility (Ecology Auto Wrecking, Inc.) is situated on a former landfill in the city of Norwalk, approximately 26 km east of downtown Los Angeles. A permit for the discharge of storm water was issued to the facility under the National Pollutant Discharge Elimination System (NPDES) in 1977. This permit included numerical effluent limitations for conventional pollutants and heavy metals. A consistent monitoring program for the facility was established in 1984. The total area of the facility presently is 68.8×10^{-3} km^2 (17 Ac), with an annual vehicle processing volume of about 15,900 vehicles. The facility generates approximately 60,182 liters (20,600 gal) of waste oil annually from the vehicle dismantling process. This waste oil is sent to a recycler. Antifreeze is similarly recycled, and gasoline is reclaimed for reuse on site.

The self-service auto recycler facility conducts vehicle compaction on site. It is therefore typical of large facilities of this type. Saleable parts are removed by the customer in an open display area. Motor vehicle fluids are removed by facility employees prior to display, and the residual auto body is sent to a shredding facility.

Only storm water from the dismantling area passes through a multi-compartment OW separator. The facility instituted additional structural modifications and improved waste management procedures in the late 1980s to reduce storm water contamination.

MATERIALS AND METHODS

Storm Water Sampling

Sampling of storm water was conducted as grab samples at a point prior to discharge to the receiving stream. Samples were transported immediately to a commercial testing laboratory. Chemical analysis as well as toxicity testing were conducted by the same laboratory (Associated Laboratories, Orange, CA) during the study period. A maximum of 45 storm discharge events were sampled from the period 1984-1993. Toxicity tests were conducted on 43 of these storm events. Data were analyzed in terms of wet seasons because of the distinct dry and wet seasons in California. The wet season was considered to extend from the month of October of the first year to April of the following year. The dry season extended from the months of May to September. The number of storm events falling within a particular wet season ranged from 2 to 10 events with a mean of 4.9 events.

Chemical and Toxicity Analyses

Data on the quantities of waste oil recycled were obtained from recycler manifests. Chemical analyses for conventional pollutants for biochemical oxygen demand, oil and grease, phenols, and pH were conducted using Standard methods (APHA 1990). Arsenic was analyzed using USEPA method 206.2, lead using USEPA method 239.2, mercury using USEPA method 245.1, and cadmium, copper, nickel, zinc, and total chromium using USEPA method 200.7. Acute toxicity tests were performed using ten to twenty fathead minnows, *Pimephales Promelas*, in ten liters of 100% effluent, in accordance with USEPA testing protocols (USEPA 1985). The definitive test, namely greater than 90 % toxicity in a 48 hour period, was considered to indicate acute toxicity.

Statistics

Statistical summaries were performed substituting half the detection limit when censored data were encountered. Censored data are data that have been reported with 'less than detection limit' values. The half detection limit substitution method, although less precise than the maximum likelihood or log probability regression method, is simple to compute and may provide a reasonable approximation of the true mean when the proportion of censored data is less than one-half (Al-Shaarawi and Esterby 1992). The percentage of censored data ranged from a low of 4.5% for zinc to a high of 90% for mercury. In addition, multiple detection limits for censored data for several analytes were also encountered in the data set. For comparative purposes, as well as to obtain better estimates of summary statistics, the data set was also analyzed by the robust log probability regression method (Helsel and Hirsch 1992, Travis and Land 1990, Helsel and Cohn 1988, Helsel and Gilliom 1986) using the MDL software program (United States Geological Survey, Fairfax, VA). This method has been recommended for estimating the mean and standard deviation, when data censoring at multiple detection limits is encountered (Helsel 1990).

Statistical testing to determine the association between concentrations of the six pollutants that were least censored (< 25%) and acute toxicity, was performed using the non-parametric Mann-Whitney Test which is an analogue to the two-sample t test (Zar 1984, Winer 1993). The non-parametric test was selected to be a conservative indicator and also partially offset sample mixture effects like analyte dependence and synergism. The Kendall coefficient of concordance was used to determine if there was any association among the pollutants that were significantly associated with toxicity (Zar 1984, Winer 1993).

RESULTS

Material Recycling

Waste oil recycling increased from a monthly mean of 787 liters per month (208 gal mth^{-1}) during the 1984-1985 wet season to a high of 10,746 liters per month (2,839 gal mth^{-1}) during the 1987-1988 wet season (Figure 12). The mean wet season recycling volume was somewhat lower in 1993 at 7,892 liters per month (2,085 gal mth^{-1}). Dry season waste oil recycling reached a maximum at 11,465 liters per month (3,029 gal mth^{-1}) during 1990. The annual per vehicle waste oil recycling ratio computed to an average of 4.9 liters (1.3 gal) for 1991, a year for which vehicle processing data was available.

Pollutant Trends

Temporal trends for the most frequently detected conventional and toxic pollutants show a decline after improvements were made at the facility. The biochemical oxygen demand of storm water runoff reached a maximum mean of 231 mg/L during the 1989-1990 wet season but declined to one fifth of that concentration for 1992-1993 at 48 mg/L (Figure 13). The mean oil and grease concentration peaked at 38 mg/L during the 1987-1988 wet season and declined to 13 mg/L for the 1992-1993 wet season (Figure 14).

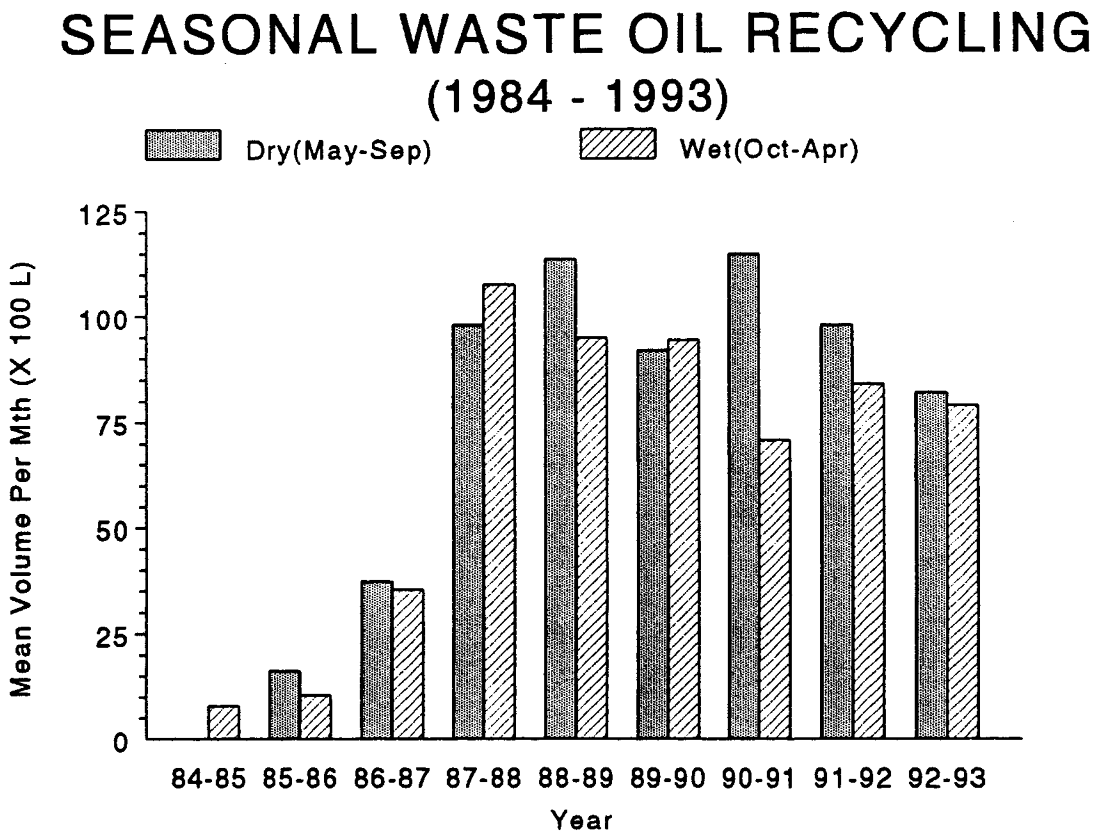

Figure 12. Seasonal volumes of waste oil recycled between 1984 and 1993. Data are graphed for both wet and dry seasons. Information on waste oil volumes recycled were obtained from waste-hauler manifests.

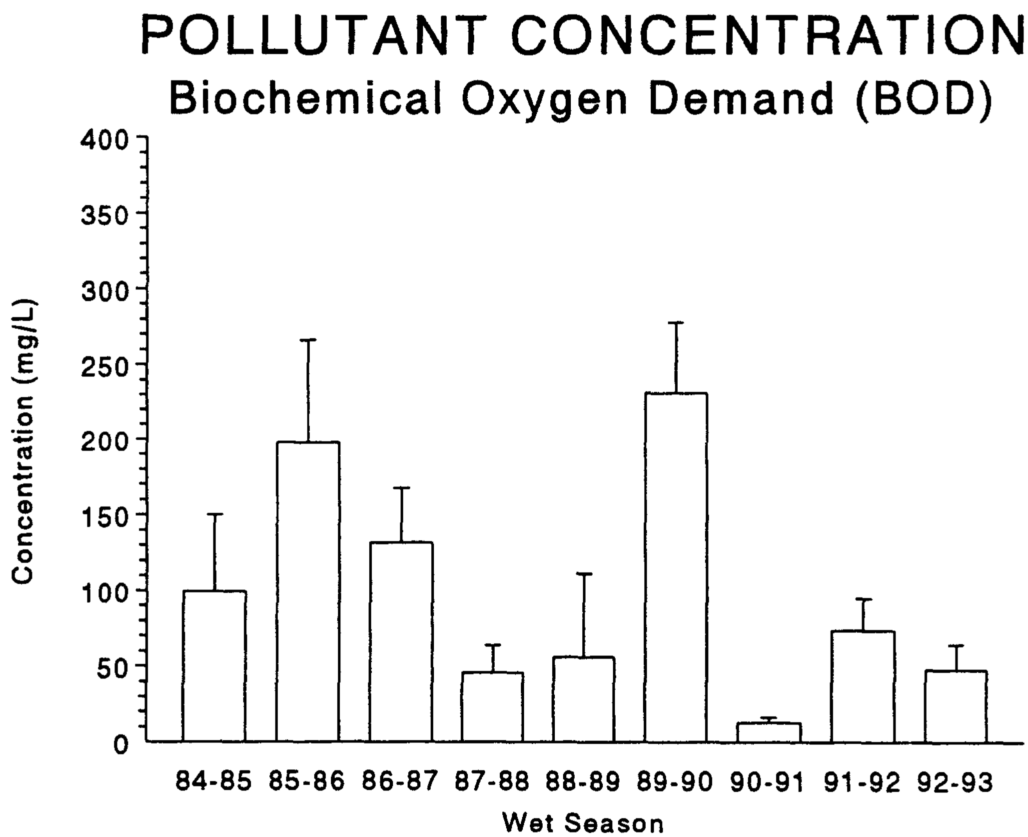

Figure 13. Trends in the mean concentration of biochemical oxygen demand in storm water between 1984 and 1993. Error bar indicates +1 standard deviation.

