

# THE USE OF MUNICIPAL WASTE COMBUSTOR ASH AS A PARTIAL REPLACEMENT OF AGGREGATE IN BITUMINOUS PAVING MATERIAL

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## ABSTRACT

Like many states, Minnesota does not yet allow the beneficial utilization of ash generated from the combustion of municipal solid waste in a municipal waste combustor (MWC). In an attempt to "turn the tide", officials from Polk County Minnesota proposed to demonstrate the economic, structural, and environmental performance of using MWC ash as a partial replacement of aggregate in bituminous for road construction.

The Polk County Solid Waste Department, located in northwest Minnesota, operates a 65-ton per day MWC that generates 12 tons per day of combined ash in the generation of energy. Due to the starved air-type combustion process employed by the Polk County facility, the combined ash consists of 98 to 99 percent bottom ash and 1 to 2 percent fly ash. The 1996 installation of an up-front materials recovery facility (MRF) resulted in the distinction of "old" ash that was generated before 1996, and "new" ash that was generated after 1996. Old ash and new ash have sufficiently distinct physical and chemical characteristics to warrant independent evaluation.

Approval was obtained from the Minnesota Pollution Control Agency (MPCA) to construct a demonstration project to evaluate the viability of replacing bituminous aggregate with MWC ash. In order to obtain MPCA approval, the potential for the demonstration project to impact the environment was evaluated. The MWC ash and bench-scale samples of ash amended bituminous were evaluated for total composition and leachability of inorganic constituents of concern as well as dioxins and furans. Concentrations were compared to EPA soil

screening levels, MPCA Soil Reference Values (SRVs) and Soil Leaching Values (SLVs), as well as EPA and Minnesota Department of Health drinking water standards. Environmental assessment showed that impacts were acceptable by federal and state standards.

Construction of a 2.25-mile section of road surface is scheduled for the spring of 2000. The road section is to be subdivided into:

- 0.75 miles with no ash, as a control,
- 0.75 miles with 20 percent replacement of the bituminous aggregate using new ash, and
- 0.75 miles with 40 percent replacement of the bituminous aggregate using old ash.

The above ash percentages were used by the Minnesota Department of Transportation (MnDOT) materials research laboratory in identifying successful bituminous mix designs. The non-uniform percentages of new and old ash (20 percent versus 40 percent) were due to density and physical performance characteristics only. The road section is to be constructed with a MnDOT Standard 2340 bituminous mix design. As part of construction, environmental monitoring devices will be installed to evaluate the potential impacts to surface water and groundwater. Results of this monitoring will be used to pursue MPCA and MnDOT approval for full-scale use of MWC ash for bituminous paving. In addition to potential environmental impacts, pavement structural performance and economic assessments will be made. This project has strong support from a variety of state and county agencies and associations.

## **INTRODUCTION**

Polk County, located in northwest Minnesota, participates in a complete integrated solid waste management program that includes four other counties in northwest Minnesota. One component of the integrated solid waste management program includes the operation of a municipal waste combustor (MWC) that combusts approximately 65 tons per day of processed solid waste. The starved air design causes low turbulence in the primary burning chamber minimizing particulate carryover through the system. This results in generation of approximately 12 tons per day of combined ash comprised of 98 to 99 percent bottom ash and 1 to 2 percent fly ash, by weight.

In 1996 the facility installed an up-front separation facility, or materials recovery facility (MRF), that removes recyclable materials as well as non-processible or objectionable materials prior to combustion. The MWC operates at an average temperature of 1450°F in the primary chamber and 1850°F in the secondary chamber. The energy produced is sold in the form of steam to adjacent businesses near the facility. The ash generated by combustion prior to the 1996 installation of the MRF is referred to as "old ash" and is landfilled in a MWC ash landfill permitted by the Minnesota Pollution Control Agency (MPCA). The ash generated since installation of the MRF is referred to as "new ash" which is also placed in the permitted landfill. The chemical and physical differences between the new and old ash are important enough to warrant the two ashes being addressed separately for purposes of a utilization demonstration project. The specifics of the chemical and physical characteristics are detailed later in this document.

Polk County intends to perform a pilot study to demonstrate the feasibility of utilizing combined MWC ash as a partial aggregate replacement in bituminous paving materials. The demonstration consists of building and monitoring a section of county road using the MWC ash-amended bituminous.

## **BACKGROUND**

It was identified by Kiser and Zannes (Kiser and Zannes, 1999) that in 1997, 103 MWCs were in operation in the United States, serving the disposal needs of more than 31 million people. These facilities generated about 2,800 MW of electricity from the combustion of 31 million tons of MSW. In the process, about 7 million tons of ash were produced. Most was used as landfill daily cover, as road bed, or was disposed of in landfills. Enabling the beneficial use of ash will assure the continued operation of MWCs, promote landfill abatement and decrease the

use of more valuable resources such as natural aggregates.

As described by Wiles (Wiles, 1999, pp. 39), the ash from MWCs is an excellent resource material that has proved to be of particular benefit in the construction of roads and highways. Field tests and demonstration projects show that processed ash can be successfully used in road base, bituminous paving, and concrete products. Substituting ash for rock aggregate in bituminous pavement, also called asphalt concrete, has proven to be a straightforward procedure in 14 field demonstrations. One thing is clear from the many field tests: asphalt pavement made from MWC ash lasts as long as conventional pavement and no environmental or health effects were reported. Ash pavements are safe and long lasting.

A selection of the most directly applicable projects are discussed below:

### **Albany, New York**

Bottom ash from the OGS Boiler Facility in Albany, New York, replaced gravel as the subbase for a parking lot constructed in 1983 at a waste shredding plant near the Rapp Road landfill. Twelve inches of bottom ash were placed on a geotextile filter membrane. The ash was covered with a 2½-inch wearing course of asphalt concrete. In this project, ferrous metal was recovered from the ash before use (at Polk County, ferrous metal is removed prior to combustion). Environmental testing in 1987 sampled groundwater and detected no heavy metals in the water. The parking lot was in good physical condition in June 1997 (Wiles, 1999, pp. 54).

### **Rochester, Massachusetts**

The SEMASS MWC facility developed an aggregate product called Boiler Aggregate™ from its bottom ash (McBath and Mahoney, 1993). The product grew from extensive development and field demonstrations in Albany, New York, and Rochester, Massachusetts. Field demonstrations took place over a period of about 12-13 years. On December 24, 1996, the Massachusetts Department of Environmental Protection issued a final beneficial use determination to Engineered Materials Company for use of SEMASS Boiler Aggregate™ in Massachusetts paving projects. The aggregate product is manufactured from MWC ash by removing ferrous metals and screening it to the desired particle size range. No other treatment occurs. It replaced 30% of conventional rock aggregate in a new asphalt concrete access road to the facility. The binder course was placed in January 1992 and the surface course followed in April of that year. A comprehensive risk assessment concluded that the

asphalt paving composition will not pose a significant risk to the environment or human health.

### Laconia, New Hampshire

Bottom ash from the Concord, New Hampshire, MWC replaced half of the natural aggregate in an asphalt paving binder course that was used to repave a section of U.S. Route 3 in Laconia, New Hampshire, during May 1993. Two years of intensive sampling and testing found no environmental or health risks (Eighmy, et.al., 1996).

### Concord, New Hampshire

Gress et.al., (1992) evaluated the performance of an asphaltic concrete replacing 25 percent of the aggregate with bottom ash from a mass-burn combustor in Concord, New Hampshire. The mix was paved, compacted, and broken up after a 7-day period with a backhoe into large pieces, typical of what might be expected to be dumped into a landfill as construction debris. The broken up pavement, ranging in size from small palm size to large 2- by 3-ft. plates, was put in a double-lined roll-off container. This system generates time-dependent data on the leachate properties of the 25 percent-ash-asphalt pavement mix. The leachate, originating from natural precipitation, was collected and analyzed for analytes. The resulting leachate met drinking water standards.

