TREATMENT
OF
AUTO SHREDDER RESIDUE

Prepared for:

CALIFORNIA CHAPTER
INSTITUTE OF SCRAP RECYCLING INDUSTRIES (ISRI)

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May 18, 2012

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I. BACKGROUND/HISTORY OF ISSUE

Auto shredder residue (ASR) is generated by scrap metal shredding facilities as a result of the process of separating specification grade metal from a huge array of recyclable scrap metals including car bodies, household appliances, manufactured metal products and myriad other types of miscellaneous scrap metal. Since the mid- to late-1980s, shredder facilities in California have treated ASR using an in-line chemical fixation process to stabilize residual soluble metals prior to beneficial use or, less often, disposal of the treated material. The purpose of this Technical Memorandum is to explain how the treatment process is conducted, the types of materials and equipment that are used, the nature of the chemical reactions that occur in the process, and how these reactions bind residual heavy metals in the ASR so as to minimize their leaching potential over time. The vast majority of treated ASR is beneficially used as Alternative Daily Cover in nonhazardous waste landfills across the state, and is not subject to the more acidic environments that can be present in hazardous waste landfills. A survey of landfill leachate data conducted by the auto recycling industry in 2009, and submitted to the Department of Toxic Substances Control (DTSC), did not identify any instance where groundwater has been adversely affected by heavy metals in treated or untreated ASR deposited in those landfills.

The treatment process was developed in the mid-1980s in response to the classification of auto shredder residue as a California-only (non-RCRA) hazardous waste under the state hazardous waste regulations that were adopted by the Department of Health Services (DHS) (the predecessor agency to DTSC) in 1984. Prior to the adoption of those regulations, ASR was regulated as a nonhazardous solid waste and was disposed of in municipal landfills without treatment. DHS regulations established a variety of ways that wastes could be classified as hazardous wastes under California law, including the presence of heavy metals in concentrations that exceeded specified Total Threshold Limit Concentrations (TTLCs) or Soluble Threshold Limit Concentrations (STLCs), the latter as determined by the California Waste Extraction Test (WET). TTLCs and STLCs were adopted for a number of heavy metals commonly found in ASR, including lead, copper, cadmium and zinc.

Collectively, California metal shredder operations produce very large quantities of ASR (ranging from 500,000 to 700,000 tons per year). There are multiple obstacles (both regulatory and economic) to reducing this volume through waste minimization and recycling programs, e.g., regulatory impediments to recycling plastics. Shredder operators implement inbound material acceptance policies that require the rejection or removal of a wide variety of hazardous materials, hazardous wastes, and other “materials requiring special handling,” as required by law or as necessary to ensure safe operations. This serves to minimize hazardous constituents in the ASR, but does little to reduce the overall volume. It was recognized by DHS that the costs associated with managing this very large volume of residual material as a hazardous waste were not warranted based on the insignificant hazard posed by the material. At the same time, DHS recognized that the cost of managing ASR as hazardous waste would impose severe economic hardship on the shredder/recycling industry and alter the economics of the industry in a way that could destroy its viability. Aside from loss of jobs, loss of the industry in California would lead to the improper handling of discarded vehicles, old appliances and other scrap metal, to the detriment of public health and safety and the environment. Thus, development of an effective in-line treatment process was seen as a means to allow ASR to continue to be managed as a nonhazardous waste and to maintain the viability of metal recycling for the benefit of the public.

Following implementation of the treatment process, the shredder operators applied for reclassification of the treated ASR as non-hazardous waste under then § 66305(e) of the Title 22 regulations (since recodified as § 66260.200(f)), on the grounds that the waste possessed mitigating physical and chemical characteristics that rendered it insignificant as a hazard to human health and the environment. Each application was supported by analytical data that compared the solubility of key heavy metals (primarily lead and cadmium) in the waste before and after treatment. Each of the applications for reclassification was granted based on the demonstrated effectiveness of the treatment process. These reclassification letters have set the standard for ASR treatment and beneficial reuse for over 25 years.

DTSC has requested preparation of a Technical Memorandum on the ASR treatment process in connection with its review of the regulatory status of treated ASR and consideration of possible alternative management standards for treated ASR. DTSC’s evaluation of the long-term effectiveness of the treatment process, and the use of treated ASR as alternative daily cover in nonhazardous waste landfills, is a critical component of this regulatory strategy.

II. DESCRIPTION OF THE PROCESS THAT RESULTS IN THE GENERATION OF ASR

ASR is generated during the recycling of end-of-life manufactured “light iron” products such as automobiles and household appliances, as well as a huge variety of other types of recyclable scrap metal (ISRI, 2011). The term “auto shredder” comes from the initial step in the recycling process in which the recyclable material feedstock (frequently containing flattened car bodies) is placed by material handler or conveyed into a large hammermill shredder to reduce the size of the scrap metal into smaller pieces that can be more easily handled and separated by material type into specification-grade scrap metal commodities. Although the term ASR implies a dedicated in-feed of scrap automobiles, ISRI has estimated that as much as 40% of ASR derives from end-of-life appliances (Hook, 2008). In the second step of the recycling process, large electromagnets are used to separate most of the ferrous metal (e.g., steel) from the nonferrous metals (e.g., copper, aluminum and stainless steel) and other non-metallic materials contained in the shredder output (“aggregate”).

Once the ferrous metal (or “shred”) has been separated from the shredder aggregate, trommels and other kinds of “downstream” separation equipment are used to separate and size the remaining materials into different fractions so that they can be further processed to optimize removal of valuable metals. These fractions can be based on weight, density or other readily distinguishable physical properties. Specification-grade nonferrous metal is typically separated from the non-metallic material by eddy current separators (which create a means for magnetic separation of the nonferrous metals) and, more recently, by more advanced mechanical separation methods (e.g., optical sortation). Other types of specialized equipment may be used to sort the nonferrous metals and other materials into a variety of recyclable commodities. Depending on the sophistication of the material separation stages that are employed, the recyclable materials can be size-sorted and density-sorted onto separate conveyor belts to improve the recovery rate of different types of nonferrous metals and other recyclable commodities. In addition, manual labor may be used along certain conveyor belts to hand-separate larger pieces of nonferrous metals, and additional magnets may also be positioned to separate out remaining ferrous metals.

The largely non-metallic material remaining after the various magnetic, mechanical and manual separation steps is referred to as ASR. The ASR is treated by the process described in this paper, which includes final screening by a magnet installed downstream of the treatment process to collect any remaining ferrous metal after the in-line treatment process.

A flow chart depicting a typical auto shredding and “downstream” material separation processes is presented in Figure 1.

Figure 1: Process Flow Diagram of Auto Shredding and Separation Processes

III. DESCRIPTION OF UNTREATED ASR

The Vehicle Recycling Partnership, LLC (VRP) estimates that up to 84% (by weight) of a shredded automobile is separated into specification-grade metals by the scrap recycling industry (Metal Bulletin Daily, 2008). USEPA estimates are slightly more conservative at 75% to 80% (USEPA, 2011a). The remaining 16% to 25% of the recycled automobile becomes ASR. Current estimates suggest that more than 5 million tons of ASR is produced in the U.S. each year, and nearly all of this is used as Alternative Daily Cover or landfilled as waste (USEPA, 2011a). California is one of the few states that require treatment of ASR prior to placement in a solid waste landfill for either disposal or use as Alternative Daily Cover.

While generally homogeneous and soil-like in overall appearance, ASR is actually a highly heterogeneous mix of material which typically includes plastics, rubber, foam, fabric, carpet, glass, wood, road dirt, and debris, along with a small amount of residual (primarily nonferrous) metal that was not removed by the prior separation processes. These materials make up a complex mix of sizes, shapes, and densities with physical and chemical properties as described in Subsections A and B below. As noted by USEPA (2011a), research on ASR composition by Hook (2008) and DeGaspari (1999) determined that plastics represent approximately 30% of ASR's weight. Foam represents approximately 5% by weight, but up to 30% of the volume of ASR.

A. PHYSICAL CHARACTERISTICS

The physical characteristics of ASR range from granular particles (e.g., sand and soil) to identifiable pieces of carpeting, wood, foam, or plastic sometimes exceeding 5 inches in cross section. While, historically, California shredders treated only the smaller fractions of ASR (which were referred to as "fines"), the treatment process has evolved over time so that now all but the largest fraction of materials contained in ASR (plus 4-inches) is treated. The plus 4-inch materials are typically returned to the shredder for re-processing.