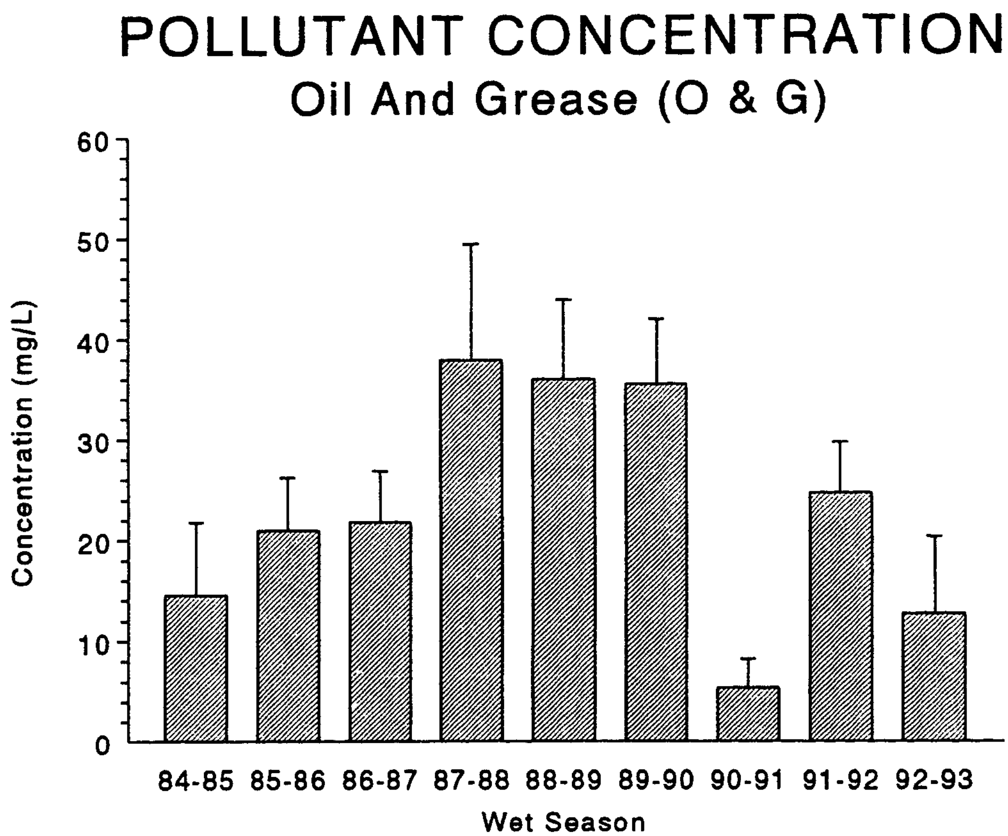

Figure 14. Trends in the mean concentration of oil and grease in storm water between 1984 and 1993. Error bar indicates +1 standard deviation.

The phenols concentration reached a mean high of 0.213 mg/L during the 1988-1989 wet season and declined to 0.018 mg/L during the 1991-1992 wet season (Figure 15). Phenols were not analyzed during the 1992-1993 wet season.

Lead and copper are two common heavy metals associated with storm water runoff at transportation-related industrial sites. The concentration trends of these two metals closely mirrored each other until the 1990-1991 wet season (Figure 16). Mean lead concentrations for the wet season reached a high of 403 μg/L during the 1988-1989 and declined to 83 μg/L for the 1992-1993 wet season. In the case of copper, the wet season maximum of 188 μg/L was reached during the 1989-1990 wet season, and declined to a mean of 37 μg/L for the 1992-1993 wet season. Zinc, another heavy metal commonly detected in urban storm water runoff, reached a mean wet season high of 1,537 μg/L during 1985-1986, and declined to 127 μg/L in 1992-1993 (Figure 17).

Statistical Methods Evaluation

For the pollutants monitored over the study period of nearly a decade, censored data at a range of detection limits were encountered. A comparison of pollutant means and standard deviations using the simpler half detection limit substitution method and the recommended robust log-probability method showed good agreement ($< \pm 12\%$ difference) for nine out of the eleven pollutants (Table 12).

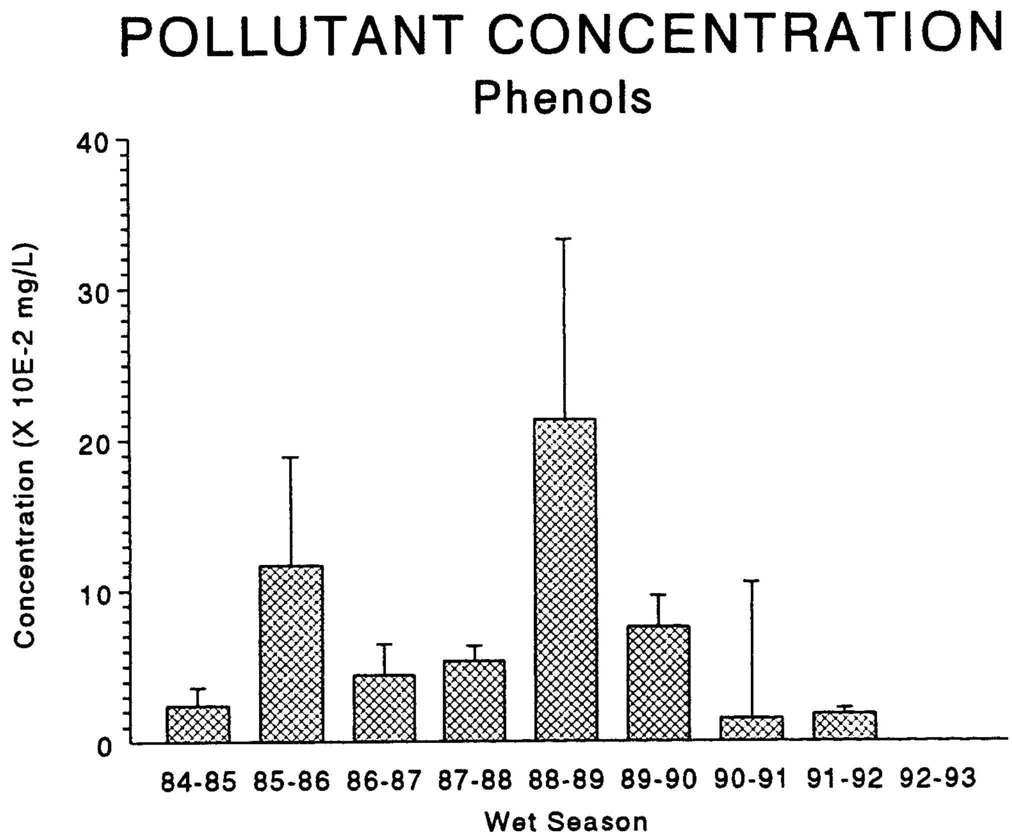

Figure 15. Trends in the mean concentration of phenols in storm water between 1984 and 1993. Error bar indicates +1 standard deviation.

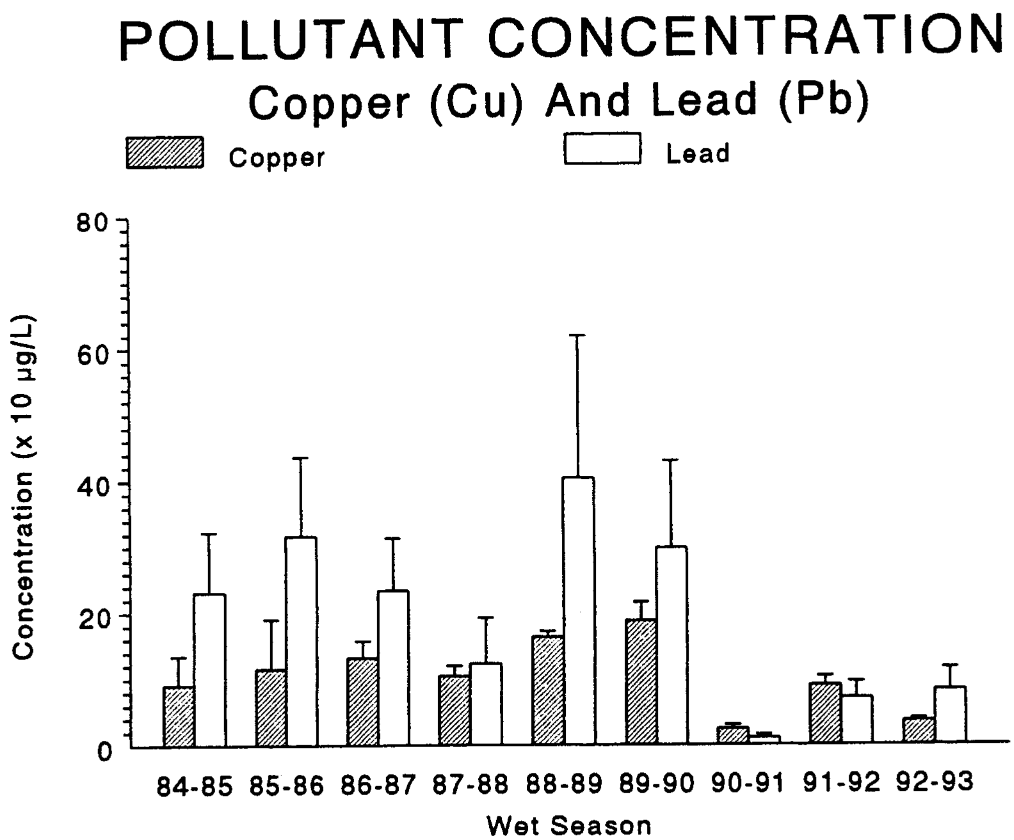

Figure 16. Trends in the mean concentration of lead and copper in storm water between 1984 and 1993. Error bar indicates +1 standard deviation. Both metals were significantly associated with acute toxicity.

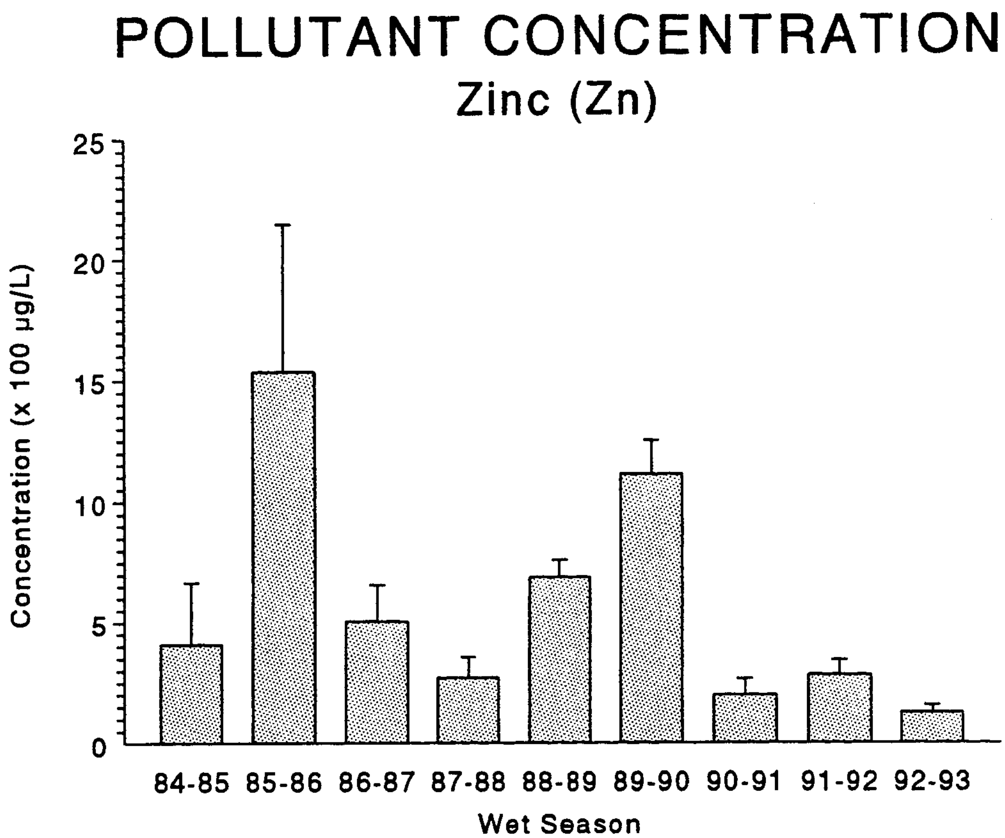

Figure 17. Trends in the mean concentration of zinc in storm water between 1984 and 1993. Error bar indicates +1 standard deviation.