### Fugitive Dust Studies

**Mullen 1990:** Mullen (1990) reported the results of a study that characterized the dust generated from uncontrolled stockpiles of processed MWC bottom ash, and from road construction activities where the processed bottom ash was used as a road subbase and base course aggregate. Results of modeling and simulations demonstrated that dust generated from the construction activities using this bottom ash did not represent a significant source of exposure to heavy metals in the ash. Air quality dispersion models were performed to predict the potential for fugitive particulate emissions from storage and construction uses of Boiler Aggregate™ and their effects on ambient air quality. Results compared favorably with Massachusetts Allowable Ambient Levels (AALs).

**NREL:** In a recent National Renewable Energy Laboratory-sponsored study (NREL, 1997), the air was monitored to measure fugitive emissions associated with processing MWC bottom ash that involved conveying, screening, and ferrous metals removal. The processed ash was stockpiled before use in a paving demonstration, and monitored for fugitive dust emissions during static conditions (no human activity) and during repeated

turning by a front end loader to simulate repeated retrieval and replacement. Upwind and downwind emissions were monitored by high volume air samplers and personnel samplers were used to measure total suspended particulates (TSPs) and respirable particulates (PM<sub>10</sub>) during processing periods.

Results of this study show that:

- There were no measurable differences between the ambient air TSPs and trace metal concentrations upwind and downwind of the stockpile during static monitoring.
- The TSP concentrations measured in the ambient air near the stockpile were similar to the TSP concentrations reported at the other air monitoring stations in New Jersey and were below New Jersey's annual TSP criteria of 75 micrograms per cubic meter (µg/m<sup>3</sup>). The TSP concentration downwind of the bottom ash stockpile was 62 µg/m<sup>3</sup>.
- During ash processing, PM<sub>10</sub> concentrations, and TSP trace metal concentrations in the emissions were significantly below OSHA permissible exposure limits (PELs).
- During the stockpile turning events, PM<sub>10</sub> concentrations were one to two orders of magnitude, TSP concentrations at least two orders of magnitude, and TSP trace metal concentrations several orders of magnitude below OSHA PELs, respectively. This was the case even though there was visible dust observed and a measurable increase in the ambient PM<sub>10</sub>, TSP, and TSP trace metal concentrations. Scanning electron microscope analyses of TSP and PM<sub>10</sub> samples collected during stockpile turning indicated that the major fraction of TSP particulate matter was in the PM<sub>10</sub> size ranges (<10 microns, with 55% to 95% evenly distributed throughout the PM<sub>10</sub> range).
- Soil quality near the stockpile was not adversely affected. Soil samples collected had elemental concentrations comparable to other soils typically found in New Jersey.

### Worldwide

The United States boasts some success stories in ash utilization, but the European countries have led the way in the successful practice of using the benefits of ash in roadways. Germany uses 60 percent of WTE bottom ash as material for road paving and similar projects (Wiles,

1999, pp. 64). The Netherlands uses more than 90 percent of the bottom ash in road base and road embankments (Chandler, et.al., 1997). In 1994, France put about 45 percent of its bottom ash to beneficial use in civil engineering projects (Sinquin, et.al., 1997).

## OBJECTIVES

The objectives of the proposed pilot study are as follows:

- A. Evaluate the constructability of a road way using bituminous paving materials in which a portion of the aggregate has been replaced with MWC ash;
- B. Utilize the ash in a way that maximize the percentage of ash in the most cost effective way, while maintaining engineering integrity, and environmental acceptability;
- C. Evaluate the structural performance of the method of utilization;
- D. Evaluate the potential for environmental impact;
- E. Evaluate both old ash and new ash independently, which will improve the applicability of the demonstration project to other potential ash utilizers and will support rulemaking efforts and/or precedence for future ash utilizers for the State of Minnesota;
- F. Collect data that will support the evaluation of the method of utilization by the MPCA and the Minnesota Department of Transportation (MnDOT) for larger scale approvals. Data collection may include impacts to surface water, groundwater, adjacent soils, and air quality.

## DESIGN

### Roadway Design

Polk County will be constructing a 2.25-mile section of CSAH 11 in the summer of 2000. The design of the road section calls for a 5-inch thick bituminous base course 25 feet wide, overlain by a 2-inch thick bituminous binder course 24 feet wide, overlain by a 1.5-inch thick bituminous wear course 24 feet wide. Since this road section is already scheduled for construction, this provides an excellent opportunity to incorporate the demonstration project into the County's construction project.

Two bituminous trial mix designs were prepared by MnDOT's Northwest District Lab, located in Bemidji,

Minnesota. These trial mix designs demonstrate that both the Polk County MWC old ash, as well as the new ash, can produce a bituminous mix that meets MnDOT specifications for a standard 2350 Type 31 Mix Design. The MnDOT mix designs replace 40 percent of the traditional aggregate with old ash, and 20 percent of the traditional aggregate with new ash. The volume resulting from 40 percent replacement is less than 2 times the volume resulting from 20 percent replacement due to the density differences in the two ashes. The percentages of ash were set for engineering purposes only. The MnDOT District Lab Supervisor that oversaw the testing indicated that the reduced percentage of new ash was due to its lower density. The old ash will be mined from previously landfilled areas while the new ash will utilize current generation. Further details of this evaluation are provided later in this report. For this demonstration project, ash-amended bituminous will be utilized in the bituminous base course and the bituminous binder course. The bituminous wear course will not contain ash. The 2.25-mile road section will be constructed as follows:

- 0.75 miles with no ash, as a control section;
- 0.75 miles, replacing 20 percent of the aggregate with new ash in the bituminous base and binder courses for a total of 935 cubic yards of new ash;
- 0.75 miles, replacing 40 percent of the aggregate with old ash in the bituminous base and binder courses for a total of 1,495 cubic yards of old ash.

Standard bituminous production, placement equipment, and procedures will be used. The production, placement equipment, and procedures will be documented in a follow-up report for the road construction. Monitoring and evaluation of the project will be performed as described in the following sections.

The old ash and new ash have sufficiently distinct characteristics so that Polk County has evaluated, and will continue to evaluate, the two ashes independently. In addition, the bituminous material produced utilizes old ash and new ash independently. Independent evaluation of the two ash types will make the demonstration project results applicable to more MWC facilities within the State of Minnesota.

The ashes used in the bituminous will be combined ash (1-2% fly ash and 98-99% bottom ash). Combined ash provides the appropriate particle size gradation to meet the MnDOT mix design. In preparing the MnDOT trial mix design, the ash was screened to remove oversized (+ 3/4 inch) and deleterious materials. This removal of + 3/4 -inch material had the effect of slightly decreasing the ratio of bottom ash to fly ash.

### Ash Sampling Methodology

All ash samples for this project were collected with the objective of obtaining samples in a statistically representative manner. The Minnesota Combustor Ash Rules, Part 7035.2910, require a rigorous sample collection methodology. Combined ash samples are taken over an 8-hour shift period each of seven continuous days.

## **STRUCTURAL EVALUATION**

### Pre-Road Construction Bituminous Evaluation

Samples of old ash and new ash were submitted to the MnDOT Northwest District Bituminous Lab. The ashes were utilized to replace a portion of the aggregate in the development of two trial mix designs for a MnDOT 2350 plant mixed bituminous pavement material. A third (non-ash) aggregate was used from a MnDOT-approved source identified as J&S Pit (#63001) located in Marcoux, Minnesota and operated by Northern Paving. The non-ash bituminous serves as a control. The MnDOT lab was instructed to utilize as much old ash and new ash as possible in independent trial mixes while preparing a 2350 bituminous that meets all MnDOT specifications. After several iterations, the lab determined that acceptable 2350 designs could be prepared while replacing 20 percent of the aggregate with new ash, or by replacing 40 percent of the aggregate with old ash. These will be set as maximum percentages for the demonstration project.

### Post-Road Construction Bituminous Evaluation

Standard bituminous production quality control procedures will be implemented based on recommendations by the Polk County Highway Engineer and MnDOT specifications. This includes monitoring and testing of the mixture components and the bituminous production parameters.

Standard bituminous pavement performance evaluation procedures will be implemented based on recommendations by the Polk County Highway Engineer and MnDOT specifications. This includes monitoring and testing during pavement placement and ongoing evaluation of the bituminous roadway for five years after placement. It is anticipated that, after one full year of environmental and structural performance evaluation, sufficient data will be available to justify additional construction of ash-amended road sections.