B. CHEMICAL CHARACTERISTICS

The chemical characteristics of ASR are typified by the presence of a very small amount of residual metals, such as lead, cadmium, copper and zinc, as well as various petroleum hydrocarbons (e.g., lubricating oils and other residual automotive fluids) and PCBs. Concentrations of certain residual metals in untreated ASR can approach or exceed California TTLCs and STLCs. For example, untreated ASR often contains total lead in excess of 1,000 mg/kg and WET extractable lead in excess of 5 mg/l. These constituents are also detected in samples of treated ASR collected by the shredders to comply with the requirements of the receiving landfills, although the extractable concentrations of metals are significantly reduced as a result of the treatment process. Concentrations of petroleum hydrocarbons, PCBs, VOCs and SVOCs are typically far below levels that would cause ASR to be classified as hazardous based on these constituents.

The residual metals found in ASR are constituents of the raw (unprocessed) scrap originally fed into the shredder. The limited chemical characteristics of untreated ASR reflect the significant efforts of the shredder facilities and their upstream suppliers to keep hazardous materials out of shredder feedstock in the first instance. Each auto shredder facility implements an inbound material acceptance policy that prohibits the inclusion of a range of hazardous materials in the shredder in-feed material. Each facility engages in stringent practices to enforce these prohibitions, including gate inspections of incoming loads of scrap by trained inspectors to identify prohibited materials in the incoming loads and yard inspections at various points en route to and at the entrance to the shredding process. Facilities also participate in the state-mandated programs to require suppliers to remove “materials requiring special handling” from automobiles and appliances prior to crushing and delivery to the facility, and to remove mercury switches, batteries and other hazardous materials from scrap auto bodies. Automotive fluids (fuels, lubricating oils, transmission fluid, antifreeze, etc.) are also drained from the vehicles prior to crushing and delivery to the shredder facility. In some cases, vehicles and appliances are received directly at the shredder facilities without having been prepared for recycling by an auto dismantler or a certified appliance recycler. Procedures are in place at the shredder facilities to remove all prohibited materials from these vehicles and appliances before they are shredded. Each of the shredder facilities reviewed for this report is a certified auto dismantler and appliance recycler.

C. PRE-TREATMENT LEVELS OF HEAVY METALS

Examples of recent WET extractable metal data from untreated ASR are provided in Table 1.

Table 1
WET Metal Values in Untreated ASR (mg/L)

Sample Date	Cd	Pb	Zn	Cu
6/18/2009	0.086	**58.7**	**925**	1.25
7/28/2009	**1.29**	**41.8**	**1320**	2.66
8/21/2009	0.657	**88.3**	**1423**	0.426
11/12/2009	**1.25**	**49.6**	**1456**	5.98
5/19/2010	**2.57**	**155**	**864**	6.83
10/26/2010	**2.09**	**109**	**2603**	9.1
1/5/2011	**1.62**	**86.7**	**1685**	3.97
1/25/2011	0.64	**74.4**	**1025**	3.35
4/28/2011	**1.26**	**68.9**	**1110**	4.51
10/31/2011	**1.86**	29.4	**1970**	4.60
11/7/2011	**1.79**	**51.0**	**1525**	2.03
Regulatory Values (CCR, Title 22 Ch. 11, § 66261.24)	**1**	**50***	**250**	**25**

Bold numbers indicate values at or above the STLC value.

* Each of the reclassification letters issued to the shredders allows a soluble lead concentration of 50 mg/L. The requirements of the reclassification letters vary with respect to other Title 22 metals.

IV. DESCRIPTION OF TREATMENT PROCESS

The treatment process at the three auto shredder facilities reviewed for this Technical Memorandum involves a chemical reaction between the ASR and inorganic binders that results in the binding and fixation of heavy metals in the ASR, thus reducing their leaching potential.

Treatment processes that chemically bind heavy metals in a solid or semi-solid matrix are referred to by USEPA as *Stabilization* treatment. Stabilization has been shown to be effective for a wide range of constituents including lead, arsenic, and chromium (USEPA, 2009). Stabilization and a similar process called *Solidification* are common remediation technologies employed at state and federal Superfund sites. USEPA estimates that 23% of the source control remedies performed at these sites between 1982 and 2005 involved the use of solidification or stabilization, and 94% of the solidification/stabilization remediations performed included inorganic binders such as cement, fly ash, lime, phosphate, soluble silicates, or sulfur (USEPA, 2009). The treatment technologies and terms Stabilization and Solidification were originally described in USEPA's "Guide to the Disposal of Chemically Stabilized and Solidified Waste" (USEPA, 1980). Unlike Solidification, which requires a substantial amount of cement or other inorganic binder to form a solid mass of material, Stabilization relies on reducing the contaminants' mobility through physical or chemical reactions involving precipitation, complexation, and adsorption (USEPA, 2006). The usefulness of this approach for stabilizing lead-impacted soil is described in the peer-reviewed *Emerging Technologies for the Remediation of Metals in Soils* by Interstate Technology and Regulatory Cooperation Working Group (ITRC, 1997).

The specific technology used to chemically bind the metals in the ASR matrix consists of the application of a blend of liquid polysilicates and additives (usually wetting agents), followed by the addition of an inorganic binder and alkaline activator (AA) such as cement, lime, or other pozzolanic materials. Depending upon the supplier, various types of silicate blends, using either potassium or sodium silicate with proprietary additives, are available and used by the auto shredding industry. Despite the variations in proprietary blends, the same basic principles of chemical reaction apply in each case.

A. CHEMICALS, POZZOLANIC MATERIALS AND EQUIPMENT USED IN THE PROCESS

The ASR treatment process, as currently conducted, uses one of two proprietary, soluble polysilicate solutions (with potassium silicate or sodium silicate as the active ingredient), and a form of pozzolanic (cementitious) material which functions as an alkaline activator (AA) in the process. The following sections discuss these liquid and dry additives, along with the process equipment necessary to deliver the treatment technology. Different treatment chemicals are evaluated from time to time, and may be used in lieu of the chemicals described in this report if determined to be more cost-effective.

B. SOLUBLE SILICATE SOLUTION

Two of the three auto shredder facilities in California that treat their ASR use a commercially-available product known as Metbond MCX-90, manufactured by Envirokem Engineering Services, LLC of Stockton, California. The active ingredient in Metbond MCX-90 is sodium silicate complex, with pH in the 10+ range (i.e., non-concentrate) (Envirokem, 2008). The Metbond MCX-90 system employs mixing tanks and a chemical-to-water mix ratio of 3% to 20% by weight, depending on the moisture content of the ASR.

The third auto shredder facility uses a product known as HP Treatment, which is manufactured by C.C.I. Chemical Corporation (formerly Cherokee Chemical), with corporate offices in Vernon, California (C.C.I., 2011). The active ingredient in HP Treatment is potassium silicate, with a pH of approximately 11.2. This product was developed by C.C.I. and the auto shredder client and includes a single-user proprietary blend. The HP Treatment system employs an in-line mixing process, and water-to-chemical mix ratio of approximately 13 to 1.

In addition to the water that is added to the polysilicate solution prior to application to ASR, the ASR itself is wetted during the shredding and separation stages, and it enters the treatment system with an average moisture content between 15% and 30% by weight.

C. ALKALINE ACTIVATOR

The California auto shredder facilities that treat ASR use Portland cement, fly ash, lime or similar dry pozzolanic material as the alkaline activator (AA). Based on the MSDS sheet for Portland Cement manufactured by CEMEX, of Victorville, California, Portland Cement has a pH in water of 12 +, and a specific gravity of 3.15 (CEMEX, 2001). Calcium salts in the blend may include: $2CaO.SiO_2$, $3CaO.Al_2O_2$, $4CaO.Al_2O_3Fe_2O_3$, and $CaSO_4.2H_2O$. Small quantities of other salts such as MgO, K_2SO_4, and Na_2SO_4 may also be included (CEMEX, 2001).

D. EQUIPMENT AND PROCESS FOR TREATMENT

Although the actual equipment may vary at different shredding facilities, the basic approach for delivering the silicate treatment is very similar. A brief description of the equipment and process follows.

The first step in the process is to thoroughly wet the material requiring treatment with the silicate blend. This is accomplished by creating a silicate/water mixture and applying it to the untreated ASR. Typically, this mixture is delivered through sprays which impinge on the material as it leaves the downstream nonferrous separation system conveyor belt. In some cases a two-compartment tank is used to create the silicate/water mixture. Here, the concentrated silicate blend from one compartment is metered along with water into a second compartment and is then pumped to a series of spray nozzles. In this case, the water acts as the carrier for the silicate blend so that the ASR can be wetted, thereby ensuring the even distribution of silicates throughout the material.

The amount of silicate necessary to effectively treat the ASR has been established through treatability studies conducted in the past, and is added in proportion to the amount of material requiring treatment. For example, if 40 tons/hour of ASR requires treatment and the appropriate silicate addition is 0.5 gallons/ton, then 20 gallons/hour of silicate concentrate would be added to the mixing tank. The amount of water/silicate mixture sprayed from the mixing tank has been determined through experience to be sufficient to ensure thorough treatment of the material. Since the water content of the in-feed to the treatment system varies (mainly due to the amount of water added in the shredder), the spray rate is adjustable to avoid free-liquid or oversaturation of the ASR. However, the amount of silicate that is added does not change.