Table 12. Comparison of statistical summaries computed by the one-half detection limit substitution method and the robust log-probability method. Detection limit range indicates range of detection limits encountered in the data set. 90^{th} tile indicates the ninetieth percentile values in the data set. SD = standard deviation

POLLUTANT PARAMETER	EVENTS SAMPLED	PERCENT BELOW DET. LIMIT	DET. LIMIT RANGE	MEDIAN	90^{th} TILE	MEAN ± SD (Half Detection Limit Method)	MEAN ± SD (Robust Log-Probability Method)
BOD (mg/L)	42	11.9	0.1-10	74	236	92.7 ± 91.7	93.1 ± 91.4
Oil and grease (mg/L)	44	6.8	0.1-1.0	21	46	24.8 ± 19.5	25.0 ± 19.2
Phenols (mg/L)	44	22.7	0.01-0.1	0.03	0.12	0.057 ± 0.077	0.054 ± 0.077
As (μg/L)	43	51.2	2-20	3	8.8	5.5 ± 7.3	3.6 ± 2.6
Cd (μg/L)	44	59.1	1-10	5.2	20	8.5 ± 8.5	8.6 ± 8.3
Cu (μg/L)	44	6.8	4-100	90	190	103.1 ± 67.6	103.8 ± 65.6
Pb (μg/L)	44	13.6	2-50	1110	495	182.3 ± 206.6	182.3 ± 203.9
Zn (μg/L)	44	4.5	10	430	1,215	521.3 ± 504.6	521.9 ± 497.6
Hg (μg/L)	45	88.9	0.2-10	0.096	0.428	0.286 ± 0.178	0.165 ± 0.205
Ni (μg/L)	44	50	10-200	29.8	100	47.3 ± 42.7	47.9 ± 37.7
Cr (μg/L)	44	45.5	3-10	7	28	21.6 ± 48.5	19.7 ± 48.4

The difference in mean values between the two methods for six of the pollutants was less than 2%. The mean values under the robust log-probability method were considerably lower than the means obtained using the substitution method for mercury (- 42.3%) and arsenic (- 34.5%). The percent data censoring for both these metals exceeded fifty percent.

Acute Toxicity

Acute toxicity to *Pimephales promelas* was observed in 53% of the storm water runoff samples collected ($n = 43$). Toxicity of storm water discharges declined from a high of 100 % in 1984-1985 to 14 % in 1992-1993 (Figure 18). Of the six pollutants that were censored no more than 25%, phenols ($p < 0.005$), copper ($p < 0.005$), and lead ($p < 0.05$) showed significant association with toxicity (Table 13). Not surprisingly, these three pollutants also showed a dependent association among their concentrations (Kendall's coefficient of concordance, $W = 0.82$; $p < 0.001$). Biochemical oxygen demand, oil and grease, and total zinc were not significantly associated with toxicity ($p > 0.05$).

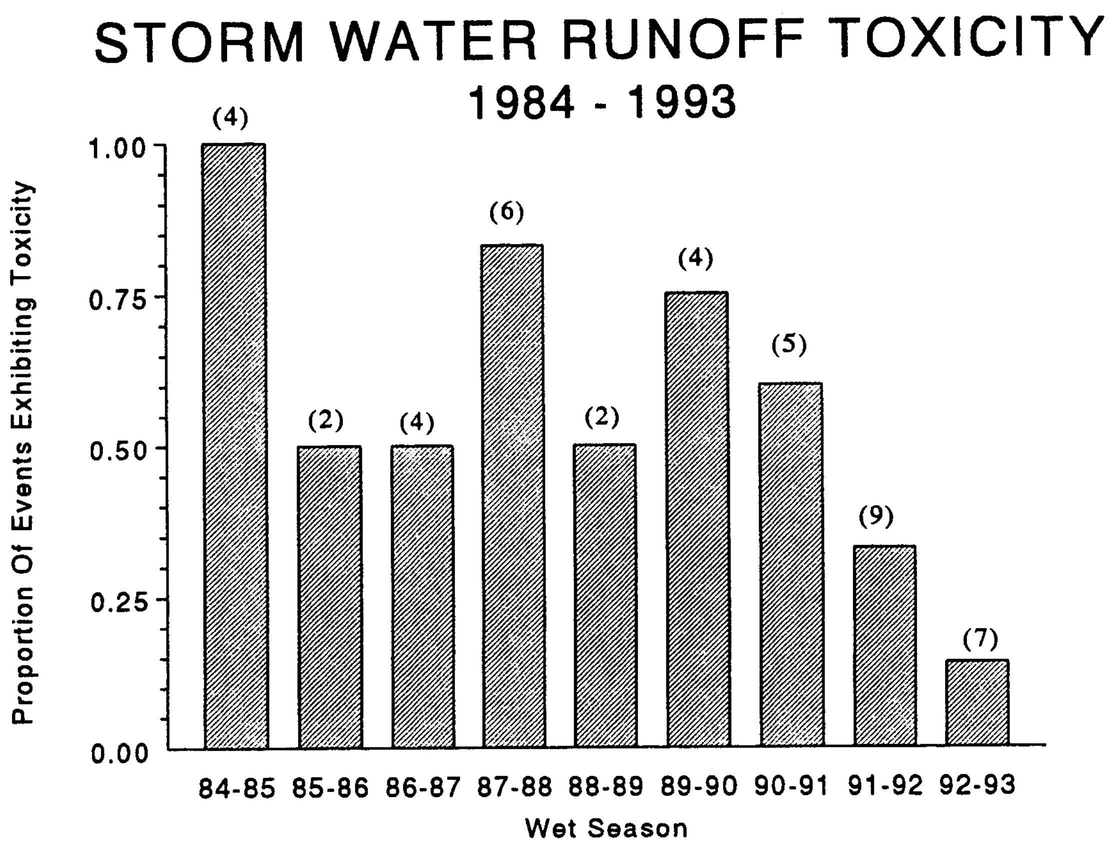

Figure 18. Proportion of storm discharge events which exhibited acute toxicity between 1984 and 1993. Sampling events within a single wet season ranged from two to nine (N = 43). The mean number of events sampled per wet season was 4.9. Acute toxicity of an event is described as one which causes greater than 20% toxicity to minnows relative to a control.

Table 13. Summary of results of acute toxicity tests on storm water using fathead minnows (*Pimephales promelas*). Tests were conducted on 43 samples between 1984 - 1993. Statistical significance was determined using the non-parametric Mann-Whitney Test.

NUMBER OF STORM EVENTS SAMPLED	PERCENT EXHIBITING ACUTE TOXICITY	STATISTICALLY ASSOCIATED POLLUTANT TOXICITY
43	53.5	BOD $p > 0.05$ O & G $p > 0.05$ Phenols $p < 0.005$ * Cu $p < 0.005$ * Pb $p < 0.05$ * Zn $p > 0.05$

* = Statistically significant at $\alpha = 0.05$

DISCUSSION

Recycling Practices

The collection, sorting, and recycling of waste oil and fluids at auto recycler and other automotive-related facilities are important best management practices to reduce site contamination and storm water runoff pollution (PARWQCP 1994, PARWQCP 1993, USEPA 1993, SCVNPSCP 1992B, USEPA 1991A, BSSWU 1990). In addition, waste oil transports significant quantities of other contaminants such as heavy metals, including Pb, Cu, Zn, and organic contaminants such as PAHs and petroleum hydrocarbons (Vaquez Duhalt 1987, see also Table 5). The increase in the amounts of waste oil recycled during the study period does not parallel the trend in oil and grease concentration in runoff, probably because of the use of OW separators for oil and grease removal.

Greater quantities of waste oil appear to have been recycled during the dry season than the wet season. This may be indicative of both greater waste oil loss during the wet season and reduced dismantling activity during rainy weather. On-site losses of waste oil and fluids at a typical auto recycler facility that practices oil recycling are difficult to determine. It has been estimated that motor vehicles at the point of dismantling generate 7 liters (1.9 gal) of waste oil and fluids (MWCOG 1991). Consequently for the study facility, where the per vehicle recycling volume was about 4.9 liters (1.3 gal), the waste oils and fluids loss translates to about 30%. For a facility that processes a large number of vehicles, this amount may be significant and require the use of OW separators to remove fugitive waste oil in storm water.

Statistical Summary

In statistically summarizing water quality data that has been censored (that is where some values are reported as below detection limits), substitution methods using zero, one-half the detection limit, or the detection limit may create a bias with unknown size and direction (El-Sharawi 1992, Travis and Land 1990, Newman and Dixon 1990, Gilliom and Helsel 1986). In addition, when censoring at multiple detection limits is encountered, additional errors may arise (Helsel and Cohn 1988). The robust log-probability method has been recommended to eliminate bias and improve summary statistical estimates like the mean and standard deviation when censoring at multiple detection limits is encountered (Helsel 1990).

In the present case, data summaries analyzed by the half detection limit substitution method and the robust-log probability method were within ± 10% of each other for most constituents. Perhaps the large number of values above detection limits minimized the biasing effect of outliers. The percentage of censoring for mercury was too high to produce reliable estimates by either method. Only in the case of arsenic does it appear that the mean and standard deviation by the half detection limit substitution method could have been inflated by outliers. The half detection limit substitution method, although less precise than distributional and robust methods, may provide adequate estimates of mean and standard deviation when the sample size is large and the proportion of censored data is less than fifty percent.

Pollutant Trends

Many of the pollutants showed declining trends that may be attributable to two specific improvements undertaken at the facility. The first was the installation of a 36.6 m x 41.5 m (120 in. x 136 in.) roof over the dismantling area to eliminate exposure. The second, a source control measure, was the institution of practices to remove motor oil and fluids prior to setting vehicles in the open display area. Other measures implemented prior to 1990 include the prompt removal of scrap, frequent cleanup of spilled oil in the dismantling area, and expansion of the capacity of the OW separators and oil recovery tanks (CRWQCB-LA 1994). These measures, no doubt, would have influenced the decline in pollutant concentrations that were observed.

Conventional Pollutants

Biochemical Oxygen Demand

Biochemical oxygen demand is a general parameter that can be strongly influenced by organic matter and other organic chemicals that are biodegradable. The mean BOD concentration of 93 mg/L observed at this site falls within the 7 to 140 mg/L range for mean values that have been observed in storm water runoff from auto recycler facilities (see Table 6). However, this value is considerably higher than the 9 mg/L benchmark suggested by the USEPA as a storm water guideline. The downward BOD trend at this facility between 1990 and 1993 may have been associated with a decrease in waste oil discharged in storm water, and better management of other organic wastes like ethylene glycols (Figure 13). An association between BOD and acute toxicity was not observed. Biochemical oxygen demand may thus not be of use to evaluate storm water quality from facilities like auto recyclers that do not process or handle organic matter or wastes.

Oil and Grease

The mean oil and grease concentration of 25 mg/L at the facility was within the 5 to 38 mg/L range of reported mean values for storm water at auto recycler facilities (see Table 6). The trend showed a considerable increase between 1987 and 1990, which may have been related to increase in vehicle volume processed in that period (Figure

14). The elimination of exposure to rainfall by the construction of a roof over the dismantling area may be an important reason for the decrease in mean concentrations of oil and grease since 1990. A significant association between oil and grease concentration in storm water and acute toxicity was not noted. Oil and grease, however, is useful as a conventional pollutant parameter for storm water because it provides a measure of the effectiveness of site management practices and is also indicative of potential nuisance impacts like habitat discoloration. A storm water benchmark for oil and grease has not yet been listed by the USEPA. In the interim, the best available technology (BAT) instantaneous maximum standard for point source waste water discharges of 15 mg/L for oil and grease, may be considered an equivalent measure for storm water quality.