## **ENVIRONMENTAL EVALUATION**

### Overview

Environmental assessment is performed to assess the potential for the ash-amended bituminous to adversely impact human health or the environment. Assessment addresses the potential impact of the demonstration project, as well as the potential impact of subsequent projects. Assessment tools are used to evaluate potential impacts to surface water, groundwater, air, and soil. These four media (surface water, groundwater, air, and soil) constitute the human exposure pathways of ingestion of drinking water or surface water, inhalation of particulates, and dermal contact and/or ingestion of soil (ash-amended products). Surface water, groundwater, air (particulates), and soil also constitute the expected potential ecological exposure pathways. The ash product flow diagram is provided as Figure 1.

A list of constituents of concern was identified for evaluation. This list includes inorganic metals, since they are known to occur in all ashes, and dioxins and furans, since they are known to occur in some MWC combustor ashes, including ash from the Polk County MWC.

Polk County, as well as all other MWC operators, has been evaluating MWC ash for many years. Organic constituents, other than dioxins and furans, have been shown to be insignificant (Wiles, 1999, Table 2.7b.).

### Basis of Risk-Based Assessment

**Introduction:** Performing an evaluation of environmental risks is a critical component of an ash utilization program. The most sophisticated risk assessment and modeling techniques relative to contaminants in the environment have developed within the Superfund programs of state and federal environmental protection agencies. Additionally, these programs have evolved procedures to set "threshold" limits for certain parameters based on "acceptable risk" criteria, or potential threat to benthic organisms.

The MPCA has developed a set of tools for comprehensively evaluating all risk pathways to all potential receptors, both human and environmental receptors. This document, currently in "working draft" form, as of October 1998, reflects the best available tool for evaluating whether ash incorporated into the matrix of bituminous may cause an unacceptable potential for environmental degradation.

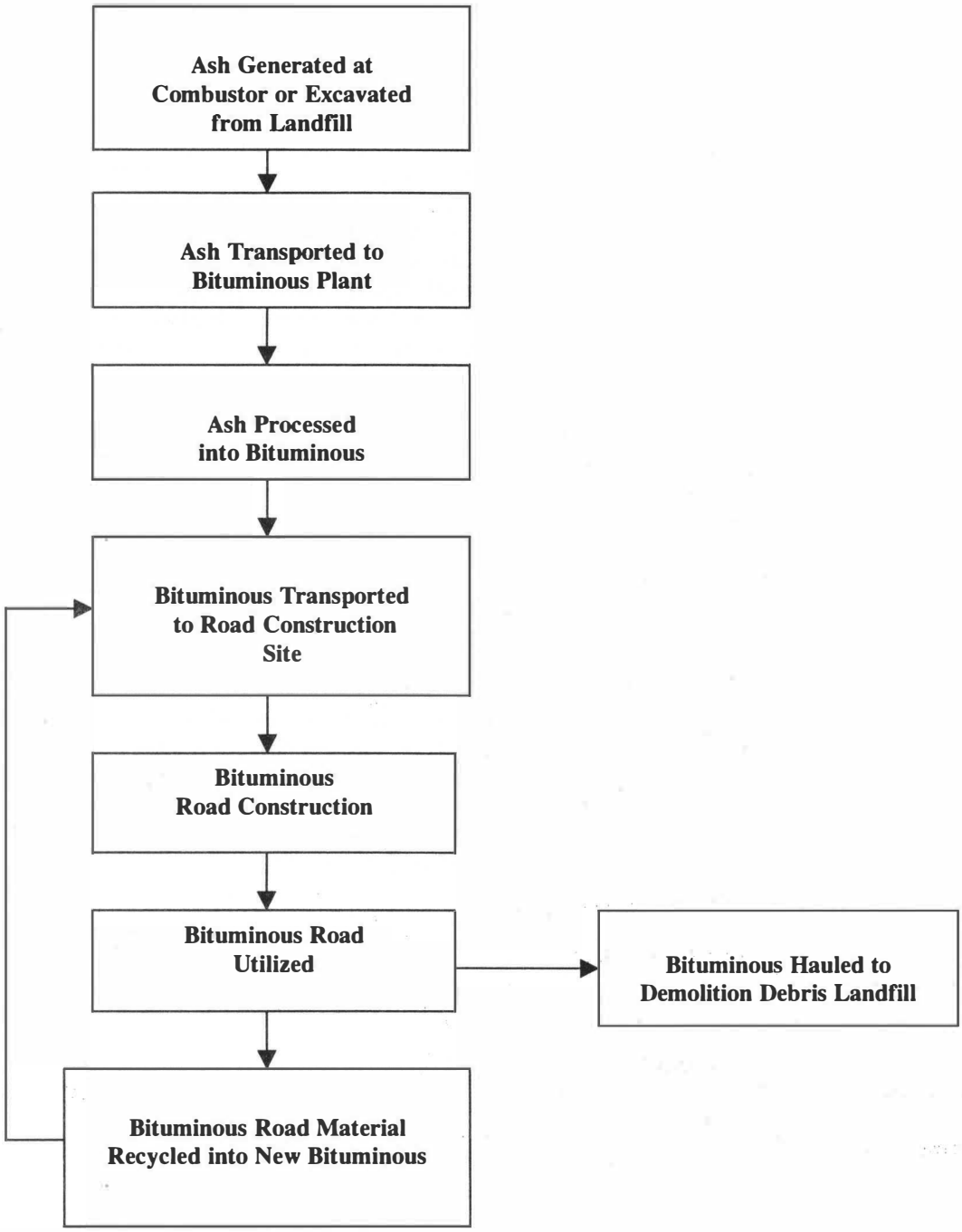


FIGURE 1  
ASH PRODUCT FLOW DIAGRAM

Constituent-specific concentrations, above which an unacceptable risk to human health is predicted to exist through direct exposure, are referred to as Soil Reference Values (SRVs). Additional criteria are also available to be protective of exposures that might be possible through the pathway of soil contamination leaching to groundwater. These criteria are known as the Soil Leaching Values (SLVs). The SRVs and SLVs have been derived by MPCA staff using standard risk assessment methodology, reference doses, modeling, and risk management policy.

In 1996 the EPA established soil screening levels (SSLs). In 1999, EPA Region 9 updated the SSLs as preliminary remediation goals (PRGs). The relevant MPCA SLVs and SRVs as well as the EPA PRGs are listed in Table 1.

**Soil Reference Value:** The risk-based assessment employs a tier-based approach to risk evaluation based on the concept of incorporating progressively more site-specific information as the evaluation proceeds upward through the tiers. A Tier 1 evaluation is a screening level characterization of the soil-human health exposure pathway. It is assumed at Tier 1 that limited site-specific information is available, or, as in this case, site conditions will vary based on the location of the utilization project. Consequently, conservative assumptions are applied to assess whether an unacceptable risk may be present. A Tier 1 risk characterization is generally accomplished by comparing maximum site soil constituent concentrations, or in this case, ash/bituminous concentrations, directly to the Tier 1 SRVs. The Tier 1 SRVs are based on the assumption that human exposure to the constituents of concern is long-term (chronic) and occurs in a residential site setting through a defined set of common exposure pathways. A residential exposure scenario is generally the most conservative human exposure scenario. This assumption is made because people typically spend a greater portion of their time living and sleeping in their homes than at their places of work or recreation. Therefore human exposure to any constituents of concern that may be present in a residential setting is proportionately greater. A Tier 2 risk assessment allows the input of greater site specific information. The resulting Tier 2 SRVs are then calculated. It is important to note that Tier 2 SRVs are not less protective than Tier 1 SRVs. They are simply adjusted for the realistic site specific exposure scenario.

Toxicity values are an important component of the risk-based assessment. There are a number of different sources of subthreshold toxicity values. When selecting toxicity information for use in quantitative risk assessment, the risk assessor should ensure that the

information is appropriate for the assessment being conducted and that it is up to date. The following is a list of sources of toxicity information used in developing the SRVs (Goeden and Jolley, 1999).

- Minnesota Department of Health (MDH) Toxicity Values,
- Integrated Risk Information System (IRIS),
- Health Effects Assessment Summary Tables (HEAST),
- National Center for Environmental Assessment (NCEA) Superfund Technical Support Center (STSC),
- Soil Screening Level Inhalation Benchmark Values,
- California Environmental Protection Agency (Cal/EPA),
- Agency for Toxic Substances Disease Registry (ATSDR),
- Calculation of a dose-response value using toxicity information from the literature.