Another method of silicate addition involves the use of a foam in-line jet pump mixer. In this application, the concentrated silicate blend is drawn from a silicate concentrate container by a combination of pressurized water and compressor airflow and sprayed onto the ASR as it falls off the end of a discharge conveyor. Adjustments can be made to the flow rates of water and silicate blend in this system, but typically the flow rate is set for the maximum feed rate of ASR on the belt.

The addition of the alkaline activator (AA) is the final step in the treatment process. After the ASR has been wetted with silicate/water solution, it enters a pug mill mixer. After an appropriate residence time in the mixer, the dry AA is introduced into the pug mill from an intermediate storage hopper, pneumatically connected to a large storage silo, via a set of variable speed metering screws. At some facilities the AA is metered directly from the silo, and multiple silos are used. The amount of AA required is a function of the known (predictable) range of concentrations of metals typically present in ASR and type of AA in use. Each system reviewed for this report included a computer-controlled metering of the AA, based on the conveyor belt weight of the ASR to be treated.

E. TREATMENT SYSTEM CONTROL AND CALIBRATION

Sampling and analysis over time has shown that shredder facilities process a relatively consistent mix of scrap, auto bodies and “tin” such that the levels of metals in shredder residue tend to remain within a relatively narrow range or band of concentrations. The treatment levels are conservatively adjusted to the higher end of the range.

The treatment process has also evolved over time, with an eye towards optimizing the process and allowing use of different, more effective or more economical treatment chemicals. Periodic sampling of the treated ASR is also used to adjust the ratios of silicates and AA to achieve the reductions in extractable metals in the treated ASR, as necessary to comply with applicable Waste Discharge Requirements of the receiving landfills or the conditions, if any, of the facilities' reclassification letters. The treatment systems are designed so that adjustments can be made to the amount of wet or dry chemicals required.

V. CHEMISTRY OF TREATMENT PROCESS

The following section describes the chemistry involved in the ASR treatment process.

A. METAL OXIDES TO METAL-SILICATES

The metals in ASR are typically present in the oxide form. Due to the strong affinity of silicates for metallic/metal oxide compounds, these metals react with the silicates, resulting in the production of compounds referred to as metal-silicates. The chemistry of the process requires two components for the development of metal-silicates. The first is a soluble reactive silicate complex and the second is the AA which creates a high alkalinity environment to enhance the dissolution reaction of the metallic particles in the ASR. The reactive silicate is formulated to react with the available metals to create the insoluble metal-silicates. The metal speciation determines the metal-silicate solubility and required dose for treatment. Furthermore, the reactive silicate is formulated to inhibit the formation of metal hydroxides. The process is a water base reaction where both reagents are thoroughly mixed with the ASR.

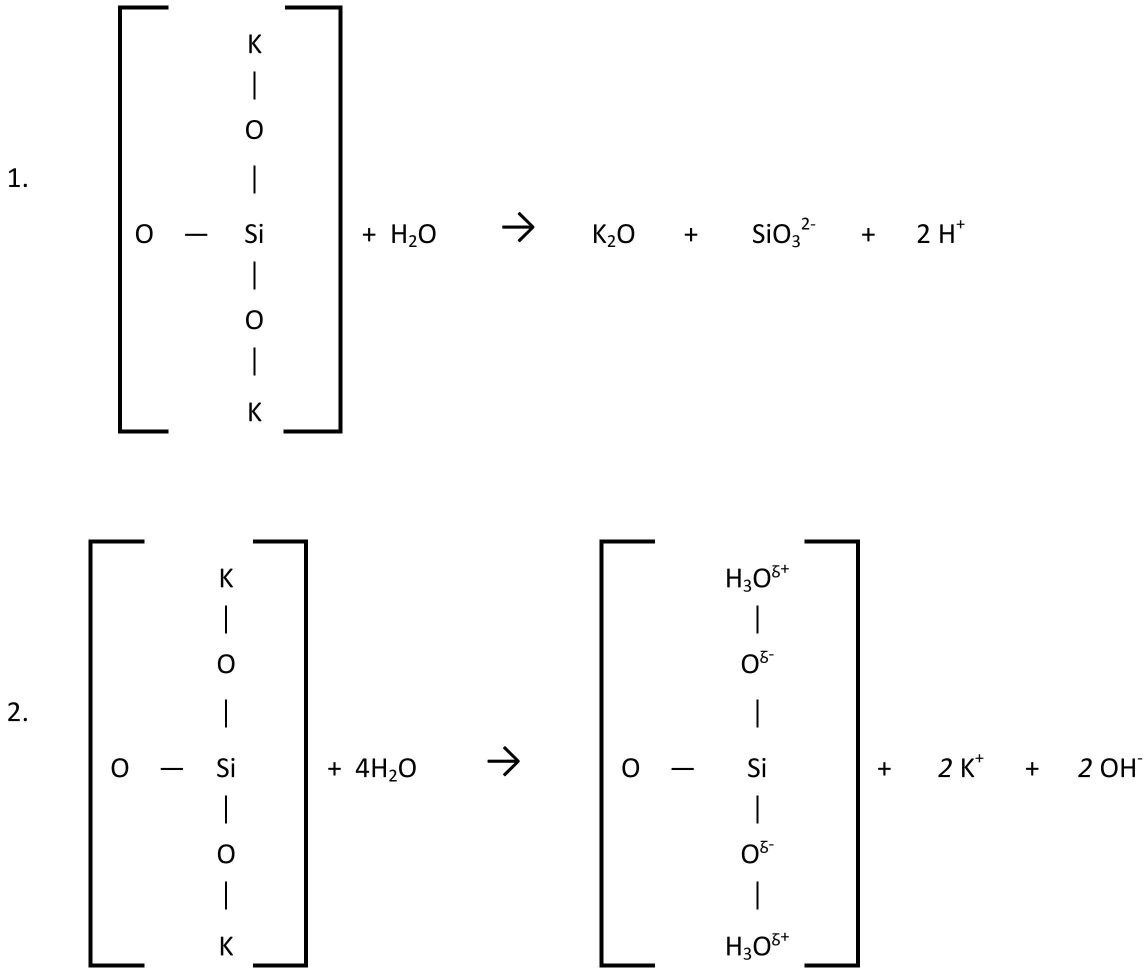
A detailed description of the chemical reaction equations is given in "Remediation of Heavy Metal Contaminated Solids Using Polysilicates," (Trezek, 1994). Example chemical equations involved in formation of liquid silicate polymer, its fixation to metallic elements, and Portland cement reaction are repeated in Figures 2 through 4.

Figure 2: Formation of Liquid Silicate Polymer

Water

$2\ H_2O \leftrightarrow H_3O^+ + OH^-$

Liquid Silicate



1.

$$\left[\begin{array}{ccc} & & \mathrm{K} \\ & & | \\ & & \mathrm{O} \\ & & | \\ \mathrm{O} & — & \mathrm{Si} \\ & & | \\ & & \mathrm{O} \\ & & | \\ & & \mathrm{K} \end{array}\right] + H_2O \rightarrow K_2O + SiO_3^{2-} + 2\ H^+$$