Phenols

The mean total phenols concentration of 0.06 mg/L observed at the auto recycler facility cannot be meaningfully compared with other sites because of the lack of phenols data (see Table 6). However, the storm water guideline suggested by the USEPA, which is an acute toxicity freshwater standard, is considerably higher at 10.2 mg/L (USEPA 1993). The association of acute toxicity with phenols concentration may thus be a case of chance covariation with Pb and Cu, or another organic compound that was not measured. The toxicity could also have been due to synergistic or additive effects of phenols. Phenols concentrations showed a decline after 1990 when significant modifications were made to the facility (Figure 15).

Heavy Metals

Copper

The mean total copper concentration of 103 μg/L observed at the auto recycler facility was at the lower end of the range of reported mean values from other studies (see Table 6). These data show an upper concentration range of 240 μg/L in storm water. The median concentration of copper of 92 μg/L is considerably higher than the 10 μg/L median reported in storm water from vehicle service areas (Pitt and Field 1991). This may be due to the fact that copper is generated from auto dismantling activities in addition to leakage and spills of waste motor oils and fluids. The concentrations of copper also appear to have declined after the 1990 modifications at the facility (Figure 16). Copper concentrations were found to be significantly associated with acute toxicity. This may not be a surprise since the USEPA suggested guideline for the metal (9 μg/L), which is an acute toxicity criterion, is about a tenth of the mean value.

Lead

The mean total lead concentration of 182 μg/L, like that of copper, lies at the lower range of reported mean values from other studies (see Table 6). These values had a maximum concentration range of 240 μg/L in storm water. The median concentration for lead of 110 μg/L is also slightly higher than the 75 μg/L median value reported for the metal in storm water from vehicle service areas, indicating contributions by sources in addition to motor vehicle waste oil and fluids. Lead concentrations in storm water, which also showed a decline since 1990, were significantly associated with acute toxicity (Figure 16). The USEPA suggested guideline for lead of 34 mg/L, an acute toxicity criterion, is about a sixth of the mean concentration observed.

Zinc

The mean total zinc concentration of 521 μg/L at the facility lies at the lower range of reported mean values from other studies (see Table 6). These values had a maximum concentration range of 980 μg/L. The median concentration of 430 μg/L is considerably higher than the 85 μg/L median value reported in storm water from vehicle service areas, indicating perhaps that the input for zinc from dismantling activities is relatively high. Zinc concentrations which followed the declining trends of lead and copper, were not significantly associated with toxicity (Figure 17). The USEPA proposed guideline, an acute toxicity criterion, at 65 μg/L is much lower than the mean concentration observed. Although an association with toxicity was not established in this study, toxicity of storm water from industrial areas has been attributed to dissolved forms of zinc and copper (Cook and Lee 1993). Unlike copper, 40 to 90% of total zinc in storm water runoff from industrial areas occurs in the dissolved form and is not associated with suspended matter. This makes it difficult to remove the metal by suspended solids settling processes (Pitt and Field 1991).

Other Metals

Mean concentrations of total arsenic (3.6 μg/L) and total cadmium (8.6 μg/L) in storm water runoff at the facility exceeded the respective USEPA guidance values of 0.02 μg/L and 2 μg/L respectively. The mean concentration of 38 μg/L for total nickel was below the USEPA proposed storm water guideline of 788 μg/L. Mean concentrations determined for mercury are unreliable because of the high percentage of censoring in the data set. However, the estimated mean value appears considerably lower than the USEPA storm water guidance value for mercury of 2.4 μg/L. The estimated mean storm water concentration for total chromium was 20 μg/L. A storm water guidance value for chromium was not available for comparison.

Toxicity

This report constitutes the first time that whole effluent toxicity evaluations of storm water from auto recycler facilities has been documented over an extended period of time. The causes for toxicity, however, will be difficult to establish definitively since a Toxicity Identification Evaluation (TIE) recommended by the USEPA was not conducted (USEPA 1991, USEPA 1989A, USEPA 1989B). The compliance protocol for the facility did not include determination of LC_{50} for samples that showed whole effluent toxicity. If this analysis had been done, it would have been possible to use the 'Correlation Approach' to establish a consistent relationship between suspected toxicants and storm water toxicity (USEPA 1989A). Instead, a robust statistical approach was attempted to determine any association between pollutant concentrations and observed toxicity. Lead, copper, and total phenols showed statistically significant associations ($p < 0.05$). Fewer incidences of storm water toxicity were observed after 1990 when the concentrations of metals declined considerably.

Lead and copper have been previously associated with toxicity in storm water runoff from industrial areas (Cook and Lee 1993, Pitt and Fields 1991). However, the association of total phenols with toxicity is difficult to explain since the Lowest Observed Effect Level (LOEL) acute freshwater criterion for total phenols is considerably higher than the range of observed values. The association of total phenols concentration with toxicity may possibly reflect chance covariation with the two metals or some unanalyzed toxic organic constituent.

The compiled toxicity data for the facility also did not fractionate the source of toxicity; whether it was due to the particulate (suspended) fraction, or the dissolved (filterable) fraction. Other studies have observed a good correlation between toxicity of storm water from industrial areas and the filterable fraction which includes dissolved metals (Cook and Lee 1993, Pitt and Field 1991). The proportion of the dissolved form of metals to the total concentration in storm water from auto recycler facilities has been reported to range from a high of 0.48 for zinc to a low of 0.06 for lead, and to often exceed water quality criteria (SSP 1992).

SUMMARY

This Section presented the results of a detailed review of the quality of storm water discharges from one auto recycler facility for which nearly a decade of data exists. These data included measurements on conventional and toxic pollutant concentrations, and acute toxicity for forty-five storm water discharge events between 1984 and 1993. Pollutant trends in storm water discharges over this period showed a decline after improvement in facility environmental management practices. Declining pollutant concentrations were attributable to the implementation of selected structural and source control best management practices. Associations between acute toxicity and lead, copper, and phenols concentrations were established, although the toxicity of phenols remained unexplained. Also presented were comparisons of two approaches to calculating statistical summaries when censoring at multiple detection limits has occurred. The simpler one-half detection limit substitution method, when compared with the more precise robust log-probability method, provides a good estimate of summary statistics when the level of censoring is less than one-half.

SECTION 7.0 REGULATORY POLICY

PRECEDENT POLICY DECISIONS

State laws in existence since the late 1960s require that auto recyclers be licensed by the State, that they notify the State Department of Motor Vehicles within 24 hours after the acquisition of a vehicle subject to registration, and hold the vehicle for seven days before dismantling (USBM 1967). Local agencies also require that facilities be located in areas zoned heavy industrial and be fenced in order to comply with the intent of the Highway Beautification Act of 1965 (USBM 1967). The Act was passed by Congress to preserve and enhance the scenic value of highways.

In the mid-1970s, the regulatory emphasis on auto recycler facilities shifted to recycling stagnant vehicle inventory and improving solid waste management practices under the Solid Waste Disposal Act. This Act which had provisions to promote scrap metal resource recovery has since been superseded by the Resource Conservation and Recovery Act. Most states established funds, collected from registration fees, to facilitate the disposition and recycling of inoperative vehicles. Auto recyclers were reimbursed for each vehicle delivered to a shredder with an additional financial incentive for vehicles delivered within 90 days of de-registration (FHWA 1976).

More recently, some states like California have passed laws prohibiting solid waste facilities from accepting motor vehicles or other metallic discards that can be economically recycled (CIWMB 1993A). These laws also mandate that materials requiring special handling be removed prior to transfer of motor vehicles to a baler or shredder.

STORM WATER REGULATIONS

The 1972 Clean Water Act did not impact auto recycler facilities because they were not perceived as generators of waste water, and storm water pollution was considered outside the Act's mandate. In some rare instances, a few large facilities that collected storm water runoff and discharged directly to a river or stream were regulated under the National Pollutant Discharge Elimination System (NPDES) program (CRWQCB-LA 1994, CRWQCB-SA 1994).

However, in 1987, the Clean Water Act was amended to require a regulatory program for storm water discharges from municipal separate storm sewer systems (MS4s) and industrial facilities. Pursuant to the Act, the USEPA in 1990 identified several categories of industries, including auto recycler facilities, as subject to the NPDES Program and applicable permit requirements (USEPA 1990). Auto recycler facilities were identified by the Standard Industrial Classification (SIC) code 5015, which describes facilities that dismantle and sell used vehicle parts. In 1992, the USEPA issued General Permit requirements for storm water discharges and required auto recyclers to implement a Pollution Prevention Plan and conduct annual monitoring for four conventional pollutant parameters (USEPA 1992A). Several states that have been delegated NPDES authority by the USEPA have also issued general permits for storm water from auto recycler facilities (ADEM 1992C, NCDEHNR 1992, ODEQ 1992), while others like California use a generic industry general permit to regulate the industry (CSWRCB 1992B). The USEPA has also recently published a notice in the Federal Register for its draft multi-sector permit for storm water discharges (USEPA 1993). This notice proposes permit requirements for auto recycler facilities to implement an industry-specific Pollution Prevention Plan and to monitor for five conventional pollutant parameters on a quarterly basis during alternate years.

ECONOMICS OF RECYCLING

An economic analysis of the costs associated with auto recycling was performed to identify factors that could optimize the environmental benefit of auto recycling. Business variables and cost factors were selected after reviewing business data from the industry, industry surveys, recycler price lists, and personal interviews (Ecology Auto Wrecking Inc. 1991, Howard 1990, ADRA 1983).

Financial Analysis

The business income (BI) per vehicle recycled was calculated as,

$$BI = SS + PS + CS + ES \tag{5}$$

where, BI is the business income per recycled vehicle (~ \$775, ≡ 100 %)

SS is the income from scrap sales (Cu and Fe) per vehicle (~ \$200, ≡ 26 %)

PS is the income from used parts sale per vehicle (~ \$500, ≡ 65 %)

CS is the vehicle abatement program collection subsidy (~ \$75, ≡ 9 %)

and, ES is a possible environmental subsidy (none at present)

The operating cost (OC) per vehicle recycled was calculated as,

$$OC = BC + VP + EC \tag{6}$$

where, OC is the operating cost per recycled vehicle (~ \$720, ≡ 100 %)

BC is the business cost per recycled vehicle (~ \$300, ≡ 42 %)

VP is the vehicle purchase cost (~ \$400, ≡ 55 %)

and, EC is the environmental compliance cost per vehicle ($\sim$ \$20, $\equiv$ 3 %)

The net recycling profit per vehicle (NP) was computed as,

$$NP = BI - OC \qquad (7)$$

This value (NP) amounts to approximately \$55 per vehicle, which is similar to the median per vehicle profit reported by a business survey (ADRA 1983). It must be noted that this is an average value and that (NP) per vehicle has been reported to range from - \$22 to +\$223 (ADRA 1983). The income from scrap sales (SS) was computed for a typical vehicle based on metal and copper content at \$65 per ton for metal and \$1,250 per ton for copper (Howard 1990). Income from parts sale (PS) was calculated as a two-thirds fraction of the total price for 26 commonly sold components per vehicle listed by a recycler (Ecology Auto Wrecking Inc. 1991). It was assumed that one-third of these components would be unusable. The collection subsidy (CS) was derived from the vehicle abatement program payment which ranges from \$50 to \$100 per vehicle. The amount of subsidy is dependent on the time elapsed from collection of a vehicle to delivery to an auto shredder (FHWA 1976).

The business cost (BC) includes salaries, payroll expenses, property lease or mortgage expenses, sales promotions, materials, and other fixed costs. The vehicle purchase cost (VP) used in the calculation is an average based on personal interviews and business surveys (Howard 1990).