The MPCA has developed Tier 2 SRVs for an industrial setting exposure scenario. These Tier 2 SRVs are utilized in this demonstration as detailed later.

**Soil Leaching Value:** Evaluation of the soil leaching pathway consists of an assessment of the risk posed to groundwater and associated receptors from a source of soil contamination, or ash-amended bituminous, in the unsaturated zone. Contaminant and generic soil (ash-amended bituminous) properties are used to predict concentration levels that are considered to represent an unacceptable risk to groundwater via the leaching pathway. These levels are referred to as Soil Leaching Values (SLVs) and are intended to serve as guidelines for making corrective action decisions. This evaluation was developed to provide cleanup criteria rather than utilization criteria. However, the method provides a means of assessing the potential for environmental impact for a given level of a constituent of concern. Therefore, the method provides valuable insight into the potential for groundwater impacts. This guidance utilizes a three-tiered approach that entails gathering progressively greater amounts of site specific information. Again, Tier 1 default SLVs assume no site specific data is available, resulting in default site conditions. The MPCA model allows the input of site specific data to calculate Tier 2 SLVs. As with the Tier 2 SRVs, Tier 2 SLVs are not less protective than Tier 1. They are simply adjusted for realistic site conditions. In fact, the realistic site conditions utilized in this Tier 2 evaluation actually resulted in some of the concentrations being lower and more restrictive than the Tier 1 concentrations. A Tier 2 SLV evaluation was performed, as detailed later.

**TABLE 1: MPCA AND EPA RISK BASED VALUES**

A	B	C	D	E	F
		MPCA Risk-Based Values			EPA
Parameter		MPCA Tier 2 SLV <sup>(a)</sup>	MPCA Residential SRV	MPCA Tier II Industrial SRV	Preliminary remediation goals <sup>(b)</sup>
Aluminum	ppm Al	na	26,000	100,000	100,000
Antimony	ppm Sb	30	14	100	750
Arsenic	ppm As	172	10	25	3
Barium	ppm Ba	11,500	1,200	12,500	100,000
Beryllium	ppm Be	880	55	290	3,400
Boron	ppm B	1,602	3,000	23,000	96,000
Cadmium	ppm Cd	1,892	35	250	930
Chromium III	ppm Cr III	> 1,000,000	34,300	100,000	450
Chromium VI	ppm Cr VI	157	19	425	64
Cobalt	ppm Co	331	2,000	13,000	29,000
Copper	ppm Cu	4,430	100	9,000	70,000
Iron	ppm Fe	NA	7,000	46,000	100,000
Lead	ppm Pb	5,775	400	700	1,000
Manganese	ppm Mn	NA	1,400	5,600	45,000
Mercury	ppm Hg	44	0.7 <sup>(c)</sup>	2 <sup>(c)</sup>	560
Molybdenum	ppm Mo	67	NA	NA	9,400
Nickel	ppm Ni	20,903	520	3,000	37,000
Selenium	ppm Se	8.2	170	1,250	9,400
Silver	ppm Ag	364	170	1,250	9,400
Strontium	ppm Sr	212,403	NA	NA	100,000
Thallium	ppm Tl	NA	3	21	150
Tin	ppm Sn	42,360	15,000	100,000	100,000
Vanadium	ppm V	5,502	210	1,340	13,000
Zinc	ppm Zn	116,660	8,700	70,000	100,000
2,3,7,8-TCDD equivalents	ppm	0.0205	0.0002	0.00035	0.00003

**NOTES:**

(a) Calculated using MPCA RBSE Model (version 11/99) with inputs representative of Polk County project.

(b) Developed as soil screening levels (SSLs) by EPA in 1996. These values were updated as preliminary remediation goals (PRGs) for industrial soils in 1999 by EPA Region 9.

(c) mercury as inorganic (elemental and mercuric chloride)



### **Human and Ecological Exposure Evaluation**

A critical component in human and ecological exposure evaluation is the specific conditions of exposure. That is, exactly how is the material exposed to the potential receptors? Upon review of Figure 1, the exposure potential, and health risk evaluation, at each stage of the demonstration are as follows (the following seven steps are synchronized with Figure 1).

**Ash Generated at the Combustor or Excavated from the Landfill:** The operation of the combustor and the landfill are currently ongoing, approved, and permitted operations. Increased handling of ash over current conditions may include pre-screening of oversized or unacceptable particles. The MPCA Industrial SRVs represent human health risk based site evaluation values for industrial sites, therefore, the Industrial SRVs are the applicable standards for this project. As shown in columns C, D, E, and F of Table 2, the old ash exceeds the Industrial SRV (in Table 1) for iron while the new ash exceeds the Industrial SRV for lead and 2,3,7,8-TCDD equivalents. Therefore, facility personnel will implement necessary personal safety protection procedures.

At this stage in the ash utilization process, there is no increased exposure to the general public or the environment since the facility is not open to the public and the operation is performed within the approved ash management system. In addition, the ash is at 40 to 50 percent moisture. Therefore, the potential generation of dust for inhalation is very low. However, for purposes of the demonstration project, fugitive dust monitoring will be performed, as detailed later.

Leaching, or runoff, are not concerns since all activities, at this stage, are within the landfill containment system.

**Ash Transported to Bituminous Plant:** As required by Minnesota Rule Part 7035.0800, ash will be transported in containers or trucks that are covered to prevent fugitive dust emissions and constructed to prevent leaking. In addition, the high moisture content of the ash results in little or no potential for fugitive dust. Therefore, there is little or no increased exposure to the general public or the environment.

**Ash Processed into Bituminous:** The ash will be processed into bituminous at a hot mix asphalt (HMA) batch plant. This is clearly an industrial setting. The MPCA risk-based assessment process includes SRVs for industrial settings. The MPCA defines industrial property use as follows:

*“... use of property for industrial purposes. MPCA may consider property use to be considered “industrial” for risk characterization where property use will not allow public access to areas where residual contamination may be present in soil. In risk evaluation scenarios, potential occupational exposure assumptions are used in the calculation of cleanup levels. Industrial property uses generally include, but are not limited to, the following: public utility services, rail and freight services, raw storage facilities, refined material storage facilities, and manufacturing facilities engaged in the mechanical or chemical transformation of materials or substances into new products.” (MPCA, 1998)*

Utilizing the Industrial SRVs in this case is highly conservative, since the SRVs are intended to be used for contaminated soil that may be exposed to employees in the environment. However, the ash is to be handled as an aggregate in a HMA plant. The normal bituminous production process includes dust collection equipment at locations where the aggregate or ash will be dried. These dust collection units will significantly reduce the potential exposure of workers to dust that may contain constituents of concern.

Exposure to constituents of concern in the HMA plant is an OSHA issue. Upon conferring with a certified industrial hygienist at the Minnesota OSHA Consultation Office, OSHA issues are summarized as follows. The characteristics of the MSW ash asphalt and assumptions include the following:

- The composition of the ash is 98 to 99 percent bottom ash (granular material) and the remainder is fly ash.
- Laboratory analysis of the ash indicates trace heavy metals.
- Dioxins on the order of less than 2 parts per billion (ppb) were found in the ash.
- The composition of the MWC ash is relatively constant with respect to metals and dioxin content. If not, a worst-case concentration will be determined and measured to ensure that coinciding exposure limits are not exceeded.

Based on this information, the primary exposure concerns involved in handling this material revolve around inhalation of particulate matter. In general, exposures to heavy metals should not be a concern because of their relatively low concentrations. If necessary, this assumption can be confirmed by collecting personal air

samples of workers involved in the MWC ash handling operations and analyzing them for these specific contaminants (metals scan) and total dust.

Similarly, dioxin exposure should be negligible because of the minute quantities found in the subject materials.

Once the HMA plant is chosen, the site will be reviewed prior to work activities and during initial startup to ensure the above rationale strategy is appropriate.

For purposes of the demonstration project, stack testing will be performed for particulate generation. Stack testing will be performed during production of bituminous with and without ash. This is further detailed later.