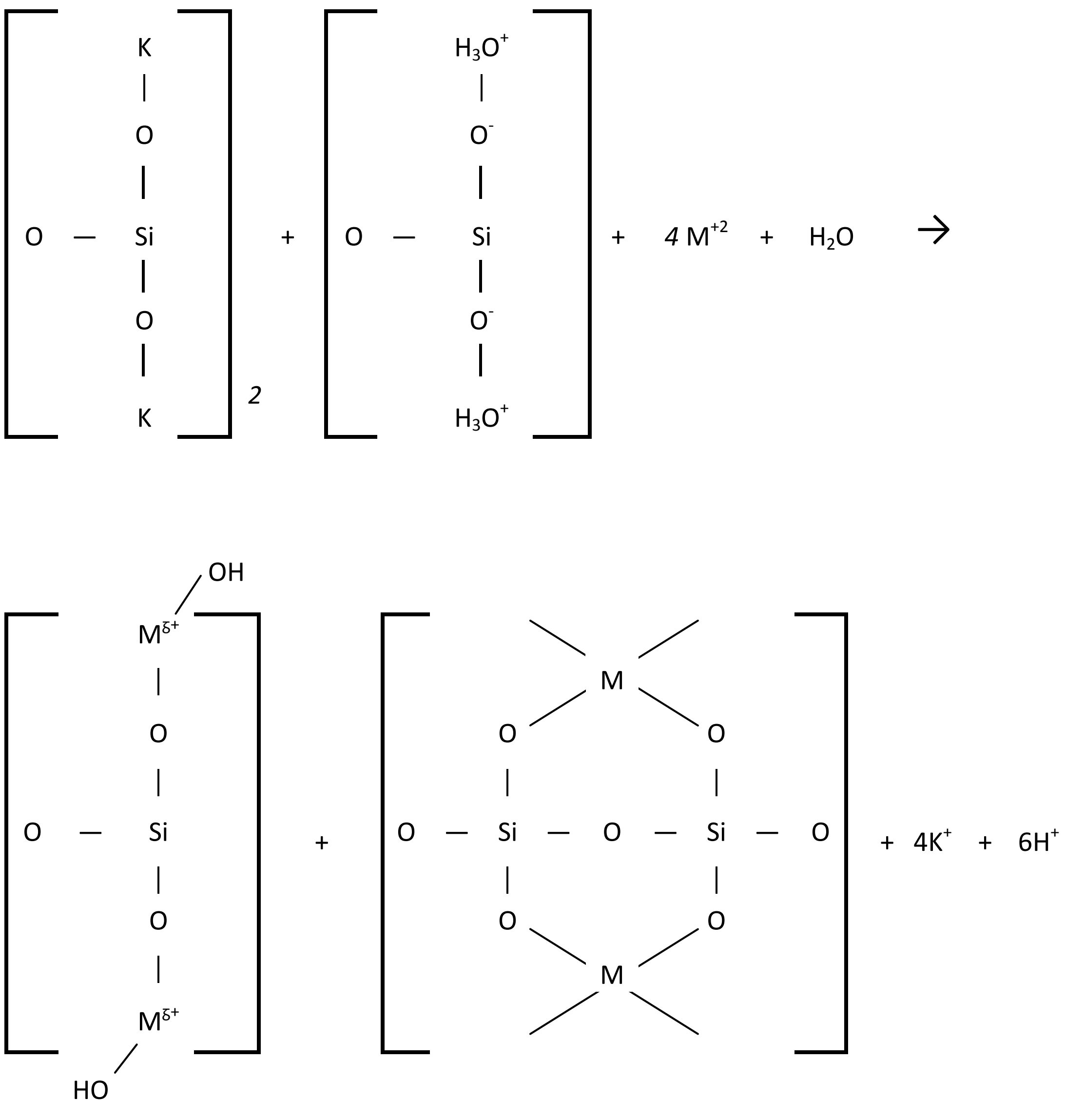
2.

$$\left[\begin{array}{ccc} & & \mathrm{K} \\ & & | \\ & & \mathrm{O} \\ & & | \\ \mathrm{O} & — & \mathrm{Si} \\ & & | \\ & & \mathrm{O} \\ & & | \\ & & \mathrm{K} \end{array}\right] + 4H_2O \rightarrow \left[\begin{array}{ccc} & & H_3O^{\delta+} \\ & & | \\ & & O^{\delta-} \\ & & | \\ \mathrm{O} & — & \mathrm{Si} \\ & & | \\ & & O^{\delta-} \\ & & | \\ & & H_3O^{\delta+} \end{array}\right] + 2\ K^+ + 2\ OH^-$$

As noted above, the liquid silicates depolymerize when mixed with water, and thereby expose their negatively charged oxygen sites. Silicone backbones continue to break down in water, creating ionically charged clusters.

Figure 3: Polysilicate Reaction with Metallic Elements

When ASR with active metallic elements is introduced, the reaction can be characterized as follows:



The evidence of structural changes in treated materials has been recorded through the application of electron microscopy and X-ray diffraction studies conducted at the Eitle Institute of Silicate Science under the direction of Professor William Kneller (Krofchak, 1979). These studies and analysis identified the presence of silicate compounds in a comparison of before and after treated material. For more information on these microscopic studies of the silicate reactions, please refer to the Krofchak reference included in Section IX.

Once the polysilicate solution has been added and thoroughly mixed with the ASR, a dry AA such as Portland cement is added to the partially-treated ASR in the pug mill. The addition of Portland cement to the treatment process yields the following reactions:

Figure 4: Portland Cement Reactions (in cement chemistry notation)

$$2C_3{\cdot}S + 6H \rightarrow 3C{\cdot}2S{\cdot}3H + 3(CH)$$

$$2C_2{\cdot}S + 4H \rightarrow 3C{\cdot}2S{\cdot}3H + CH$$

$$4C{\cdot}A{\cdot}F + 10H + 2(CH) \rightarrow 6C{\cdot}A{\cdot}F{\cdot}12H$$

$$3C{\cdot}A + 12H + CH \rightarrow 3C{\cdot}A{\cdot}CH{\cdot}12H$$

$$3C{\cdot}A + 10H + C\overline{S}{\cdot}2H \rightarrow 3C{\cdot}A{\cdot}C\overline{S}{\cdot}12H$$

Where: $C = CaO$, $S = SiO_2$, $H = H_2O$, $A = Al_2O_3$, $F = Fe_2O_3$, $C\overline{S} = CaSO_4$, (USEPA, 2008, p. A-3).

Although, at the time this report was prepared, each of the auto shredders reviewed for this report was using Portland cement as its AA additive, similar reactions and results can be achieved by using other pozzolanic AA additives.

The underlying principle of the technology is the transformation of the metal oxides into insoluble metal-silicates. Thus, it is the silicates that are the primary treatment chemical, with the AA in the supporting role of pH adjuster. The solubility curves of the primary metals of concern, such as lead, cadmium, zinc, have parabolic shapes with the lowest solubility inflection points falling within a range of approximately 9.5 to 11 on the pH scale (Cullinane, Jones & Malone, 1986). It is the behavior of these curves that controls the optimum amount of AA addition. For example, if a five percent addition gives good results, doubling the amount to ten percent will not be twice as effective. Instead, this action would result in a shift to a higher part of the solubility curve or a higher solubility constant. Controlling the amount of AA addition is part of the ongoing monitoring process, and is necessary to maximize treatment efficiency and minimize the cost of treatment additives and the incremental increase in the weight of the treated ASR.

B. CHEMICAL REACTION, NOT DILUTION

Dilution is not a factor in this treatment process, as seen by a simple mass balance of metal solubility and treated ASR weight increases. If the addition of silicates and AA increase the overall treated weight of ASR by 5% to 10%, then simple dilution would decrease the soluble metal concentrations by a similar amount. However, test results show that reductions in metal solubility are in the range of 67% to 99% for the primary metals of concern in ASR samples (Cd, Pb and Zn). See Table 3.

It should also be noted that the silicate treatment is designed to reduce only metal leachability or solubility. This treatment does not alter the total concentration of metals in the ASR beyond the modest decline associated with an increase in weight due to the addition of 5% to 10% cement or other AA.

C. INFLUENCE OF PARTICLE SIZE

The reduction of metals leachability in the ASR is caused by the chemical reactions previously described, as well as by the increase in small particle size attributed to the adsorption of silicate followed by the AA binder. The addition of silicates reduces the time required for curing of the cementitious AA binder, and increases its hardness and resistance to acid attack (PQ® Corp, 2011). This effect was studied by Davis, Krumrine, Boyce and Falcone in the mid-1980s. Their experiments determined that the time required for a highly acidic solution to leach away 50% of a 2 cm particle size can be increased 100-fold by the addition of soluble silicates (Davis, Krumrine, Boyce, and Falcone, 1986). Experiments by Dr. Trezek in the 1980s also confirmed that this significant reduction in metals leachability is even more pronounced in smaller particles, when exposed to multiple simulated landfill leachate extractions using either of two dilute acidic solutions (Trezek, 1994). These experiments and others, along with the known characteristic of cementitious materials to continue to harden for years after initial reaction, confirm that the effectiveness of the treatment will continue after the ASR is placed in the landfill environment. The long-term effectiveness of the treatment process is discussed in Section VI.