Sharing Environmental Costs

Auto recycler operators today are being required to pay greater attention to environmental concerns that include nonpoint source pollution, groundwater contamination, hazardous waste management, waste materials recycling, and occupational health and safety measures. Given the modest profit margin per recycled vehicle, it becomes important to ensure that the environmental cost EC to the industry does not make it prohibitive to continue recycling vehicles.

A review of equation (5) will indicate that there may be several opportunities to counterbalance the effect of increasing environmental costs. One would be to increase income from scrap sales SS by promoting markets for plastics, glass, motor fluids, metals (other than copper and iron), tires, and other waste materials. A second would be to provide some form of environmental subsidy ES that comes from the original vehicle buyer or the auto manufacturer to account for the environmental cost to the end receiver. Linking this subsidy to the manufacturer will provide an incentive to reduce environmental costs. The auto manufacturer may achieve this cost reduction by identifying and using the least environmentally damaging processes and materials, by working together with auto recyclers to develop improved facility designs and recycling methods to reduce the EC, and by creating markets for recycled products. The collection subsidy CS from the vehicle abatement program of earlier years should remain to ensure that even the least profitable vehicles are picked up by recyclers.

INDUSTRY PERSPECTIVE

The auto recycler industry has come to accept the reality of environmental regulatory programs and has started to take a more participatory role. The industry's recent comments on recycling and waste management provides some insight into this new approach. The California Integrated Waste Management Board surveyed auto recyclers in 1992 to solicit recommendations on improving material and waste management programs (CIWMB 1993A).

Notable recommendations included, (i) promotion of maximum motor vehicle recycling, (ii) creation of complete recycling centers for batteries, waste oil, anti freeze, tires, and fuel tanks, (iii) levying of a vehicle waste surcharge to reduce the burden on recyclers and prevent illegal disposal, (iv) providing recyclers incentives to comply with environmental requirements, (v) streamlining duplicate environmental requirements by coordinating government efforts, and (vi) establishment of an appropriate infrastructure prior to implementing new rules. These recommendations, in combination with the economic analysis of auto recycling, may provide a useful starting point for local, state, and federal agencies in their development of regulations and industry guidelines to minimize pollution.

TRENDS IN GLOBAL RECYCLING POLICY

Germany's Mandate

Perhaps the willingness of the auto recycling industry to accommodate environmental concerns and take proactive steps is in part to preempt U.S. federal action similar to that undertaken by Germany. The German regulations that implement the *Gesetz zür Vermeidung und Entsorgung von Abfällen* (Waste Avoidance and Management Act) specify clear mandates for the auto manufacturing and recycling industries to optimize material and waste recycling (BUNR 1987, BRD 1986)). These include requirements for, (i) the manufacturer, recycler or a designated third party to take the motor vehicle back from the last owner free of cost, (ii) waste management methods to give priority to material recycling and reuse, (iii) manufacturers and distributors to assume the responsibility of developing the necessary dismantling and material recovery infrastructure for motor vehicles, and (iv) manufacturers to consider material reuse and recyclability in the design and development of all new vehicles (BUNR 1990A, BUNR 1990B). The original date for the vehicle recycling infrastructure to be in place was January 1994, but the schedule has been extended.

Since automobile manufacturing is a global industry, U.S., European, and Japanese manufacturers and recyclers are likely to adapt their European experience to the U.S. market to preclude similar strict regulations on waste management, auto recyclability, and material recycling. One clear sign that this is already beginning to happen is the new partnerships that are being formed between auto manufacturers in the U.S. and auto recycling associations to improve motor vehicle recycling practices.

Industry Initiatives in the U.S.

BMW has started an environmental databank to encourage the development of environmentally safe production processes and products (Brooke *et al.* 1990). The environmental databank acts as a repository of information on all automotive materials, production processes and their environmental impact. Volvo publishes scrapping and dismantling guidance documents for all new models to assist auto recyclers (Volvo 1992). U.S. manufacturers have formed an automobile recycling research consortium that includes participation from national auto recycler associations to improve the dismantling and recycling of motor vehicles.

Concurrently, the Auto Recyclers Association is starting a clean auto recycler facility certification program called Certified Automotive Recycler or CAR (Murphy 1993). Anticipated advantages to a CAR facility include, (i) good public relations visibility, (ii) cheaper insurance rates, (iii) potential designation by automobile manufacturers as a pilot recycling study facility, (iv) better resale value of property, and (v) some latitude in meeting environmental standards.

SUMMARY

This Section reviewed the history of environmental policy that has influenced the auto recycling industry, and the status of implementation of the recent storm water regulations. It provided an analysis of the economics involved in auto recycling, and presented the industry perspective on improving environmental programs. This Section also discussed the influence of trends in global policy on auto recycling which are helping to build partnerships between auto manufacturers and auto recyclers to promote improved recycling methods.

SECTION 8.0 CONCLUSIONS

The auto recycler industry in the U.S. is a small business industry, very susceptible to excessive regulation. Its survival is in the best interest of the public, automotive distributors, and the motor vehicle manufacturing industry, because it performs the environmentally valuable function of dismantling and recycling scrap vehicles.

Storm Water Pollution

Storm water runoff from auto recycler facilities is contaminated with metals (including lead, copper, zinc), and organic compounds (including petroleum hydrocarbons and light PAHs). The primary sources of pollutants are motor vehicle fluids that are drained (organics and to a lesser extent metals), and corrosion, wear and tear of the motor vehicle body and parts (metals), when they come in contact with storm water runoff.

Storm water discharges from auto recycler facilities may be acutely toxic to aquatic biota. Common heavy metals like copper, lead, and perhaps zinc, which occur in high concentrations may be the cause of toxicity. While the appropriateness of the use of existing water quality criteria to evaluate storm water discharges from these facilities may be questionable, the need to eliminate acute toxicity is not controversial.

Pollution Prevention and Control

The storm water regulatory program provides a unique opportunity to promote a facility-wide waste management approach towards preventing pollution through the implementation of cost-effective best management practices. Non-treatment best management practices that focus on fluid recycling, pollutant containment, and minimal contact of pollutant sources with storm water runoff should be emphasized. Two such best management practices that have been demonstrated to be effective are the roofing of the dismantling area to eliminate exposure, and procedures to maximize waste oil and fluid recycling prior to dismantling in order to reduce loss and spillage.

Off-line OW separators with the option to bypass large storm events (and which are properly maintained), may offer an effective treatment technology to remove some common pollutants for medium to large size recycler facilities. Enhanced treatment using aeration-flocculation processes is not cost-effective because of the intermittent nature of storm water discharges and the necessary maintenance required for optimum performance. Additional studies are needed to provide the auto recycling industry with adequate guidance on the effectiveness of other types of treatment BMPs.

Storm Water Regulations

The industry presently includes facilities that range in size from less than 2×10^{-3} km^2 (0.5 Ac) to 8.1×10^{-1} km^2 (200 Ac), and process from less than 50 to more than

25,000 vehicles a year. Current approaches taken by the USEPA to regulate storm water from auto recycler facilities appear to be both too broad because they impose the same regulatory burden on many small facilities, and do too little because they do not ensure reduction of toxic pollutants. An alternative that could be considered to address these shortcomings is a tiered approach based on facility size, vehicle throughput or both. Smaller facilities would be required to implement best management practices and conduct no sampling, while larger facilities would be required to sample for both conventional and toxic pollutants, in addition to implementing BMPs. Sampling for toxic pollutants can be terminated when the established benchmark levels are attained.

Economics of Auto Recycling

An analysis of the economics of recycling indicates that the net profit per vehicle at $55 is modest, and that increasing environmental costs may endanger some auto recycler operators and threaten a public benefit. At least two factors were identified to counterbalance environmental costs. These include, (i) diversifying the market for scrap sales to include other automotive waste materials, and (ii) providing an environmental subsidy from auto manufacturers to account for the environmental cost to auto recyclers of handling the end product. It was suggested that deriving the environmental subsidy from auto manufacturers and suppliers may encourage them to develop environmentally safer materials and processes, and to work cooperatively with the auto recycler industry to reduce the cost of the subsidy.

Environmental Partnerships

Efficient recycling of automobiles, minimization of automotive wastes, and storm water pollution reduction can only be achieved if the environmental initiative is shared by automobile manufacturers, material suppliers, and auto recyclers. The auto manufacturing, scrap recycling and waste management infrastructure is not fully integrated at present. Failure to develop an efficient recycling infrastructure may result in the U.S. automotive industry having to assume greater responsibility in the disposal and management of its end products. Automobile manufacturers and suppliers may consider partnerships with auto recycling operators to develop environmentally safe recycling methods and facility designs to reduce the cost and burden of waste management to those downstream.

REFERENCES

ADEM. 1992A. *Site Visitations, Sample Collection Procedure, and Chemical Analyses to Support Development of Best Management Plans for Automotive Salvage Yards, General Salvage Yards and Recycled Facilities.* Alabama Department of Environmental Management, Final Report, B. Brown and J. Shepherd, Auburn University, AL. 23 pp.

ADEM. 1992B. *A Best Management Plan for General Salvage Yards.* Final Report, B. Brown and J. Shepherd. Auburn University, Alabama Department of Environmental Management. 9 pp.

ADEM. 1992C. *National Pollutant Discharge Elimination System General Permit ALG180000.* Storm Water Discharges Associated with Salvage and Recycling. Alabama Department of Environmental Management. 17 pp.

ADRA. 1993. Electronic Transmittal of Group Monitoring Data. By Gannett Fleming, Inc., for Automotive Dismantlers and Recyclers Association, Washington, D.C.

ADRA. 1992. *Revised NPDES Stormwater Group Permit Application Submittal, Automotive Dismantlers and Recyclers Association.* Submittal to Office of Water Enforcement and Compliance, USEPA, Washington D.C. May 12, 1992. 248 pp.

ADRA. 1983. *Profile: Automotive Dismantling Industry.* Automotive Dismantlers and Recyclers Association, Washington, D.C. 22 pp.

APHA. 1990. *Standard Methods for the Examination of Water and Wastewater.* 17th Edition, American Public Health Association, Washington, D.C.

Bain, A. 1993. Stormwater Discharge Group Permitting Program. *Automotive Recycling*, Vol. 13(3), 22-23.

Bever, M. B. 1978. Recycling the 1985 Automobile. In, *Measurements of the Impacts of Materials Substitution - A Case Study in the Automobile Industry*, A. Blelloch, editor. The American Society of Mechanical Engineers, New York, NY. pp. 55-63.

Blake, P., C. S. Chamberlain, D. Chambers, B. Clarke, and J. Mendham. 1987. Heavy Metal Contamination near Scrap Metal Yards and Car Breakers Yards. *The Science of the Total Environment*, Vol. 59, 9-18.

BMW. 1992. BMW Announces U.S. Recycling Initiative. BMW of North America, Inc., Press Release, Detroit, MI. 2 pp.

BMW. 1991. Vehicle Recycling Project. Preimesser Presentation, BMW Allegemeine Gesselschaft, H. Wolf, October 1991. 9 pp.

BRD. 1986. *Gesetz über die Vermeidung und Entsorgung von Äbfallen (Abfallgesetz)*, Federal Republic of Germany, Bonn, 27 August, 1986, 33 pp.

Brooke, L., G. Kobe, and C.A. Sawyer. 1990. Recyclability. *Automotive Industries*, Vol. (09/90), 40-48, 50, 52, 56.

Brown, L. R. 1994. *State of the World*. Worldwatch Institute Report on Progress Toward a Sustainable Society, W.W. Norton and Co., NY.

BSSWU. 1990. *Water Quality Protection for Automotive Businesses*. City of Bellvue Storm and Surface Water Utility, City of Bellvue, WA. 62 pp.