To preclude a concern with leaching or runoff from ash at the HMA plant, ash will only be transported to the plant in quantities that can be protected from the environment or processed into bituminous within 24 hours.

#### **Bituminous Transported to Road Construction Site:**

Once the ash is incorporated into bituminous, the contaminants are very effectively encapsulated and absorbed by the highly organic asphaltic matrix as demonstrated in Tables 1 and 2. A review of columns E, G, H, I, J and K of Table 2, indicate that the ash-amended bituminous meets all of the parameters identified for the MPCA Industrial SRVs. Ash-amended bituminous is not intended to be used on residential streets, therefore, use of the Residential SRVs is not appropriate.

Leachability is not a concern during transportation in a sealed vehicle.

**Bituminous Road Construction:** It is appropriate to classify the bituminous road construction site as an industrial setting. In fact, even an industrial setting classification would be highly conservative since the construction project is very temporary. The same discussion provided above is appropriate here.

**Bituminous Road Utilized:** The actual utilization of the bituminous road is the one scenario that has the potential to approach a residential exposure scenario, since homes may be adjacent to the roadway, and exposure may occur for many years.

However, once the bituminous road is constructed, the ash-amended bituminous will be overlain by a wear course of traditional non-ash bituminous, which provides an additional layer of encapsulation. This results in the public being only exposed to the traditional bituminous, as long as the wear course layer remains intact.

However, if the wear course layer deteriorates significantly, the underlying ash-amended bituminous may become exposed. This would be a limited exposure until the wear course layer was repaired. The limited exposure and the compliance with almost all of the Residential SRVs (Column D of Table 1) indicate that there is very little health risk. Since this stage of utilization is the most long-lived, a cumulative health risk was also evaluated and is described in the next section. The hypothetical situation of a significantly deteriorated bituminous layer was incorporated into the Tier 2 SLV calculation, as detailed later.

#### **Bituminous Road Material Recycled into New**

**Bituminous:** When a bituminous road surface deteriorates to the point of needing repair, there are three options available. If the deterioration is localized, the deterioration may be patched. However, if the deterioration is significant and generalized, the entire wear course may need to be repaired. This is performed by installation of an overlay course. According to the Polk County Highway Department, bituminous road surfaces in the county typically last 15 to 20 years before an overlay is required (Polk County, 1999). An overlay in turn lasts about 7 years. Standard practice at Polk County is to place about three overlays before an entire road surface has to be removed and replaced. This removal and replacement may include recycling the deteriorated bituminous. However, removal and replacement does not typically occur for 35 to 40 years after initial construction. Rather than deferring an evaluation of recycleability for 35 years, 350 feet of ash-amended road section will be constructed at the Polk County landfill site. After a period of about 3 years, this pavement will be evaluated for recycleability.

It is anticipated that the ash-amended bituminous would be reused by cold in-place recycling. This should not be a concern, since the worst case scenario would have the road rebuilt with similar ash-amended bituminous.

#### **Leachability of Metals**

The leachability of metals from the ash-amended and unamended bituminous was evaluated with two different methods: 1) the MPCA Risk Based Evaluation of the Soil Leaching Pathway (to determine Tier 2 SLVs), and 2) direct leaching of the material. Tables 1 and 2 provide a comparison to the Tier 2 SLVs and Table 3 shows the leachability of the ash-amended bituminous. These results include an important level of conservatism. That is, since the bituminous sample was mechanically broken down to less than 3/8-inch particle size for leaching, this would represent a highly deteriorated road base course and binder course. As previously discussed, a bituminous

TABLE 2: POLK COUNTY ASH/ASPHALT ANALYSIS (UPDATED APRIL 4, 2000)

A Parameter	B	C		D		E		F Ash in exceedance of Industrial SRV <sup>(b)</sup>	G		H		I Asphalt (total composition, average of 3 samples) w/new ash	J Fraction asphalt is of Industrial SRV <sup>(d)</sup>	K Asphalt exceeds Tier 2 SLV <sup>(b)</sup>
		1998 Avg. <sup>(a)</sup>	1999 Avg. <sup>(a)</sup>	Combined Ash (Total Composition) old ash: average of 3 samples	1998 Avg. <sup>(a)</sup>	1999 Avg. <sup>(a)</sup>	Asphalt Virgin <sup>(c)</sup>		Asphalt Virgin <sup>(c)</sup>	w/new ash	w/old ash				
Aluminum	ppm Al	35,200	---	---	---	2,130	11,567	12433	0.12	---	---	---	---	---	---
Antimony	ppm Sb	na	11.9	16.8	---	<0.8 <sup>(e)</sup>	2.38 <sup>(f)</sup>	6.72 <sup>(g)</sup>	0.09	---	---	---	---	---	---
Arsenic	ppm As	7.53	---	---	---	3.3	7.8	10	0.39	---	---	---	---	---	---
Barium	ppm Ba	270	---	---	---	21	127	130	0.01	---	---	---	---	---	---
Beryllium	ppm Be	na	<6.54	<4.0	---	<3.8	<3.5	<3.9	0.01	---	---	---	---	---	---
Boron	ppm B	119	---	---	---	19	53	86	0.004	---	---	---	---	---	---
Cadmium	ppm Cd	25.7	---	---	---	1.2	6.6	12	0.05	---	---	---	---	---	---
Chromium III <sup>(h)</sup>	ppm Cr III	36.8	---	---	---	8.9	22	29	0.0003	---	---	---	---	---	---
Chromium VI <sup>(h)</sup>	ppm Cr VI	---	(h)	(h)	---	(h)	(h)	(h)	---	---	---	---	---	---	---
Cobalt	ppm Co	na	6.38	10.3	---	4.1	6.0	7.8	0.001	---	---	---	---	---	---
Copper	ppm Cu	1,990	---	---	---	997	887	4054	0.45	---	---	---	---	---	---
Iron	ppm Fe	na	---	54,767	---	7,180	15,500	37100	0.81	---	---	---	---	---	---
Lead	ppm Pb	1,030	---	---	---	20	168	300	0.43	---	---	---	---	---	---
Manganese	ppm Mn	342	---	---	---	215	306	556	0.10	---	---	---	---	---	---
Mercury	ppm Hg	0.212 <sup>(i)</sup>	---	---	---	0.12	0.25	0.23	0.12	---	---	---	---	---	---
Molybdenum	ppm Mo	na	6.14	16.7	---	4.8	6.7	6.6	NA	---	---	---	---	---	---
Nickel	ppm Ni	<396 <sup>(j)</sup>	61	92.6	---	53	22	50	0.02	---	---	---	---	---	---
Selenium	ppm Se	<1.49 <sup>(k)</sup>	---	---	---	<1.6 <sup>(e)</sup>	<1.6 <sup>(e)</sup>	<1.6 <sup>(e)</sup>	0.001	---	---	---	---	---	---
Silver	ppm Ag	4.78	---	---	---	0.58	1.21	1.61	0.001	---	---	---	---	---	---
Strontium	ppm Sr	---	93	66	---	40	60	67	NA	---	---	---	---	---	---
Thallium	ppm Tl	---	0.6	<0.8 <sup>(l)</sup>	---	<0.4 <sup>(e)</sup>	<0.36 <sup>(e)</sup>	<0.41 <sup>(e)</sup>	0.02	---	---	---	---	---	---
Tin	ppm Sn	<354 <sup>(l)</sup>	---	---	---	<3.9 <sup>(e)</sup>	24	58	0.001	---	---	---	---	---	---
Vanadium	ppm V	na	9.73	11.0	---	8.0	13	15	0.01	---	---	---	---	---	---
Zinc	ppm Zn	3,830	---	---	---	153	772	1057	0.02	---	---	---	---	---	---
2,3,7,8-TCDD equiv	ppm	---	0.001647 <sup>(l)</sup>	0.000205 <sup>(m)</sup>	---	---	0.000329 <sup>(n)</sup>	0.000082 <sup>(o)</sup>	0.94	---	---	---	---	---	---

(a) Average of 6 samples collected during each annual ash sampling event. This is new ash. (b) O = old ash exceeds ; N = new ash exceeds ; V = Virgin (i.e. non-ash) material exceeds. (c) Virgin asphalt is asphalt produced using traditional aggregate and no ash. (d) Using greatest value between old ash and new ash. (e) All values were below MDL. (f) Conservatively calculated by multiplying average antimony concentration in new ash by 0.2, since bituminous will contain 20% new ash. (g) Conservatively calculated by multiplying average antimony concentration in old ash by 0.4, since bituminous will contain 40% old ash. (h) Due to highly reduced nature of ash, chromium is very unlikely to be in (VI) form. Most likely in (III) form. (i) Total mercury. (j) Average of 6 data points, with all data points below MDL. (k) Average of 6 data points, with 5 of 6 data points below MDL. (l) Average of 2 samples collected during 1997 (@1.915 ug/Kg) and 2 collected during 1999 (@1.379 ug/Kg) annual ash sampling events. (m) Average of samples analyzed annually from 1991 - 1995. (n) Calculated by multiplying the concentration in ash by 0.2, since the bituminous contains 20% new ash. (o) Calculated by multiplying the concentration in ash by 0.4, since the bituminous contains 40% old ash.

road with such an extreme level of deterioration is very unlikely, especially since it is overlain by an unamended wear course.