VI. LONG-TERM EFFECTIVENESS OF TREATMENT PROCESS

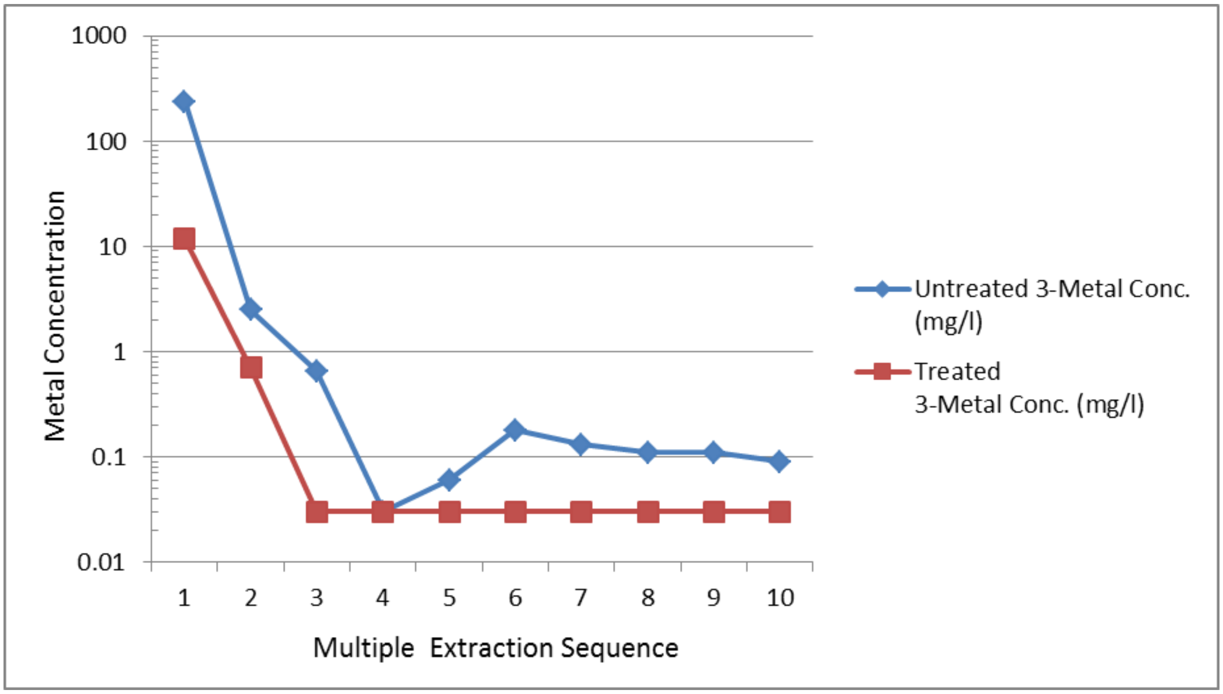
As part of the early development of the polysilicate treatment technology in the late 1980s, Dr. Trezek studied the effect of metals leachability during successive extractions on identical samples of treated and untreated soil media (Trezek, 1994). In order to evaluate the durability or time-dependent stability of treated material, USEPA developed the Multiple Extraction Procedure (MEP) as a test method. The details of this procedure are described in SW-846, Method 1320 (USEPA, 1986). The California Waste Extraction Test (WET) and the Multiple Extraction Procedure were applied sequentially to soil contaminated with copper, lead, and zinc.

This treatability study included one initial extraction by the California WET method and nine additional extractions of the same sample by EPA Method 1320. The results of the initial WET on the untreated soil yielded extractable metal concentrations of 22 mg/l for copper, 110 mg/l for lead, and 106 mg/l for zinc (a total of 238 mg/l for all three metals) (Trezek, 1994). Comparisons between the treated and untreated samples, and subsequent extraction results, were performed using the extractable total of all three metals. Results of these multiple extraction tests are tabulated below, and graphed in Figure 5, which follows.

Table 2
Long-Term Effectiveness Study Using Multiple Extractions

Extraction/Method	Untreated 3-Metal Conc. (mg/l)	Treated 3-Metal Conc. (mg/l)	Reduction in Conc. of Extractable Metals (Treated vs. Untreated)	Percent Reduction from Prior Treated Extraction
#1 / WET Method	238	11.7	**95%**	NA
#2 / Method 1320	2.5	0.7	72%	**94%**
#3 / Method 1320	0.65	0.03	95%	**96%**
#4 / Method 1320	0.03	0.03	0%	0%
#5 / Method 1320	0.06	0.03	50%	0%
#6 / Method 1320	0.18	0.03	83%	0%
#7 / Method 1320	0.13	0.03	77%	0%
#8 / Method 1320	0.11	0.03	73%	0%
#9 / Method 1320	0.11	0.03	73%	0%
#10 / Method 1320	0.09	0.03	67%	0%

Figure 5 Log Graph of 3-Metal Concentration Using Multiple Extractions



As noted in Table 2, extractable target metals present in the untreated sample were reduced by 95% using polysilicate/cement treatment, as evidenced by the first extraction of treated and untreated samples using the WET method. The comparison of initial WET extractions of untreated and treated samples is also graphically depicted above as extraction #1.

Subsequent extractions by EPA Method 1320 (extractions 2 thru 10 on the graph) showed a decline in extractable metals in the treated sample over the next two extractions (94% and 96%, respectively), then reached the equilibrium extractable value (0.03 mg/l) for the remainder of the extraction tests. The untreated sample required four extractions to reach the same extractable metal concentration observed in the third extraction of the treated sample, and then rebounded to a higher concentration in the remaining extraction tests. This long-term effectiveness study demonstrates that treatment by polysilicate solution and alkaline additive reduces the WET-extractable metals concentration in soils by an average of 95%, and that this treatment benefit is durable enough to withstand multiple extractions (by Method 1320).

It should be noted that the Multiple Extraction Procedure (MEP) is designed to simulate 1,000 years of freeze and thaw cycles and prolonged exposure to an acidic environment (USEPA, 2003). The MEP also gradually removes excess alkalinity from the sampled material, thereby decreasing the pH and ultimately increasing the solubility of most metals. This pH reduction is significant because of the alkaline activator employed in the treatment system and the metals solubility curves previously discussed, and further validates that the treatment has long-term effectiveness, even in an acidic environment.

Although this study used soil as the treated media, similar long-term effectiveness can be expected in soil-like ASR, as evidenced by the treatability studies and empirical data for treated ASR, which are discussed in the following sections.

A. HISTORICAL ASR TREATABILITY STUDIES

Dr. Trezek has been performing treatability studies on ASR since the late 1980s, and the following tables provide treatability data from his initial work, as well as more recent studies by Dr. Trezek and others.

Historical total (mg/kg) and extractable (mg/l) metal concentrations, as determined by the California WET method, for California shredder facilities are provided in Table 3 below. These data, which are from the 1988-1989 time period, were collected as part of the original ASR treatability studies conducted by Dr. Trezek. These data were generated for the purpose of demonstrating the effectiveness of the polysilicate/cement treatment in substantially reducing the extractability of metals found in ASR. Table 3 features cadmium (Cd), lead (Pb) and zinc (Zn), as these were the primary metals of concern to DTSC.

Table 3
Historical ASR Treatability Data

SAMPLE DATE	SAMPLE TYPE	TYPE OF ANALYSIS	WET results in mg/L Total results in mg/kg		
			Cd	Pb	Zn
3/17/1988	Untreated	WET	2.9	65	950
		Totals	76	2900	14000
	Treated	WET	0.14	39	140
		Totals	35	2800	6500
3/18/1988	Untreated	WET	2.60.	73	780
		Totals	52	2400	12000
	Treated	WET	0.17	16	23
		Totals	37	1800	7400
3/19/1988	Untreated	WET	2.4	93	570
		Totals	56	2400	9800
	Treated	WET	0.26	7.1	12
		Totals	30	1500	5700

Table 3 - Historical ASR Treatability Data (continued)

SAMPLE DATE	SAMPLE TYPE	TYPE OF ANALYSIS	WET results in mg/L Total results in mg/kg		
			Cd	Pb	Zn
3/22/1988	Untreated	WET	1.8	73	530
		Totals	54	3200	11000
	Treated	WET	0.2	19	53
		Totals	50	2800	7900
3/25/1988	Untreated	WET	1.4	48	440
		Totals	20	970	5100
	Treated	WET	0.11	19	110
		Totals	17	1500	4100
3/29/1988	Untreated	WET	1.8	65	67
		Totals	100	1900	8500
	Treated	WET	0.85	19	160
		Totals	90	1900	5900
4/1/1988	Untreated	WET	0.75	34	180
		Totals	26	1000	6500
	Treated	WET	0.48	31	82
		Totals	18	1200	5500
4/5/1988	Untreated	WET	0.45	24	150
		Totals	35	1100	8300
	Treated	WET	0.6	25	140
		Totals	20	650	5100
4/8/1988	Untreated	WET	0.8	31	260
		Totals	29	1300	9000
	Treated	WET	0.25	5.5	12
		Totals	18	1700	7700
4/12/1988	Untreated	WET	0.78	36	240
		Totals	17	660	3100
	Treated	WET	0.05	6.4	7.6
		Totals	22	1200	4600

Table 3 - Historical ASR Treatability Data (continued)