BUNR. 1990A. *Zielfestlegung der Bundesregierung zur Vermeidung, Verringerung oder Verwertung von Abfällen aus der Kraftfahrzeugentsorgung*. Entwurf. Referat WA II 3 530 114-2/6, Federal Republic of Germany, Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit. 5 pp.

BUNR. 1990B. *Dritte Allgemeine Verwaltungsvorschrift zum Abfallgesetz*. Teil 2: Technische Anleitung zur Verwertung und sonstigen Entsorgung von Shredderrückständen. Entwurf. Referat WA II 5-30 121-1/22, Federal Republic of Germany, Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit. 25 pp.

BUNR. 1987. The New Waste Avoidance and Waste Management Act. H. Schnurer and B-A Szelinski, Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit, Bonn, Germany. 17 pp.

Butler, J. D., V. Butterworth, S. C. Kellow and H. G. Robinson. 1984. Some Observations on the Polycyclic Aromatic Hydrocarbon (PAH) Content of Surface Soils in Urban Areas. *The Science of the Total Environment*, Vol. 33, 75-85.

Cayless,G. E. 1974. Corrosion of the Exhaust System. In, *Corrosion of Motor Vehicles*. Conference Publication, London, 1974. The Institution of Mechanical Engineers, London, U.K. pp. 60-65.

CDHS. 1989. *Treatment Levels for Auto Shredder Wastes*. Technical Support Document, E. Nieto, California Department of Health Services, Toxic Substances Control Division, Alternative Technology Section, Sacramento, CA. 79 pp.

CDHS. 1988A. *Guide to Oil Waste Management Alternatives*. Report by Energy and Environment Research Corp., Irvine, CA, California Department of Health Services, Toxic Substances Control Division. 232 pp.

CDHS. 1988B. *Hazardous Waste Reduction Assessment Handbook, Automotive Repair Shops*. California Department of Health Services, Toxic Substances Control Division, Alternative Technology Section, Sacramento, CA. 24 pp.

CDHS. 1988C. *Oil Waste Management Alternatives Symposia*. Report by Energy and Environment Research Corp., Irvine, CA, California Department of Health Services, Toxic Substances Control Division, Sacramento, CA. 171 pp.

CDHS. 1987. *Waste Audit Study, Automotive Repairs*. Report, W.E. Toy, California Department of Health Services, Toxic Substances Control Division, Alternative Technology Section, Sacramento, CA. 143 pp.

CDMV. 1993. Table of Estimated Fees Paid Vehicle Registrations by County as of December 31, 1992. California Department of Motor Vehicles, Public Information Unit, Sacramento, CA. 1 pp.

CDMV. 1992. Electronic Transmittal of Automobile Dismantler Operations in California. California Department of Motor Vehicles, Occupational Licensing Division, Case Assignment Records Unit, Sacramento, CA.

CDMV. 1991. Summary Printout of Cancelled Vehicle Registrations in Los Angeles County for the Year 1990. 12/90 Transmittal, California Department of Motor Vehicles, Program and Policy Administration Division, Registration Automation Development Unit, Sacramento, CA. 4 p.

CDMV. 1990. Summary Printout of Automobile Dismantler Operations in California. 07/90 Transmittal, California Department of Motor Vehicles, Occupational Licensing Division, Case Assignment Records Unit, Sacramento, CA.

CDTSC. 1991. *Issues and Analysis. Regulation of Ethylene Glycol Wastes in California: A Regulatory Interpretation*. Final Document, California Department of Toxics Substances Control, Alternative Technology Division, Sacramento, CA. 27 pp.

CIWMB. 1993A. *Metallic Discards in California*. Final Report, California Integrated Waste Management Board, Research and Technology Development Division, Sacramento, CA. 146 pp.

CIWMB. 1993B. *Draft Metallic Discards Management Plan*. Report, California Integrated Waste Management Board, Research and Technology Development Division, Sacramento, CA. 23 pp.

CIWMB. 1990A. Antifreeze. *Household Hazardous Waste Bulletin*, California Integrated Waste Management Board, Sacramento, CA.

CIWMB. 1990B. Lead Acid Batteries. *Household Hazardous Waste Bulletin*, California Integrated Waste Management Board, Sacramento, CA.

Cook, T. , and C.-C Lee. 1993. Toxicity Identification Evaluations (TIE) in San Francisco Bay Area Urban Storm Water Runoff. *Proceedings of the Water Environment Federation 66th Annual Conference*, October 1993, Anaheim, CA. 9 pp.

CRWQCB-LA. 1994. *Norwalk Dump Co. (Automobile Dismantling), Santa Fe Springs, Los Angeles County, NPDES File CA0056928*, Monitoring and Reporting Program File 6041, California Regional Water Quality Control Board, Los Angeles Region, Monterey Park, CA.

CRWQCB-SA. 1994. *Ecology Auto Wrecking, Inc. (Automobile Dismantling), Rialto, San Bernardino County, WDR File 89-101*, Monitoring and Reporting Program, California Regional Water Quality Control Board, Santa Ana Region, Riverside, CA.

CSAC. 1989. *California County Fact Book '88-'89.* County Supervisors Association of California.

CSWQTF. 1993. *Industrial/Commercial Best Management Practice Handbook*, California Stormwater Quality Task Force, 259 pp.

CSWRCB. 1993. Notice of Intent Database for Storm Water Discharges Associated with Industrial Activity. California State Water Resources Control Board, Division of Water Quality, Programs Unit, Sacramento, CA.

CSWRCB. 1992. *NPDES Permit for Discharges of Storm Water Associated With Industrial Activities Excluding Construction Activities, General Permit CAS000001*. California State Water Resources Control Board, 20 pp.

CSWRD. 1993. *Action Plan Demonstration Project, Demonstration of Gasoline Fueling Station Best Management Practices, Phase 1 Report.* County of Sacramento, Water Resources Division. 118 pp.

CWC. 1990A. Time Bombs of Oil. *Bulletin, California Waste Containment*, Fremont, CA.

CWC. 1990B. EPA Tightens Regulations on Oil Filter Disposal. *Bulletin, California Waste Containment*, Fremont, CA.

Ecology Auto Wrecking Inc. 1991. Used Parts Price List. Ecology Auto Wrecking Inc., Colton, CA and Rialto, CA. 1 pp.

Eganhouse, R. P., D. L. Blumfield, and I. R. Kaplan. 1982. Petroleum Hydrocarbons in Stormwater Runoff and Municipal Wastes: Input to Coastal Waters and Fate in the Marine Sediments. *Thalassia Jugoslavica*, Vol. 18(1-4), 411-431.

Eganhouse R. P., B. R. T. Simoneit, and I. R. Kaplan. 1981. Extractable Organic Matter in Urban Stormwater Runoff. 2. Molecular Characterization. *Environ. Sci. Technol.*, Vol. 15(3), 315-325.

El-Sharawi, A. H., and S. R. Esterby. 1992. Replacement of Censored Observations by a Constant: An Evaluation. *Water Research*, Vol. 26(6), 835-844.

Evans, W. H., and E. J. David. 1974. Biodegradation of mono-, di- and triethylene glycols in River Waters under Controlled Laboratory Conditions. *Water Research*, Vol. 8(2), 97-100.

Fam, S., M. K. Stenstrom, and G. Silverman. 1987. Hydrocarbons in Urban Runoff. *Journal of Environmental Engineering*, Vol. 113(5), 1032-1046.

FHWA. 1992. *U.S. Highway Statistics 1991*, Table MV-1. United States Department of Transportation, Federal Highway Administration, Office of Highway Information Management, Washington, D.C. 1 pp.

FHWA. 1989. *Analytical Investigations of Pollutant Loadings and Impacts from Highway Stormwater Runoff*: Final Report FHWA-RD-88-008, Woodward-Clyde Consultants, United States Department of Transportation, Federal Highway Administration, Washington, D.C. 150 pp.

FHWA. 1979. *Junkyards, The Highway and Visual Quality*. Final Report DOT-FH-11-9327, R.F. Blum, United States Department of Transportation, Federal Highway Administration, Washington, D.C. 134 pp.

FHWA. 1976. Junkyards and Solid Waste Disposal in the Highway Environment. *Proceedings of a National Seminar, Silver Spring, MD, 1975*, United States

Department of Transportation, Federal Highway Administration, Washington, D.C. 234 pp.

Harrell, B. 1991. Nissan Takes on Plastic Recycling. *Nissan Technology Newsline* No. 1991.9, 1 pp.

Helsel, D. R., and R. M. Hirsch. 1992. *Statistical Methods in Water Resources*, Elsevier Publications, New York, N.Y. 522 pp.

Helsel, D. R. 1990. Less than Obvious. *Environ. Sci. Technol.*, Vol. 24(12), 1766-1774.

Helsel, D. R. and T. A. Cohn. 1988. Estimation of Descriptive Statistics for Multiply Censored Water Quality Data. *Water Resources Research*, Vol 24(12), 1997-2004.

Hoffman, E., G. L. Mills, J. S. Latimer, and J. G. Quinn. 1984. Urban Runoff as a Source of Polycyclic Aromatic Hydrocarbons to Coastal Waters. *Environ. Sci. Technol.*, Vol 18(8), 580-587.

Holusha, J. 1991. Recyclers Wring New Life from Old Cars. *Sacramento Bee*, Section D- Automotive, June 28, 1991, Sacramento, CA. 1 pp.

Howard, B. 1990. Junkyards on the Cutting Edge. In, Monday Business, Daily News of Los Angeles, Aug. 6, 1990, Woodland Hills, CA., pp. 1,3,15.

Krikorian, G. 1992. The Last Stop. Wrecked Car Remains of a Car-crazy City End Up in Wilmington Junkyards. *Los Angeles Times*, South Bay News, Los Angeles, CA. pp. B3, B8.

Latimer, J. S., G. L. Mills, E. J. Hoffman, and J. G. Quinn. 1986. Treatment of Solids and Petroleum Hydrocarbons in Storm Runoff with an On-site Detention Basin. *Bull. Environ. Contam. Toxicol.*, Vol. 36, 548-555.

Link, L. J. 1992. Nissan Develops "Bumpers" for the Environment. *Nissan Technology Newsline* No. 1992.3, 1 pp.

Lord, B. N. 1987. Nonpoint Source Pollution from Highway Stormwater Runoff. *The Science of the Total Environment*, Vol. 59, 437-446.

Maestri, B. and B. N. Lord. 1987. Guide for Mitigation of Highway Storm Water Runoff. *The Science of the Total Environment,* Vol. 59, 467-476.

Marsalek, J., and H. Y. F. Ng. 1989. Evaluation of Pollution Loadings from Urban Nonpoint Sources: Methodology and Applications. *J. Great Lakes Res.*, 15(3), 444-451.

McCosh, D. 1990. Recycling the Car. *Popular Science*, Vol (12/90), 106-110,122.

Menzie, C. A., B. B. Potocki, and J. Santodonato. 1992. Exposure to Carcinogenic PAHs in the Environment. *Environ. Sci. Technol.*, Vol 26(7), 1278-1283.

MnTAP. 1988. *Success Story: Waste Minimization, Auto Salvage Yard.* Minnesota Technical Assistance Program, University of Minnesota. 3 pp.

Murphy, C. 1993. Certified Automotive Recycler. *Automotive Recycling,* 13(3), 18-19.

MWCOG. 1993. *The Quality of Trapped Sediments and pool Water within Oil Grit Separators in Suburban Maryland -- Interim Report.* T. Schuler and D. Shepp. Metropolitan Washington Council of Governments, Washington, D.C. 48 pp.

MWCOG. 1991. *Pollution Prevention Project, Identification and Quantification of Vehicular Wastes in the Metropolitan Washington Area.* Report by J.M. Snarr and G.L. Nichols, Metropolitan Washington Council of Governments. 99 pp.