**Soil Leaching Value:** The Tier 2 SLV calculation is only intended to address this specific demonstration project. Actual field data will be collected to address subsequent utilization opportunities. Tier 2 SLVs were developed by utilizing the MPCA Soil Leaching Value spreadsheet (updated November 1999). Detailed and site-specific inputs were developed based on reasonable yet conservative conditions expected to be found at the project site. An example of conservatism includes the values of total soil porosity and estimated infiltration rate of the bituminous layer that were input. The inputs used are typical of a "clean sand" which is defined by the MPCA model as having a total porosity of 0.41 and an infiltration rate of 17 cm/hr. This simulates a highly degraded bituminous layer. In addition, the project site location in Polk County is characterized by aquifer conditions of very low hydraulic conductivity and gradient. These conditions and others resulted in a model dilution attenuation factor (DAF) of 1.0. The Tier 1 SLVs are calculated with a DAF of 10. These are some of the inputs that make this Tier 2 evaluation very conservative.

As shown in Columns G, H, I, and K of Table 2, all metals are below the Tier 2 SLVs. Therefore, this modeling exercise is intended to suggest that, if the material were placed into the environment, with direct opportunity for leaching into the groundwater, the drinking water standards for parameters evaluated would not be exceeded. In addition, a very low permeability bituminous wear course is placed over the ash-amended bituminous. Furthermore, bituminous pavement surfaces are sloped to shed water directly off the surface. Therefore, the potential for groundwater impact is very low or non-existent.

Note that the bituminous produced without ash, using only traditional aggregate, contains similar or comparable concentrations of constituents of concern. This is the case for beryllium, cobalt, copper, manganese, mercury, molybdenum, nickel, selenium, strontium, and thallium. The bituminous produced without ash is higher in nickel than the bituminous with ash.

**Synthetic Precipitation Leachability:** The second method used to evaluate the leachability of the ash-amended bituminous, is direct leaching with the Synthetic Precipitation Leaching Procedure (EPA Method 1312). In this procedure the bituminous is mechanically reduced to particle size less than 3/8 inch in diameter. The

material is rigorously agitated for 18 hours in a nitric and sulfuric acid solvent designed to simulate the effects of acid precipitation.

As shown in Table 3, the bituminous produced with old ash and with new ash exceeds the Minnesota Department of Health, Health Risk Limit (HRL) for antimony. In addition, due to the extremely low HRL for beryllium (0.00008 ppm), the laboratory method detection limit (MDL) was above this value for the ash-amended and traditional bituminous. The bituminous produced without ash exceeds the HRL for lead. All of the other constituents of concern leached at concentrations at or below the HRL. It is important to note the significance of this evaluation. What this means is that, if the ash-amended bituminous were ground up to less than 3/8-inch particle size, directly introduced into an acidified, stagnant (non-replenished) water source (at a ratio of 50 grams of solid per liter of liquid), and continuously agitated for 18 hours, then some of that water would not meet the MDH drinking water standard for only one metal, antimony. Clearly, the likelihood of this scenario to occur is very remote.

#### **Dioxins (PCDDs) and Furans (PCDFS)**

**Background:** Dioxins and furans are common throughout the environment. They are unintentionally created in two major ways: 1) by the processes used to manufacture some products, for example, certain pesticides, preservatives, disinfectants, and paper products; and 2) when materials are burned at low temperatures, for example, certain chemical products, leaded gasoline, plastic, paper and wood.

A study by the New York State Energy Research and Development Authority (NYSERDA) concentrated on PCDDs and PCDFs because of their reported toxicity (Koppleman and Tannenbaum, 1993). These compounds, particularly 2,3,7,8-TCDD equivalent and 2,3,7,8-TCDF equivalent had received the most attention with respect to the organic compounds present in combustion residues. Based on an extensive review of the literature available at that time, the Long Island Regional Planning Board (LIRPB) and NYSERDA concluded that, although other trace organic contaminants had been detected at higher concentrations than these compounds, it was highly unlikely that any of them would pose potential health hazards during beneficial use of the ash. The study did, however, pay special attention to chlorinated benzenes and chlorinated phenols because their presence in the ash could result in the formation of dioxins and furans during any applications requiring heat. Although trace amounts of these compounds were detected (appreciably higher in

**TABLE 3: POLK COUNTY ASH/ASPHALT LEACHABILITY VS. REGULATORY LIMITS**

A		B	C	D	E	F	G	H
Parameter		HRL or HRL equivalent (lowest value) <sup>(a)</sup>	MCL	Asphalt (SPLP)			Asphalt exceeds HRL or MCL <sup>(c)</sup>	
				Virgin: average of 3 samples <sup>(b)</sup>	w/new ash: average of 3 samples	w/old ash: average of 3 samples		
Aluminum	ppm Al	na	na	0.12	0.17	0.17	---	
Antimony	ppm Sb	0.006	0.006	<0.002 <sup>(d)</sup>	0.010	0.030	N, O	
Arsenic	ppm As	na	0.05	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	---	
Barium	ppm Ba	2	2	0.4	0.3	0.3	---	
Beryllium	ppm Be	0.00008	0.004	<0.0003	<0.0002 <sup>(d)</sup>	<0.0002 <sup>(d)</sup>	V,N,O	
Boron	ppm B	0.6	na	0.40	0.25	0.33	---	
Cadmium	ppm Cd	0.004	0.005	0.0002	0.0006	0.0011	---	
Chromium III <sup>(e)</sup>	ppm Cr III	20	na	0.0097	0.0184	0.0138	---	
Chromium VI <sup>(e)</sup>	ppm Cr VI	0.1	0.1 <sup>(f)</sup>					
Cobalt	ppm Co	0.030	na	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	---	
Copper	ppm Cu	1.0	1.3	0.008	0.012	0.013	---	
Iron	ppm Fe	na	na	na	na	na	---	
Lead	ppm Pb	0.015	0.050	0.021	0.005	0.006	V	
Manganese	ppm Mn	0.1	na	<0.05 <sup>(d)</sup>	<0.05 <sup>(d)</sup>	<0.05 <sup>(d)</sup>	---	
Mercury	ppm Hg	na	0.002	<0.0002 <sup>(d)</sup>	<0.0002 <sup>(d)</sup>	<0.0002 <sup>(d)</sup>	---	
Molybdenum	ppm Mo	0.03	na	0.005	0.008	0.006	---	
Nickel	ppm Ni	0.01	0.01	0.010	0.010	0.011	---	
Selenium	ppm Se	0.03	0.05	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	---	
Silver	ppm Ag	0.03	na	0.0005	0.0007	0.0008	---	
Strontium	ppm Sr	4.0	na	<0.1 <sup>(d)</sup>	<0.1 <sup>(d)</sup>	<0.1 <sup>(d)</sup>	---	
Thallium	ppm Tl	0.0006	na	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	---	
Tin	ppm Sn	4	na	<0.05 <sup>(d)</sup>	<0.05 <sup>(d)</sup>	<0.05 <sup>(d)</sup>	---	
Vanadium	ppm V	0.05	na	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	<0.002 <sup>(d)</sup>	---	
Zinc	ppm Zn	2	na	0.233	0.267	0.23	---	

**NOTES:**

HRL is the Minnesota's Department of Health Health Risk Limit (state drinking water standard)

MCL is the EPA's Maximum Contaminant Limit (federal drinking water standard)

(a) HRL equivalent includes the lowest of the HRL, MDH Health Based Value, or EPA Action Level.