SAMPLE DATE	SAMPLE TYPE	TYPE OF ANALYSIS	WET results in mg/L Total results in mg/kg		
			Cd	Pb	Zn
4/15/1988	Untreated	WET	0.59	25	450
		Totals	20	1000	5700
	Treated	WET	0.03	3.5	12
		Totals	20	650	3800
4/19/1988	Untreated	WET	1.5	30	590
		Totals	21	790	6800
	Treated	WET	0.06	5.8	30
		Totals	25	1000	5700
4/22/1988	Untreated	WET	1.1	47	480
		Totals	35	3900	9400
	Treated	WET	0.3	19	81
		Totals	34	2700	10000
2/15/1989	Untreated	WET	0.95	34.8	463
		Totals	29.9	1750	3710
	Treated	WET	ND	10.0 / 1.81	13.6
		Totals	37.9	3340	7630
2/16/1989	Untreated	WET	1.84	441	629
		Totals	26.5	5200	6870
	Treated	WET	ND	ND	0.16
		Totals	21.2	4260	8330
2/17/1989	Untreated	WET	1.71	28.1	640
		Totals	31.5	1550	7270
	Treated	WET	ND	10.4	21.1
		Totals	35.1	2040	8880
2/21/1989	Untreated	WET	1.77	33.3	766
		Totals	24.9	1470	7070
	Treated	WET	ND	12.6 / 3.15	61.7
		Totals	34.5	2670	10500
2/22/1989	Untreated	WET	1.76	1110	679
		Totals	26.1	22100	11300
	Treated	WET	ND	ND	0.17
		Totals	33.2	7830	8780

SAMPLE DATE	SAMPLE TYPE	TYPE OF ANALYSIS	WET results in mg/L Total results in mg/kg		
			Cd	Pb	Zn
2/23/1989	Untreated	WET	2.25	44.30	717.00
		Totals	42.5	2270	5170
	Treated	WET	ND	20.9 / ND	22.0
		Totals	24.6	3770	7680
2/24/1989	Untreated	WET	1.68	71.1	635
		Totals	28.3	1980	8650
	Treated	WET	ND	0.73	0.16
		Totals	28.9	7080	9980
Mean Values	Untreated	WET	1.49	120	511
		Totals	37.5	2992	7962
	Treated	WET	0.19	12.5	49.1
		Totals	31.6	2620	7084
Treatment Reduction (as % of Untreated Conc.)		WET	**87.0%**	**89.6%**	**90.4%**

N.D. = non-detect, or concentration less than lab reporting limit.

As noted by the bold figures at the bottom of Table 3 above, treatment efficiency for extractable cadmium, lead and zinc averaged between 87% and 90%.

Similar reductions were achieved for the four other metals that were evaluated (Cr, Cu, Hg and Ni). The average treatment reduction of extractable (WET) nickel was similar to the ratios expressed above for cadmium, lead and zinc. Extractable chromium and mercury values for untreated samples were too low to generate comparable reduction data in the treated samples. The fourth metal, copper, showed a slight increase in extractability with treatment, although all samples, both treated and untreated, were well below the STLC (25 mg/l).

B. RECENT ASR TREATABILITY STUDIES

More recent treatability studies have been conducted to evaluate the effectiveness of ASR treatment. Results of one such study are presented in the Table 4 and involve ASR conveyor belt samples collected before and after treatment.

Table 4

Recent Treatability Study Using Belt-Collected ASR Samples

Sample Date	Sample Type	Type of Analysis	Parameter		
			Cd (mg/L)	Pb (mg/L)	Zn (mg/L)
4/23/2009	Untreated	WET	0.776	73.8	1170
4/23/2009	Treated	WET	0.239	2.47	186
4/23/2009	Untreated	WET	0.228	42.6	1050
4/23/2009	Treated	WET	0.14	3.20	78.2
4/23/2009	Untreated	WET	0.931	28.1	1420
4/23/2009	Treated	WET	0.102	7.33	73.4
Mean Values	Untreated	WET	0.645	48.17	1213
	Treated	WET	0.160	4.33	113
Treatment Reduction (as % of Untreated Conc.)		WET	**75%**	**91%**	**91%**

Note: Samples were collected from ASR conveyor belt, before and after treatment, with pairs sampled approximately 5 minutes apart to allow for average pug mill treatment dwell time.

In addition to treatment studies involving one formulation of treatment chemicals, there is ongoing activity within the auto shredding industry to advance the efficacy of ASR treatment through formula modifications. This typically involves a collaborative effort between the manufacturer of the chemicals and the auto shredder.

Collaborative treatability studies between the chemical manufacturer and the auto shredder often involve applying various treatment protocols to bench scale samples. For example, 150 gram quantities of ASR taken from a 10,000 gram composite stockpile are common. The testing involves the application of various types and quantities of silicate blends and alkaline activators. Although each manufacturer claims to have a proprietary blend, the basic components are either potassium silicate or sodium silicate, combined with other additives such as phosphates and wetting agents. The original Lopat K20 blend that was developed in the 1980s contained three different viscosity potassium silicates, with borax and glycerin as additives. Thus, the goal has been to develop blends that provide the maximum effectiveness while minimizing the use of Portland cement or other alkaline activators.

During the past several years, one chemical manufacturer and a California auto shredder facility have collaborated to conduct a variety of ASR treatability studies concentrating on the target metals of cadmium, lead, copper, and zinc. The testing generally involved: (1) treating ASR with reformulated silicate blends (usually with sixteen aliquots and three or four alkaline activators), (2) measuring the metal concentrations in an accredited laboratory, and (3) selecting the most promising combination for further evaluation. More than thirty different blends were evaluated using these basic parameters. A summary of these treatability results for varying polysilicate blends is provided in Table 5 below.

Table 5
Comparison of Treatment Formulations
(WET results, mg/L)

Formula	Date	Sample #	Cd	Pb	Zn	Cu	Application Sequence
NMET	8/3/2009	1	ND	5.23	19.6	19.2	1nmet,10L
	8/3/2009	3	0.094	7.63	21.2	6.14	1nmet,7C
	8/3/2009	5	0.079	16.3	25.6	17.9	2nmet,10L
	8/3/2009	6	0.332	7.21	118	20.1	2nmet,7l
NMET2&W	11/12/2009	9	0.252	31.2	221	21.7	1nmet2,50w,10L
	11/12/2009	10	0.12	25.8	75.2	**30.5**	1nmet2,50w,7L
NMET3&W	11/12/2009	14	0.119	14.7	87.5	**36.4**	1nmet3,50W,7L
	11/12/2009	16	0.12	15.3	93.8	**36.2**	1nmet3,50W,5L
NMET3GS	2/18/2010	5	ND	19.9	90.7	**36.6**	nmetgs,10L
NMET4	2/18/2010	9	ND	22.4	113	**25.1**	nmet4,10L
NMETG	8/3/2009	9	ND	17.1	91.1	24.6	1nmeg,10L
	8/3/2009	13	0.051	12.9	55.8	20.1	2nmetg,10L
NMETNK	8/14/2000	1	ND	26.7	47.8	**27.7**	1nmetnk,10L
	8/14/2009	5	0.407	2.74	208	4.96	2nmetnk,10L
NMETNKG	8/14/2009	9	ND	9.71	47.3	**27.4**	1nmet-,10L
	8/14/2009	13	ND	21.6	44.5	22.6	2nmet-10L
MET535G	8/21/2009	5	ND	67.6	187	22.3	met535g,10L
	8/21/2009	9	0.147	21.1	142	0.53	2met535g,10L
MET540	8/21/2009	13	0.116	7.24	65.1	0.622	1met540,10L
KMET	7/28/2009	13	0.212	14.7	124	15.8	1kmet,10L
	7/28/2009	9	0.188	14.2	139	**26.8**	2kmet,10L
	7/14/2009	1	0.075	4.19	25.8	2.51	2kmet,10L
	7/14/2009	3	0.333	1.59	105	1.88	2kmet,10C
	7/14/2009	8	ND	3.61	24.3	0.18	2kmet,10L
KMET&TRIA	10/26/2009	8	0.398	19.4	125	21.1	kmet,tria,7L
K90	7/14/2009	4	0.083	6.15	39.1	13	2k90,10L
	7/14/2009	7	ND	7.54	40.9	0.273	1,k90,10L
	7/14/2009	6	0.795	1.57	**283**	1.36	2k90,10C
	7/28/2009	5	0.147	16.3	153	**29.4**	1k90,10L
	7/28/2009	1	0.276	11.2	109	2.6	2k90,10L
K90&N	7/14/2009	9	0.092	17.6	67	12.4	1k90,2n,10L
	7/14/2009	10	0.27	1.18	**268**	0.785	1k90,2n,10C
N1	7/9/2009	5nd	ND	10.6	89.7	1.06	1,2n1,10L
	7/9/2009	6	0.06	18.1	82.2	22.1	0,2n1,10L
	6/18/2009	7	ND	1.47	141	0.08	1,2n1,10L
	6/18/2009	4	ND	0.447	**286**	ND	2,1n1,10L
	7/21/2009	4	0.071	6.58	28.4	2.72	1n1,10L