Miller Jr., S. F. 1971. *Junkyard Valuation. Salvage Industry Appraisal Principles Applicable to Highway Beautification.* National Cooperative Highway Research Program Report 112, Highway Research Board, National Research Council, Washington, D.C.

Nauss, D. W. 1994. The Pressure Mounts to Recycle Used Vehicles. *Los Angeles Times*, World Report Special Edition, March 1, 1994, Los Angeles, CA. p H 5.

NCDEHNR. 1992. *General Permit No. NCG100000 (Used Motor Vehicle Parts and Automobile Wrecking for Scrap) to Discharge Storm Water under the NPDES.* North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. Raleigh, NC. 25 pp.

Ness, H. 1984. The Automobile Scrap Processing Industry. In, *The Impacts of Material Substitution on the Recyclability of Automobiles*, A. Blelloch, editor. The American Society of Mechanical Engineers, New York, NY. pp. 39-97.

Newman, M. C., and P. M. Dixon. 1990. UNCENSOR: A Program to Estimate Means and Standard Deviations for Data Sets with Below Detection Limit Observations. *American Environmental Laboratory*, Vol (4/90), 26-30.

Niemczewski,C.M. 1984. The Changing Materials Content of Automobiles. In, *the Impacts of Materials Substitution on the Recyclability of Automobiles*, A. Blelloch, editor. American Society of Mechanical Engineers, New York, NY. pp. 11-37.

Nobile, N. 1991. Maintaining Mother Earth. *SAAB Surroundings*, Vol. 29(1), 10-12.

NRC. 1990. *Monitoring Southern California's Coastal Waters.* Report, National Research Council, Marine Board, Commission on Engineering and Technical Systems, Washington, D.C. 168 p.

OCPC. 1965. *Scrap Metal Operations and Automobile Wreckers: A Review of Locational Policies.* Oakland City Planning Commission, Oakland, CA. 8 pp.

ODEQ. 1991. *General Permit No. 1200-R* (Metal Scrap Yards, Battery Reclaimers, and Salvage Yards Classified under SIC Codes 5015 and 5093; Automobile Wrecking Yards; and Hazardous Waste Treatment, Storage, or Disposal Facilities). Oregon Department of Environmental Quality, Portland, CA. 16 pp.

OECD. 1986. *Environmental Effects of Automotive Transport, The OECD Compass Project.* Organization for Economic Development and Cooperation, Paris, France. 172 pp.

PARWQCP. 1994. *Vehicle Service Facility Waste Minimization Program. 1993 Summary Report.* By Uribe & Associates, Palo Alto Regional Water Quality Control Plant, Palo Alto, CA. 50 pp.

PARWQCP. 1993. *Vehicle Service Facility Waste Minimization Program. 1992 Summary Report.* By Uribe & Associates, Palo Alto Regional Water Quality Control Plant, Palo Alto, CA. 99 pp.

Pasquini, R., and S. Monarco. 1983. Detection of Mutagenic/Carcinogenic Compounds in Unused and Used Motor Oils. *The Science of the Total Environment*, Vol. 32, 5-64.

Pitt, R.E. and R. Field. 1990. Hazardous and Toxic Wastes Associated with Urban Stormwater Runoff. In, *Remedial Action, Treatment, and Disposal of Hazardous Wastes, Proceedings of the Sixteenth Annual RREL Hazardous Waste Research Symposium.* Environmental Protection Agency Report, EPA 600-9-90-037, pp. 274-289.

Pruell, R. J., and J. G. Quinn. 1988. Accumulation of Polycyclic Aromatic Hydrocarbons in Crankcase Oil. *Environmental Pollution*, Vol. 49, 89-97.

Purcell, A. H. 1978. Material Substitution in the Automotive Industry, Environmental Impacts. In, *Measurements of the Impacts of Materials Substitution - A Case Study in the Automobile Industry*, A. Blelloch, editor. American Society of Mechanical Engineers, New York, NY. pp. 39-53.

R.L. Polk & Co. 1992. U.S. Passenger Car Population Growth Lowest since World War II; Truck Growth Stays Steady. R.L. Polk & Co. Statistical Services Division Press Release Report, Detroit, MI, 6 p.

Renner, M. 1988. *Rethinking the Role of the Automobile.* Worldwatch Paper 84. Worldwatch Institute, Washington, D.C., 70 pp.

Rolph, P. 1991. Scrap Tires: Signs of Progress. *Automotive Recycling*, Vol. 11(4), 7-10.

Rouse, D. 1991. Big 3 Forming Recycling Trade Consortium. *Automotive Recycling*, Vol. 11, 10.

SCADA. 1993. *SCADA Group Storm Water Monitoring Program, 1993/1994.* State of California Auto Dismantlers Association, Sacramento, CA. 21 pp.

SCAQMD. 1993. *Final Environmental Assessment, Proposed Rule 1610 - Old Vehicle Scrapping.* South Coast Air Quality Management District, Office of Planning and Technology Advancement, Diamond Bar, CA. 120 pp.

SCCWRP. 1990. *Congener-Specific Characterization and Source Identification of PCB Input to Los Angeles Harbor.* Contribution C 338, Final Report to California Regional Water Quality Control Board, Los Angeles Region, by R.P. Eganhouse, R. Gossett, and G.P. Hershelman, Southern California Coastal Water Research Project . 45 p.

SCCWRP. 1988. *Storm Runoff in Los Angeles and Ventura Counties.* Contribution C 292, Final Report by Schaefer,H., and R. Gossett to California Regional Water Quality Control Board, Los Angeles Region, Southern California Coastal Water Research Project. 86 p.

SCVNPSCP. 1994. *Contribution of Heavy Metals to Storm Water from Automotive Disc Brake Pad Wear.* Public Review Draft Report by Woodward-Clyde Consultants, Santa Clara Valley Nonpoint Source Pollution Control Program, Santa Clara, CA. 42 pp.

SCVNPSCP. 1992A. *Source Identification and Control.* Report by Woodward-Clyde Consultants, Santa Clara Valley Nonpoint Source Pollution Control Program, Santa Clara, CA. 158 pp.

SCVNPSCP. 1992B. *Best Management Practices for Automotive-Related Industries, Practices for Sanitary Sewer Discharges and Storm Water Pollution Control.* Santa Clara Valley Nonpoint Source Pollution Control Program, Santa Clara, CA. 15 pp.

Silverman, G.S., M.K. Stenstrom, and S. Fam. 1986. Best Management Practices for Controlling Oil and Grease in Urban Stormwater Runoff. *The Environmental Professional,* Vol. 8, 351-362.

SSP. 1992. *Auto Dismantler Storm Runoff Study.* Final Report, Brown and Caldwell Consultants, Sacramento Stormwater Program, Sacramento County Water Agency, Sacramento, CA. 60 pp.

Stenstrom, M.K., G.S. Silverman, and T.A. Bursztynsky. 1984. Oil and Grease in Urban Stormwaters. *Journal of Environmental Engineering*, Vol. 110(1), 58-72.

Suitts, D.M. 1985. The Auto Dismantling and Recycling Industry in San Diego. Masters Thesis. Department of City and Regional Planning, University of California at Berkeley. 41 pp.

Svenson, G.E. 1974. Corrosion in Cars in Sweden. In, *Corrosion of Motor Vehicles. Conference Publication*, London, 1974, The Institution of Mechanical Engineers, London, U.K. pp 29-34.

UBA. 1989. *Report of the Waste Management Policies of the Federal Republic of Germany*, Federal Republic of Germany, Umwelt Bundes Amt. 49 pp.

USBM. 1985. *Bureau of Mines Research on Recycling Scrapped Automobiles.* Bulletin 684, K.C. Dean, J.W. Sterner, M.B. Shirts, and L.J. Froisland, United States Department of the Interior, Bureau of Mines, Washington, D.C. 46 pp.

USBM. 1967. *Automobile Disposal, a National Problem. Case Studies of Factors that Influence the Accumulation of Automobile Scrap.* Report, United States Department of the Interior, Bureau of Mines, Washington, D.C. 569 p.

USDOT. 1977. *Automobile Scrappage and Recycling Industry Study Overview.* Report. DOT-TSC-OST-77-11, R. Kaiser, R.P. Wesson, and A.C.W. Daniels, H.H. Aerospace Design Co., Inc. United States Department of Transportation, Office of Systems Engineering, Washington, D.C. 409 pp.

USEPA. 1993. Water Pollution Control, NPDES General Permits and Fact Sheets: Storm Water Discharges From Industrial Activity; Notice. United States Environmental Protection Agency, Washington, D.C. *Federal Register*, Vol 58(222): 61146-61596.

USEPA. 1992A. Final NPDES Permits for Storm Water Discharges Associated with Industrial Activity. United States Environmental Protection Agency, Washington, D.C. *Federal Register,* Vol. 57(175), pp 41236-41356.

USEPA. 1992B. *Storm Water Sampling Guidance Document.* Report EPA 833-B-92-001, Office of Water, United States Environmental Protection Agency, Washington, D.C. 162 pp.

USEPA. 1991A. *Guides to Pollution Prevention. The Automotive Repair Industry.* Report EPA/625/7-91/013, Office of Research and Development, Cincinnati, OH, United States Environmental Protection Agency, Washington, D.C. 46 pp.

USEPA. 1991B. *Methods for Aquatic Toxicity Identification Evaluations: Phase 1 Toxicity Characterization Procedures.* EPA/600/6-91/003, T.J. Norber-King et al. 2nd Edition. United States Environmental Protection Agency, Washington, D.C.. 84 pp.

USEPA. 1991C. *National Air Quality and Emissions Trends Report, 1989.* Report EPA/450/4-91/003, Office of Air Quality Planning and Standards, Technical Support Division, Research Triangle Park, NC. 134 pp.

USEPA. 1990. National Pollutant Discharge Elimination System Permit Application Regulations for Stormwater Discharges; Final Rule, United States Environmental Protection Agency, Washington, D.C. *Federal Register*, Vol. 55(222), pp 47990-48091.

USEPA. 1989A. *Methods for Aquatic Toxicity Identification Evaluations: Phase 11 Identification Evaluation Procedures.* EPA/600/3-88/035, D.I. Mount and L. Anderson-Carnahan, United States Environmental Protection Agency, Washington, D.C.. 31 pp.

USEPA. 1989B. *Methods for Aquatic Toxicity Identification Evaluations : Phase 111 Toxicity Confirmation Procedures.* EPA/600/3-88/036, D.I. Mount, United States Environmental Protection Agency, Washington, D.C. 25 pp.

USEPA. 1985. *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms*. Report EPA/600/4-85/013, Environmental and Monitoring Laboratory, Cincinnati, OH, United States Environmental Protection Agency, Washington, D.C. 216 pp.

USEPA. 1983. *Final Report of the National Urban Runoff Program*. Water Planning Division, United States Environmental Protection Agency, Washington D.C. 234 pp.

USEPA. 1975. *Contributions of Urban Roadway Usage to Water Pollution*. Report EPA-600/2-75-004, D.G. Shaheen, United States Environmental Protection Agency, Washington, D.C. 358 pp.

USEPA. 1973A. *The Automobile Dismantling Industry. A Survey of Solid Waste Management Practices in Four Cities*. Open File Report SW-103of. by U.S. Department of Commerce, United States Environmental Protection Agency, Washington, D.C.. 36 pp.

USEPA. 1973B. *An Analysis of the Abandoned Automobile Problem*. Report EPA-670/2-73-013, Booz-Allen Applied Research, Inc., Bethesda, MD, National Environmental Research Center, Cincinnati, OH, United States Environmental Protection Agency, Washington, D.C. 196 pp.

Vazquez-Duhalt, R. 1989. Environmental Impact of Used Motor Oil. *The Science of the Total Environment*, Vol. 79, 1-23.

Volvo. 1991. Environment Friendly Scrapping of Cars. *Environmental Report* No. 23, Volvo Car Corporation, Sweden. 9 pp.