(b) virgin asphalt is asphalt produced using traditional aggregate and no ash.

(c) O = old ash exceeds ; N = new ash exceeds ; V = Virgin (i.e. non-ash) material exceeds.

(d) all values were below MDL.

(e) due to highly reduced nature of ash, chromium is very unlikely to be in (VI) form. Most likely in (III) form.

(f) standard is for total chromium.

the fly ash than in the bottom and combined fractions), the investigators concluded that it would be very unlikely that any PCDD/PCDF concentrations in the ash would be increased by the conversion of chlorinated benzenes and chlorinated phenols to PCDF or PCDD. This is consistent with earlier studies, and with the observed low yields of PCDDs and PCDFs (usually less than 1%) from the combustion or pyrolysis of chlorinated benzenes and chlorinated phenols.

The report concluded that it was very unlikely that dioxins or furans in the bottom ash will be a concern when assessing the environmental or health consequences of ash use. The report did, however, caution that a beneficial use application that resulted in exposing workers to high levels of fugitive dust could be of some concern, because the PCDDs and PCDFs are more likely concentrated in the finer particle size fractions.

Leaching studies were not conducted. They were judged not to be warranted based on the low levels of PCDDs and PCDFs found in the ashes compared to other leaching studies of ashes containing much higher initial levels of these compounds. Such studies had shown that leachates from the ashes had extremely low levels of these compounds (Wiles, 1999, pp. 83-84). Many other studies have demonstrated that PCDDs and PCDFs have extremely low aqueous solubilities, and partition to solid phases.

**Polk County Ash Dioxins and Furans:** The 1997 and 1999 Polk County ash sampling and collection events resulted in rigorously representative samples of combined ash. These were each duplicate samples composed of a 7-day and 4-quarter composite. The average of the two 1997 samples contained 1.379 ug/Kg of 2,3,7,8-TCDD equivalent while the average of the two 1999 samples contained 1.915 ug/Kg of 2,3,7,8-TCDD equivalent. This results in a 1997/1999 average of 1.647 ug/Kg for 2,3,7,8-TCDD equivalent.

The average of the "old" ash samples (1991 through 1995) is 0.205 ug/Kg. Analysis for 2,3,7,8-TCDD equivalent is only required once per two years, therefore, there are no 1996 or 1998 values.

The new ash was amended to the bituminous mix at a 20 percent aggregate replacement. Therefore, the 2,3,7,8-TCDD equivalent value was multiplied by 0.2, for a concentration in the bituminous, due to ash, of 0.329 ug/Kg. Similarly, the old ash was amended to the bituminous mix at a 40 percent aggregate replacement rate. This resulted in a 2,3,7,8-TCDD equivalent

concentration of 0.082 ug/kg in the bituminous produced with old ash.

Polk County ash-amended bituminous is estimated to have a final concentration of 0.082 ug/Kg in the bituminous with old ash and 0.329 ug/Kg in the bituminous with new ash. The MPCA Industrial SRV for 2,3,7,8-TCDD equivalent is 0.35 ug/Kg. The contaminant, 2,3,7,8-TCDD, is one of several dozen isomers of dioxins. However, it is the most toxic and has been designated with a toxicity equivalent factor (TEF) of 1. 2,3,7,8-TCDD equivalent is a calculation that multiplies the concentration of all of the dioxin and furans by their associated TEF. The industrial site standard for this contaminant is not exceeded in the bituminous with new ash or with old ash. In addition, there is very limited exposure potential to the ash-amended bituminous since it is not used in the pavement wear course. The final estimated concentration of 2,3,7,8-TCDD equivalent in the bituminous is also below the Centers for Disease Control (CDC) recommended limit of 1 ug/Kg for residential soils.

**Cumulative Effects:** Long-term cumulative effects were evaluated by performing the MPCA Tier 2 Industrial Scenario Risk Evaluation (1999 Version). This model is based on a limited multiple pathway scenario that evaluates risk to non-cancer endpoints, whole body, as well as excessive lifetime cancer risk.

The model was run by incorporating the contaminant concentrations found in bituminous that had been amended with old ash at a 40 percent aggregate replacement and a bituminous that had been amended with new ash at a 20 percent aggregate replacement. The 2,3,7,8-TCDD equivalent was also included in this cumulative assessment.

The model output resulted in a cumulative site excess lifetime cancer risk (ELCR) for all contaminants of  $6.42 \times 10^{-6}$  for old ash, and  $1.26 \times 10^{-5}$  for new ash. The MPCA recommended criteria for an industrial exposure is  $1.0 \times 10^{-5}$ . Therefore, if the ash-amended bituminous were utilized as a wear-course (which it is not), where long-term exposure were a potential, the material would be below, for old ash, and 26 percent above, for new ash, the chronic cumulative limits. This exceedance of MPCA-recommended limit is primarily driven by the concentration of 2,3,7,8-TCDD equivalent. The CDC recommended limit for this constituent in residential soils is three times higher than the MPCA industrial criteria. Since the ash-amended bituminous is not utilized as a wear course, cumulative exposure concerns are minimal.

In addition, the model also provides for a site hazard quotient and cumulative hazard index for non-cancer target end points. None of the recommended levels were exceeded.

### **Ecological Assessment:**

**Overview:** Ecological receptors may be exposed to soil contaminants through dermal (or root) contact, by incidental ingestion of soil particles, by eating plants or soil invertebrates contaminated via bioaccumulation from soil, or by inhalation of soil vapors/particles. Direct soil contact benchmark values were derived for terrestrial plants, soil invertebrates, and soil microorganisms because these organisms represent important components of terrestrial ecosystems. If soil contaminant concentrations are below identified levels for these receptors, it is reasonable to expect that impacts from direct soil exposure will be minimal for other receptors. Ecological Soil Screening criteria, developed by the MPCA Voluntary Investigation and Cleanup Program for the risk-based evaluation process, apply to the uppermost 4 feet of soil.

Soil contaminants can also bioaccumulate in plants and soil invertebrates, and be passed to higher animals that feed on them (food chain exposure). Because this can be an important exposure route for certain chemicals, such as mercury and PCBs, screening criteria were also developed for bioaccumulative contaminants for the food chain pathway.

Note that the ecological soil screening criteria do not address inhalation exposure, so in some cases they may not be adequately protective for exposure to volatile contaminants. However, volatile contaminants from the proposed ash-amended bituminous are not expected to exceed those from unamended bituminous.

**Assessment:** As stated in the MPCA Site Characterization and Sampling Guidance (MPCA, 1998), "In general, ecological soil screening criteria are to be applied in areas that provide wildlife habitat (i.e., vegetated areas such as grassy, brushy, or wooded areas) or may do so in the future. Areas that are, or will be, covered with impervious materials (e.g., pavement) do not need the application of ecological soil screening criteria". Therefore, according to MPCA guidelines, the proposed ash-amended bituminous products do not pose an ecological risk and no further evaluation is needed.