Table 5
Comparison of Treatment Formulations
(WET results, mg/L)

Formula	Date	Sample #	Cd	Pb	Zn	Cu	Application Sequence
N1&TRI	10/26/2009	1	0.234	4.09	73.7	2.57	1n1,1tr1,7L
N1A	5/19/2010	4	ND	49.5	51.5	20.4	n1a,10L
N1B	5/19/2010	8	0.112	26.9	34.9	22.3	n1b,10L
N1C	5/19/2010	12	ND	10.8	48.2	5.67	n1c,10L
N1D	5/19/2010	16	0.247	17.1	57.9	**26.5**	n1d,10L
MCX90N	8/21/2009	1	0.181	15.5	143	0.988	1mcx90n,10L
MCX90CS	2/9/2010	1	0.412	2.16	206	4.46	mcx90,10L
	2/9/2010	5	0.266	4.26	75.1	5.96	2mcx90,10L
MCX90CH	10/26/2010	4	0.317	16.4	109	56.8	mcx90,10L
MCX90N2B	2/18/2010	1	0.143	5.59	50.3	3.88	mcx90n2b,10L
MCX90N1&	1/25/2011	8	0.314	3.47	119	2.39	mcx90n1,10L
MCX90N1&M	4/28/2011	8	ND	0.119	168	0.169	mcx90n1,10M,5L
	4/28/2011	9	ND	0.844	157	0.806	mcx90n1,10M,5C
MCX90N1&MTT	8/23/2011	2	0.256	7.44	109	4.64	mcx90n1,1mtt,7L
	8/23/2011	4	0.159	2.91	112	3.12	mcx90n1,1mtt,10L
	9/14/2011	4	0.288	4.18	99.4	2.75	mcx90n1,1mtt,10L
MCX90N1&MFT	8/23/2011	6	ND	0.539	130	0.475	mcx90n1,1mft,7L
	9/14/2011	8	ND	5.54	53.6	1.54	mcx90n1,1mft,10L
MCX90N1&LTT	8/23/2011	10	ND	3.83	40.7	1.89	mcx90n1,10ltt,7L
	8/23/2011	12	ND	2.15	12.8	1.44	mcx90n1,10ltt,10L
	9/14/2011	12	ND	5.22	43.2	4.2	mcx90n1,10ltt,10L
PREA	10/20/2009	8	0.195	8.37	158	2.69	1.5prea,10L
RG	7/21/2009	5	0.166	12.9	134	22.9	2rg,10L
RGK	7/21/2009	6	0.7	4.5	41.9	2.17	2rgk,10L
RGS	7/21/2009	7	0.74	9.05	58.6	3.74	2rgs,10L
Ka,Kb	7/21/2009	1	0.071	8.12	43.6	2.65	1ka,1kb,10L
	7/21/2009	2	0.374	2.91	122	1.71	1ka,1kb,10C
	7/21/2009	3	**1.1**	1.98	246	1.5	1ka,1kb,10C/L
RUOH	9/9/2009	5	0.221	13.2	156	8.32	1ruoh,10L
	10/20/2009	12	0.236	15.2	248	4.11	1ruoh,10L
K20A,K20B	11/12/2009	1	ND	24.6	132	**36.9**	1a,b,10L
K20A,K20B&W	11/12/2009	5	0.147	**112**	173	**42.9**	1a,b,25w,10L
	11/12/2009	6	0.215	39.7	92.6	**35.9**	1a,b,25w,7L
K20A&TSUL	11/4/2099	6	0.9	9.19	220	10.4	10k,28t,10L
125A&B	7/21/2010	10	0.329	3.4	156	**40.3**	2,125ab,7L
	7/21/2010	12	ND	2.68	31.2	**34.1**	2,125ab,10L
STLC Values (from CCR, Title 22 Ch. 11, § 66261.24)			**1**	**50***	**250**	**25**	

Key to table: ND=no detection, below reporting limit. . ***Bold text*** *represents results in excess of the STLC. For ASR, the de facto STLC for lead is 50 mg/l, as per the DTSC reclassification letters. The requirements of the reclassification letters vary with respect to other Title 22 metals.*

VII. Treated ASR – Characterization Data Required By Landfills

The following section discusses landfill characterization data for treated ASR using either the standard or a modified WET method. Under the modified WET method, landfill leachate from the specific landfill that is receiving treated ASR is used as the extraction solution in lieu of the citrate buffer. For some landfills, the Waste Discharge Requirements may specify use of deionized water as the extraction solution.

A. Landfill Leachate Test Data

A summary of treated ASR results using landfill leachate (from Potrero Hills) as the extraction medium is provided in the following table.

Table 6
Summary of Landfill Leachate Testing of Treated ASR

SAMPLE DATE	Parameter							
	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Pb (mg/L)	Hg (mg/L)	Ni (mg/L)	Zn (mg/L)	Cr VI (mg/L)
1/20/2009	< 0.05	< 0.050	0.45	< 0.100	< 0.005	0.20	0.18	< 0.020
4/3/2009	< 0.050	< 0.050	0.06	< 0.100	< 0.005	0.236	0.275	< 0.020
7/7/2009	< 0.050	< 0.050	< 0.05	< 0.100	< 0.005	0.123	0.201	< 0.020
10/15/2009	< 0.050	< 0.100	0.165	< 0.100	< 0.100	0.142	0.351	< 0.100
1/18/2010	< 0.020	< 0.100	1.2	< 0.100	< 0.100	0.217	< 0.100	< 0.100
4/8/2010	< 0.020	< 0.100	1.25	< 0.100	< 0.005	0.147	< 0.100	< 0.020

Note: purple cells represent results below laboratory reporting limit (N.D.).

In contrast to the results from standard WET method analysis, solubility testing conducted with landfill leachate (which is representative of actual conditions in the landfill, as opposed to the WET) shows little to no leachable heavy metals in the treated ASR.

C. Treated ASR Characterization Data (Total and WET)

Table 7 presents Total and extractable data gathered between January 2009 and January 2012 as part of routine characterization testing of treated ASR conducted by California auto shredders. Many of these analyses were required by the reclassification letters issued to certain of the shredder facilities and/or by the Waste Discharge Requirements or other permits for certain landfills that accept treated ASR for use as alternative daily cover. In some cases, WET data is required to be submitted to the landfills on a quarterly basis, as part of existing alternative daily cover acceptance agreements between the landfills and the individual auto shredders.