VW. 1991. *Recycling at Volkswagen*. Report, Research for the Future, Volkswagen Allegemeine Gesselschaft, Germany. 26 pp.

Wakeham, G. S. 1977. A Characterization of the Sources of Petroleum Hydrocarbons in Lake Washington. *Journal WPCF*, Vol. 49(7), 1680-1687.

WDEC. 1994. *Draft Guidance Document for the Selection of BMPs for Auto Dismantler and Similar Facilities*. Washington Department of Ecology, Olympia, WA. 26 pp.

Winer, B. J., D. R. Brown, and K. M. Michels. 1991. *Statistical Principles in Experimental Design*. Third Edition, McGraw-Hill, New York, NY. 1057 pp.

Zar,J.H. 1984. *Biostatistical Analysis*. Second Edition, Prentice Hall, Englewood, NJ. 717 pp.

APPENDIX

Appendix Table A-1. Summary of data on auto recycler facilities and motor vehicle registrations in U.S. states. NC = Not computed because of insufficient data.

STATE	NUMBER OF RECYCLERS (ESTIMATED)	MEAN FACILITY SIZE (x 10^3 km^2)	POPULATION	NUMBER OF REGISTERED VEHICLES	NUMBER OF VEHICLES DISMANTLED (ESTIMATED)	REGISTERED VEHICLES TO RECYCLER RATIO (x 10^3)
ALABAMA	468	42	4,062,608	3,698,602	215,980	7.90
ALASKA	46	51	551,947	470,903	27,498	10.24
ARIZONA	303	27	3,677,985	2,848,537	166,341	9.40
ARKANSAS	165	36	2,362,239	1,479,637	86,404	8.97
CALIFORNIA	1,286	20	29,839,250	22,252,741	1,628,195	17.30
COLORADO	680	50	3,307,912	3,045,247	177,828	4.48
CONNECTICUT	276	32	3,295,669	2,588,777	151,172	9.38
DELAWARE	46	103	668,696	533,567	31,158	11.60
FLORIDA	652	35	13,003,362	9,980,076	582,788	15.31
GEORGIA	1,258	NC	6,508,419	5,714,189	333,681	4.54
HAWAII	9	NC	115,274	785,004	45,840	87.22
IDAHO	82	52	1,011,986	1,055,369	61,628	12.87
ILLINOIS	478	50	11,466,682	8,192,744	478,416	17.14
INDIANA	1,038	47	5,564,228	4,413,624	257,734	4.25
IOWA	312	58	2,787,424	2,668,436	155,824	8.55
KANSAS	1,065	46	2,485,600	1,879,442	109,750	1.77
KENTUCKY	1,065	57	3,698,969	2,962,763	173,011	2.78
LOUISIANA	147	29	4,238,216	3,045,788	177,859	20.72
MAINE	55	NC	1,233,223	978,849	57,160	17.80
MARYLAND	615	38	4,798,622	3,630,236	211,988	5.90
MASSACHUSETTS	377	66	6,029,051	3,663,843	213,951	9.72
MICHIGAN	496	39	9,328,784	7,244,938	423,069	14.61
MINNESOTA	1,148	NC	4,387,029	3,273,153	191,136	2.85
MISSISIPPI	110	59	2,568,443	1,887,441	110,217	17.16
MISSOURI	257	NC	5,137,804	3,950,125	230,668	15.37
MONTANA	248	45	803,655	765,754	44,716	3.09

(CONTINUED)

STATE	NUMBER OF RECYCLERS (ESTIMATED)	MEAN FACILITY SIZE (x 10³ km²)	POPULATION	NUMBER OF REGISTERED VEHICLES	NUMBER OF VEHICLES DISMANTLED (ESTIMATED)	REGISTERED VEHICLES TO RECYCLER RATIO (x 10³)
NEBRASKA	230	34	1,584,617	1,404,444	82,013	6.11
NEVADA	37	30	1,206.152	881,274	51,462	23.82
NEW MEXICO	156	27	1,521,779	1,320,488	77,110	8.47
NEW YORK	937	57	18,044,505	9,771,437	570.604	10.43
NEW HAMPSHIRE	432	26	1,113,915	906,464	52.933	2.10
NEW JERSEY	285	31	7,748,634	5,518,957	322.280	19.37
NORTH CAROLINA	1,111	54	6,657,630	5,216,177	304,599	4.70
NORTH DAKOTA	73	95	641,364	628,672	36,711	8.61
OHIO	955	48	10,887,325	8,684,599	507,138	9.09
OKLAHOMA	276	34	3,157,604	2,669,312	155,875	9.67
OREGON	863	NC	2,853,733	2,506,950	146,394	2.91
PENNSYLVANIA	220	59	11,924,710	8,037,808	469,369	36.54
RHODE ISLAND	37	32	1,005,984	628,407	36.696	16.98
SOUTH CAROLINA	220	70	3,505,707	2,471,245	144,309	11.23
SOUTH DAKOTA	83	70	699,999	701,987	40,993	8.46
TENNESSEE	202	54	4,896,641	4,541,676	265,212	22.49
TEXAS	1,506	41	17,059,805	12,696,540	741,416	8.43
UTAH	73	24	1,727,784	1,229,730	71,810	16.85
VERMONT	129	NC	564,964	446,819	26,092	3.46
VIRGINIA	716	52	6,216,568	5,268,612	307,661	7.36
WASHINGTON	321	35	4,887,941	4,403,604	257,149	13.72
WEST VIRGINIA	230	60	1,801,625	1,273,444	44,716	5.54
WISCONSIN	303	61	4,906,745	3,684,938	215,182	12.16
WYOMING	18	NC	455,975	468,566	27,362	26.03
TOTAL	22,095		248,004,783	188,371,935	11,328,744	

Appendix Table A-2. Summary of characteristics of the auto recycling industry in California and indices of potential environmental impacts.

COUNTY	POPULATION	NUMBER OF RECYCLERS (ESTIMATE)	IMPACTED LAND AREA COEFFICENT ($x10^{-2}$)	IMPACTED WATER AREA COEFFICIENT ($x10^{-3}$)	MOTOR VEHICLES REGISTERED	VEHICLES TO RECYCLER RATIO	VEHICLES RECYCLED (ESTIMATE)
Alameda	1,313,100	40	3.22	2.56	916,564	22,914	69,002
Alpine	1,200	1	NC	NC	1,088	1,088	63
Amador	32,150	4	0.16	1.13	30,428	7,607	1,689
Butte	191,200	13	0.33	30.80	144,849	11,142	10.046
Calaveras	35,700	3	0.23	2.49	37,129	12,376	1,875
Colusa	17,00	2	NC	NC	15,226	7,613	893
Contra Costa	836,900	36	5.18	5.95	645,153	17,921	43,972
Del Norte	27,600	2	NC	NC	17,902	8,951	1,450
El Dorado	137,200	6	0.60	1.13	120,275	20,046	7,208
Fresno	713,700	32	0.50	8.70	469,120	14,660	37.499
Glenn	25,800	9	0.11	7.01	21,091	2,343	1,356
Humboldt	123,600	12	0.08	1.06	100,682	8,390	6,494
Imperial	117,400	11	NC	NC	95,027	8,639	6,168
Inyo	18,750	2	NC	NC	17,958	8,979	985
Kern	584,100	47	0.68	30.09	393,686	8,376	30,689
Kings	107,500	7	NC	NC	62,610	8,944	5,648
Lake	54,100	4	NC	NC	52,395	13,099	2,842
Lassen	28,700	5	NC	NC	21,999	4,400	1,508
Los Angeles	9,087,400	355	4.43	93.09	5,824,169	16,406	477,461

(CONTINUED)

COUNTY	POPULATION	NUMBER OF RECYCLERS (ESTIMATE)	IMPACTED LAND AREA COEFFICENT ($x10^{-2}$)	IMPACTED WATER AREA COEFFICIENT ($x10^{-5}$)	MOTOR VEHICLES REGISTERED	VEHICLES TO RECYCLER RATIO	VEHICLES RECYCLED (ESTIMATE)
Madera	97,200	4	NC	NC	72,467	18,117	5,107
Marin	237,000	5	0.30	0.23	201,700	40,340	12,452
Mariposa	15,600	1	NC	NC	16,004	16,004	820
Mendocino	83,400	7	NC	NC	73,349	10,478	4,382
Merced	187,100	16	1.51	11.67	122,217	7,639	9,831
Modoc	10,150	1	NC	NC	8,801	8,801	533
Mono	10,400	1	NC	NC	9,910	9,910	546
Monterey	366,600	13	0.12	406.12	245,104	18,854	19,262
Napa	114,800	13	2.54	4.96	93,131	7,164	6,032
Nevada	83,600	3	NC	NC	77,518	25,839	4,392
Orange	2,512,200	37	1.49	37.47	1,835,716	49,614	131,993
Placer	186,900	1	0.06	0.10	163,714	163,714	9,820
Plumas	20,750	4	0.05	0.26	21,153	5,288	1,090
Riverside	1,289,700	41	0.38	4.14	840,221	20,493	67,762
Sacramento	1,099,100	78	7.41	22.56	763,626	9,790	57,748
San Benito	38,150	4	0.02	2.84	29,404	7,351	2,004
San Bernardino	1,530,600	83	0.13	7.86	990,008	11,928	80,419
San Diego	2,602,200	88	2.32	38.55	1,786,413	20,300	136,722
San Francisco	728,700	10	NC	NC	396,450	39,645	38,287
San Joaquin	502,000	28	1.86	9.62	332,913	11,890	26,376
San Luis Obispo	221,900	18	0.04	1.38	170,321	9,462	11,659

(CONTINUED)

COUNTY	POPULATION	NUMBER OF RECYCLERS (ESTIMATE)	IMPACTED LAND AREA COEFFICENT ($x10^{2}$)	IMPACTED WATER AREA COEFFICIENT ($x10^{-3}$)	MOTOR VEHICLES REGISTERED	VEHICLES TO RECYCLER RATIO	VEHICLES RECYCLED (ESTIMATE)
San Mateo	670,100	9	NC	NC	606,086	67,343	35,208
Santa Barbara	379,000	9	0.26	10.49	273,272	30,364	19.913
Santa Clara	1,531,800	52	1.34	12.50	1.167,020	22,443	80,482
Santa Cruz	231,600	10	0.68	49.46	180,056	18,006	12,169
Shasta	157,700	20	1.05	7.61	130,700	6,535	8,286
Sierra	3,340	0	NC	NC	3,486	3,486	175
Siskiyou	44,800	5	0.06	6.20	42,304	8,461	2,354
Solano	364,700	7	0.46	0.85	250,705	35,815	19,162
Sonoma	407,200	21	0.42	3.60	334,195	15,914	21,395
Stanislaus	393,400	25	1.95	13.81	279,350	11,174	20,669
Sutter	69,000	9	0.64	NC	54,655	6,073	3,625
Tehema	52,700	7	0.34	NC	40,762	5,823	2.769
Trinity	13,450	4	NC	NC	12,665	3,166	706
Tulare	330,000	25	0.40	28.30	215,304	8,612	17,338
Toloumne	51,700	4	NC	NC	47,704	11,926	2,717
Ventura	686,900	16	0.21	3.05	516,635	32,290	36,090
Yolo	149,200	9	0.63	NC	106,633	11,848	7,839
Yuba	61,100	7	0.76	23.53	43,204	6,172	3,210
STATE TOTAL	30,989,040	1,286			22,210,417		1,628,195

* Estimates are for 1992 (References: CIWMB 1993A, CDMV 1993, CDMV 1992)
Auto recycler estimates are based on CDMV data corrected for auxiliary facilities (body repair shops)
Recycled vehicles estimates are based on CIWMB report of 1,628,195 vehicle units scrapped and tonnage by county.