### **Post-Demonstration Project Evaluation**

Pre-demonstration project data, as discussed in this paper, provides significant information on the potential impacts

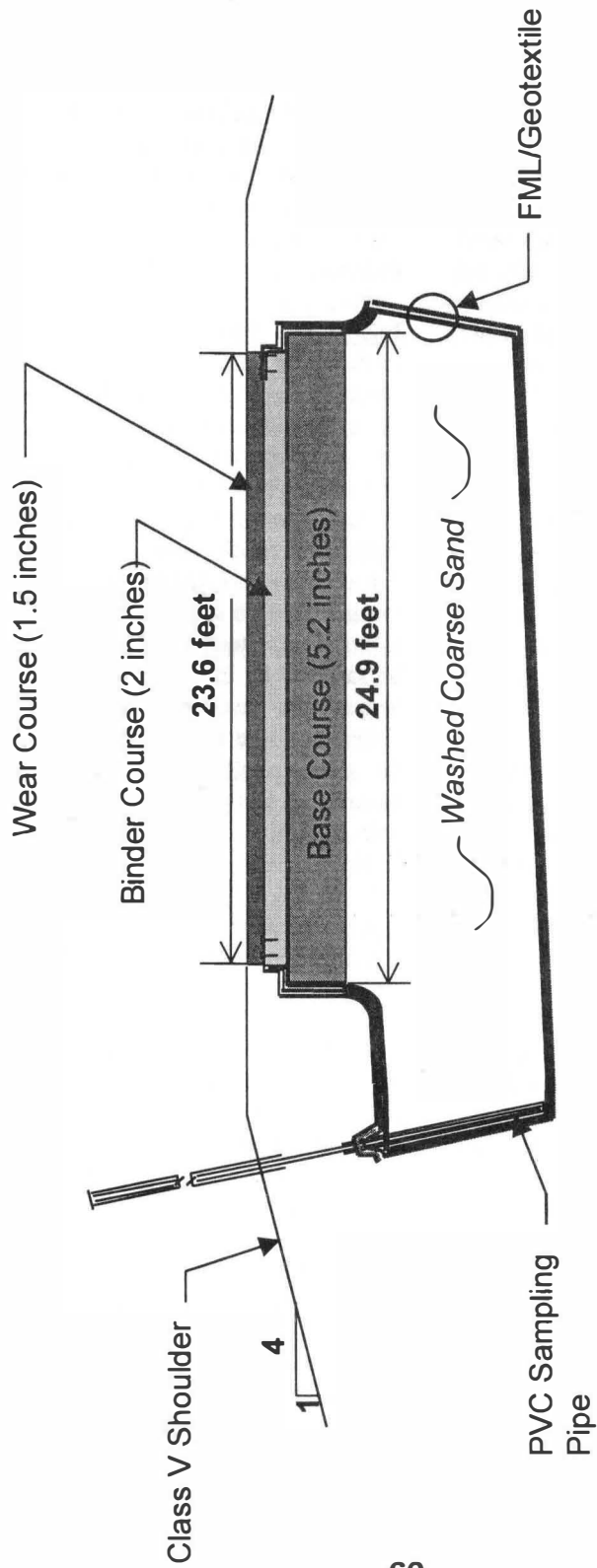
of the ash-amended bituminous. However, the demonstration project will also be monitored to further assess the potential for impact to human health or the environment. As previously stated, this is accomplished by further consideration of potential impacts to surface water, groundwater, adjacent soils, and air quality.

**Surface Water:** The potential for the proposed method of utilization to impact surface water has been thoroughly considered. Since the bituminous wearing course will not contain ash, surface water that contacts this surface does not have the potential to be impacted by ash. Consequently, surface water that contacts and runs off the wearing course does not have the potential to impact the environment. Therefore, surface water from the demonstration project will not be monitored.

**Infiltration Water:** The potential for the proposed method of utilization to impact groundwater was considered. This resulted in the conclusion that a field evaluation of infiltration water should be performed. Infiltration water is defined as water that migrates through the non-ash wear course and contacts or migrates through one of the underlying ash-amended bituminous layers. This infiltration water could continue to migrate vertically toward groundwater, or it could move laterally toward the road edge, thus contributing to surface water. Infiltration water from both of these potential paths will be sampled by installing collection and sampling devices beneath the pavement. Separate collection and sampling systems will be installed to collect samples from each of the three road sections (control section without ash, bituminous section with new ash, and bituminous section with old ash). The details of this collection device are shown in Figure 2.

**Adjacent Soils:** The potential for the proposed method of utilization to impact adjacent soils has been thoroughly considered. The bituminous wearing course will not contain ash. Therefore, dust emissions or surface water from the completed road surface do not have the potential to be impacted by ash. Consequently, dust emissions or surface water from the completed road surface do not have the potential to impact the environment (due to ash). Thus, impact to adjacent soil from the demonstration project is not monitored.

**Air Quality:** *Introduction* - As previously discussed, the duration of human exposure to the ash or the ash-amended bituminous is limited. The longest and most intense exposure would be that experienced by workers processing the ash or the bituminous. These two scenarios will be evaluated during the ash processing and bituminous production stages. Evaluation will include



Vertical Exaggeration = 5X

Figure 2: Lysimeter Cross-Section



sampling for total particulates at the landfill during ash processing and for total particulates during bituminous production.

*Particulate Exposure Evaluation at the Landfill:*

The landfill is a secured environment that is not open to the public. Therefore, acute emissions at the landfill are relevant to persons working near the source, as opposed to general environmental impacts. Personal air monitoring will be conducted on two operators to characterize exposure levels to total particulate dust. Monitoring will occur during an 8-hour work shift while excavating and screening the ash. In order to evaluate background conditions, monitoring will also be performed during two 8-hour shifts while the operators are performing routine activities at the landfill or incinerator. Each operator will be equipped with a personal sampling pump for collecting the air samples. Sample collection will be performed according to OSHA standards.

*Particulate Emissions at the Bituminous Plant:*

The ash has a high moisture content prior to processing. However, the ash has been characterized and found to contain a high percentage of fine particles when compared to traditional aggregate. Therefore, the potential emission of fugitive particulates will be evaluated.

Processing operations and sources of potential concern include stockpile storage, on-site vehicle traffic, loading/unloading and conveying. Since the ash has a high moisture content these operations will not be an air quality concern, as the moisture will prevent dust from becoming airborne from these operations. This assumption is being evaluated as previously discussed. The remaining operations (e.g., drying, screening, storage, mixing) occur in enclosed structures. Emissions from these latter operations (particularly drying) are routed to air pollution control equipment – typically a bag filter or wet scrubber.

The particular facility that will produce the ash-amended bituminous has not yet been chosen. However, the MPCA files of the bituminous plants in the project area were reviewed to determine possible plants that could feasibly process the ash into bituminous to determine air permitting requirements and ramifications. Of the local files reviewed, all of the hot mix

bituminous facilities were operating under Option D, registration air quality permits.

For a facility operating under an Option D registration permit, the MPCA can provide written approval to utilize alternative materials, such as ash, if the owner/operator conducts performance testing to determine actual emission rates from the use of the material, fuel or additive.

Performance testing will be accomplished by stack testing of the dryer exhaust for particulate matter. Stack testing will be done as part of the ash utilization demonstration project and will be conducted in accordance with Minnesota Performance Test rules. After measuring particulate emissions, any contaminants of concern can be evaluated since the concentrations of contaminants in the bituminous are already known.

**REMAINING EFFORTS AND CONCLUSION**

The MPCA has provided a conditional approval for the ash utilization demonstration project to progress. However, in order for the demonstration to be considered a success, many significant hurdles must be overcome, as identified below:

- The regulatory agency, MPCA, must approve the Sampling and Analysis Plan for the project;
- MPCA air permit issues must be resolved for the bituminous plant;
- On-spec, ash-amended bituminous must be demonstrated to be practical to produce;
- The road (demonstration project) with infiltration water collection devices must be constructed;
- Good quality environmental samples must be collected and analyzed during the 2000/2001 sampling season;
- Post-construction structural evaluations must show that the ash-amended bituminous meets industry standards;
- Structural and environmental data must be presented to the MPCA and MnDOT in order to obtain approval for future construction of ash-amended bituminous roadways.

This last hurdle is the overall goal for the entire project. However, it is also, by far the most challenging. Past experiences have shown that

Minnesota is a very difficult place for ash utilization. The MPCA has attempted for many years to rigorously regulate utilization of ash. Even coal ash, which is highly consistent and relatively benign, is very difficult to utilize in Minnesota. The few attempts to utilize MWC ash in Minnesota have been miserable failures. However, advances in MWC utilization around the United States and the world, suggest that Minnesota may now be more open to utilization.

Very recently, MnDOT has taken a highly conservative position on utilization of wastes or byproducts in paving materials. It is anticipated that MnDOT approval will be the greatest hurdle to overcome.

Even with all of the above challenges, beneficial utilization of MWC ash in ways that are environmentally responsible and cost effective, is an important goal. If MWC ash, as well as other byproducts can be put to beneficial use, rather than landfilled, all components of our society will be better off.

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