Table 7 - Total and WET Results for Treated ASR

SAMPLE DATE	Total							WET						
	Cd (mg/kg)	**Cr (mg/kg)**	**Cu (mg/kg)**	**Pb (mg/kg)**	**Hg (mg/kg)**	**Ni (mg/kg)**	**Zn (mg/kg)**	**Cd (mg/L)**	**Cr (mg/L)**	**Cu (mg/L)**	**Pb (mg/L)**	**Hg (mg/L)**	**Ni (mg/L)**	**Zn (mg/L)**
1/7/2009	-	-	-	690	-	-	-	-	-	-	35	-	-	-
1/16/2009	< 0.5	408	**4390**	835	0.890	< 2.5	**9950**	< 0.1	1.03	6.12	6.27	< 0.02	0.625	144
1/16/2009	16	110	**37000**	1000	0.89	150	**11000**	0.11	0.84	9.8	1.4	0.0017	0.96	22
1/16/2009	< 0.5	56.2	**5350**	**1110**	1.02	< 2.5	**15000**	< 0.1	0.669	9.91	4.70	< 0.02	0.565	34.7
4/10/2009	19.4	77.9	807	**1040**	2.48	184	**11100**	0.073	0.688	6.04	2.17	< 0.02	0.589	31.3
4/11/2009	12.7	103	1010	991	1.64	145	**9140**	0.109	0.816	7.92	6.96	< 0.02	0.680	94.1
5/26/2009	< 0.5	84.7	**16300**	**3340**	0.991	258	**11500**	< 0.1	0.948	10.6	10.4	< 0.01	0.638	48.9
7/2/2009	-	-	-	150	-	-	-	-	-	-	22.0	-	-	-
7/2/2009	-	-	-	910	-	-	-	-	-	-	**51.0**	-	-	-
7/10/2009	65.4	83.9	**16300**	**1360**	0.300	< 2.5	**10500**	< 0.1	1.13	7.76	7.08	< 0.01	0.593	52.0
7/17/2009	183	217	**10800**	**1420**	1.23	305	**15100**	0.313	1.15	16.6	3.49	< 0.01	0.860	94.5
7/18/2009	58.2	100	333	**1010**	0.823	< 2.5	**8980**	< 0.1	0.889	4.30	4.63	< 0.02	0.758	154
10/2/2009	< 0.5	137	2150	**1400**	0.499	390	**11700**	< 0.1	1.10	12.1	6.17	< 0.02	< 0.3	38.8
10/9/2009	< 0.5	150	**3520**	**1060**	1.07	286	**8720**	0.085	1.00	5.87	6.11	< 0.01	< 0.3	32.0
10/10/2009	< 0.5	81.5	707	**1020**	0.647	< 2.5	**11170**	0.038	0.841	7.26	3.99	< 0.02	< 0.3	32.6
2/1/2010	-	-	-	**1284**	-	-	-	-	-	-	39.16	-	-	-
2/1/2010	-	-	-	901	-	-	-	-	-	-	4.86	-	-	-
2/1/2010	-	-	-	**2577**	-	-	-	-	-	-	47.24	-	-	-
2/3/2010	< 0.5	136	2100	**1810**	2.60	< 2.5	**9540**	0.358	1.84	8.42	2.64	< 0.01	1.17	123
2/5/2010	< 0.5	113	1920	785	8.15	< 2.5	**9140**	< 0.1	1.62	8.04	14.3	< 0.02	< 0.3	58.2
2/6/2010	< 0.5	121	**17600**	843	2.42	< 2.5	**6470**	0.152	1.30	12.4	1.37	< 0.01	0.846	38.2
4/9/2010	< 0.5	118	976	**1160**	1.65	< 2.5	**10900**	0.372	1.08	5.59	5.13	< 0.02	0.947	198
4/10/2010	< 0.5	196	**3440**	**1440**	2.45	311	**14300**	0.075	0.769	10.9	6.93	< 0.02	1.09	46.5
4/12/2010	< 0.5	114	**17100**	**1330**	0.581	< 2.5	**10600**	0.121	0.725	8.76	1.43	< 0.01	0.646	22.1
7/7/2010	< 0.5	173	**7300**	**6450**	1.15	269	**16400**	0.065	0.976	23.7	6.64	< 0.01	0.563	28.7
7/10/2010	< 0.5	154	**20400**	830	1.67	< 2.5	**9180**	< 0.050	0.843	6.71	1.13	< 0.01	0.751	11.0
7/16/2010	10.1	160	**8610**	681	1.27	337	**8000**	0.659	1.54	1.43	3.97	< 0.01	1.97	233
7/26/2010	-	-	-	**2600**	-	-	-	-	-	-	3.20	-	-	-
7/26/2010	-	-	-	740	-	-	-	-	-	-	4.30	-	-	-
7/26/2010	-	-	-	700	-	-	-	-	-	-	5.60	-	-	-

Table 7 - Total and WET Results for Treated ASR

SAMPLE DATE	Total							WET						
	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Ni (mg/kg)	Zn (mg/kg)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Pb (mg/L)	Hg (mg/L)	Ni (mg/L)	Zn (mg/L)
10/9/2010	18.9	82.3	**2740**	879	0.558	141	**8570**	0.233	1.33	7.21	2.64	< 0.01	0.839	45.6
10/9/2010	10.6	62.9	870	469	1.49	122	**5430**	< 0.1	0.697	8.49	1.17	< 0.01	0.742	5.62
10/21/2010	20.6	68.5	**3260**	997	1.24	182	**11900**	< 0.1	0.756	11.6	2.10	< 0.01	0.605	12.7
1/7/2011	7.12	84.8	240	400	0.702	92.8	**6300**	< 0.1	0.902	4.18	1.41	< 0.01	0.496	11.3
1/7/2011	21.7	88.0	2040	854	0.312	159	**9530**	0.056	1.13	14.4	2.11	< 0.02	0.575	8.59
1/8/2011	15.2	86.9	2190	742	0.617	159	**7730**	< 0.1	0.900	4.40	0.637	< 0.01	0.534	4.30
1/12/2011	-	-	-	630	-	-	-	-	-	-	11.0	-	-	-
1/12/2011	-	-	-	360	-	-	-	-	-	-	4.10	-	-	-
1/12/2011	-	-	-	360	-	-	-	-	-	-	28.0	-	-	-
4/9/2011	15.5	132	**7030**	731	1.11	108	**7750**	< 0.1	0.719	4.09	2.27	< 0.02	0.467	16.1
4/9/2011	16.0	104	1290	**1150**	1.55	188	**8380**	0.190	1.31	4.63	2.07	< 0.01	0.758	111
4/15/2011	50.3	91.4	412	957	0.578	138	**7650**	0.097	0.758	13.0	6.46	< 0.02	0.775	118
7/6/2011	-	-	-	1000	-	-	-	-	-	-	< 0.25	-	-	-
7/6/2011	-	-	-	1000	-	-	-	-	-	-	0.48	-	-	-
7/6/2011	-	-	-	**1100**	-	-	-	-	-	-	2.00	-	-	-
7/9/2011	7.72	496	**5670**	433	0.966	135	3630	< 0.1	0.606	7.57	1.58	< 0.01	0.554	7.29
7/15/2011	18.4	76.4	**17000**	**1400**	0.768	145	**8190**	< 0.1	1.00	6.47	1.30	< 0.02	0.435	3.97
7/23/2011	15.5	67.9	**6810**	711	1.25	153	**9370**	< 0.1	0.622	6.63	4.32	< 0.01	0.567	22.6
10/5/2011	7.88	41.7	750	449	0.252	51.3	3310	0.086	0.934	12.8	0.753	< 0.02	0.390	7.22
10/7/2011	8.33	43.3	368	665	0.474	140	**6090**	0.038	0.631	6.25	6.01	< 0.01	5.24	31.4
10/8/2011	12.7	66.2	**14800**	877	0.794	429	**9090**	< 0.1	0.821	5.18	1.07	< 0.01	0.514	6.15
1/20/2012	-	-	-	970	-	-	-	-	-	-	0.81	-	-	-
1/20/2012	-	-	-	**1100**	-	-	-	-	-	-	6.20	-	-	-
1/20/2012	-	-	-	920	-	-	-	-	-	-	0.54	-	-	-
# in Data Set	36	36	36	54	36	36	36	36	36	36	54	36	36	36
90% UCL Value	27.0	142.2	**8966**	**1499**	1.56	185	**10114**	0.137	1.035	9.55	12.2	< 0.02	1.22	69.2
TTLC / STLC	100	2500	2500	1000	20	2000	5000	1	*5 / 560	25	50	0.2	20	250

Notes: USEPA ProUCL Software Version 4.1.01 was used to calculate 90% UCL values. Non-detect values were included in UCL data sets, and distribution model recommended by program for 95% UCL was used for each set. The results shown in the purple cells are below the lab reporting limit. **Bold** values are in excess of standards.

* The STLC standard for Cr VI is 5 mg/l, whereas the Total or Cr III STLC for samples passing the TCLP test is 560 mg/l. NA=not applicable, highest ND value used instead.

The preceding Table 7 of total and WET Results for Treated ASR includes a minimum of 36 sample sets, for seven Total and WET-extractable metals, collected over a 3-year period. Eighteen additional Total and WET-extractable lead-only results from a California shredder during the same period were also included in the data set.

USEPA's ProUCL Software Version 4.1.01 was utilized to calculate the 90% Upper Confidence Limits (90% UCLs) for each metal in the sample data set (USEPA, 2011b). This statistical value is intended to represent the upper limit (with 90% confidence) of the true mean of any randomly drawn subsets of the data. Comparison of total concentrations of metals in the untreated ASR with extractable concentrations in the treated material clearly demonstrates the effectiveness of the ASR treatment process.

VIII. CONCLUSIONS

This report has been prepared at the request of the California Chapter of the Institute of Scrap Recycling Industries (ISRI) to objectively evaluate whether the auto shredder residue (ASR) treatment process currently employed at three California shredders effectively reduces the amount of extractable metals in ASR, such that treated ASR is suitable for disposal or beneficial use as Alternative Daily Cover in nonhazardous waste landfills. The ASR treatment process involves the use of soluble silicates in an aqueous solution, in combination with dry cement or another alkaline activator, which alters the chemical characteristics of leachable heavy metals in the ASR matrix. This treatment technology is known to the USEPA as *Stabilization*, and has been studied and shown to be effective on a wide range of constituents including heavy metals (USEPA, 2009).

Treatability studies by Dr. Trezek and others on the specific use of this technology for treatment of ASR began in the early 1980s, and concluded that the extractability of lead, cadmium, zinc and other heavy metals can be reduced by 90% to 99% with the use of this technology. These treatability study findings were submitted to DTSC and, on that basis, DTSC determined that treated ASR was eligible for reclassification on the grounds that it possesses mitigating physical and chemical characteristics that render it insignificant as a hazard to human health and the environment. The current review demonstrates that the earlier reclassification decision continues to be supported by analytical data related to the extractability of heavy metals (primarily lead, cadmium and zinc) in the waste before and after treatment.

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