ENVIRONMENTAL ANALYSES OF HOT MIX ASPHALT MADE WITH MINING WASTE MATERIALS[1]

C. F. Gause, R.W. Nairn and M. Zaman[2]

Abstract. Beneficial reuse of mining residuals may represent a cost-effective and environmental responsible option in land reclamation. At the Tar Creek Superfund Site of northeastern Oklahoma, approximately 75 million tons of un-vegetated mining waste materials (known as chat) litter the surface in large piles. Chat is primarily composed of chert, dolomite and calcite, and contains elevated concentrations of metals, particularly lead (Pb), zinc (Zn), and cadmium (Cd). Metals concentrations are particularly elevated in the finer (<0.425 mm) size fractions. At the present time, many county roads in the mining district are graded with raw or pile run chat gravel, raising substantial air and water quality concerns. However, chat also possesses certain properties indicative of high quality aggregates, e.g., hardness and angularity. Therefore, this laboratory study was designed to examine the mechanical and environmental properties of asphalt products which maximize the amount of raw (not size-fractionated) chat. Mix designs containing 80% and 50% raw chat, for surface and base mix designs, respectively, were found to meet mechanical criteria of the Oklahoma Department of Transportation. Detailed results are presented in a companion poster. In addition, raw chat, size-fractionated chat, asphalt products and residues created by simulated asphalt weathering were subjected to Toxicity Characteristic Leaching Procedure (EPA method 1311) and total metals analyses (EPA method 6010). Pb wipe tests (HUD method) were conducted as well. The results of these environmental analyses indicate that incorporation of raw chat into hot mix asphalt presents a beneficial reuse of this contaminated material. Concentrations in both weathered surface and base mix designs were below EPA action levels for Pb in soil and water. TCLP regulatory limits for Pb (5.0 mg/L) were not exceeded by either design. Longer-term, field-scale examinations of similar mix designs are planned through construction and monitoring of a pavement test section.

Additional Key Words: Chat asphalt, chat pavement, mining reclamation, Tar Creek Superfund Site

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[1] Paper was presented at the 2005 National Meeting of the American Society of Mining and Reclamation, Breckinridge, CO, June 19-24, 2005. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502

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Proceedings America Society of Mining and Reclamation, 2005 pp 398-414
DOI: 10.21000/JASMR05010398

https://doi.org/10.21000/JASMR05010398

Introduction

The Tar Creek Superfund Site is part of the Tri-State Mining District (the corners of OK, KS, and MO) and is contaminated with high concentrations of Pb, Zn, and Cd in waste materials (chat), water and soils. Located within the site are the communities of Picher, Cardin, Commerce, Quapaw, and North Miami (EPA, 1997). Seventy years of past underground mining operations have left a devastated landscape of over 100 km^2 of disturbed land surface and contaminated water resources, 500 km of tunnels, 35 million m^3 of processed mine waste, 300 hectares of tailing impoundments, and over 2600 open shafts and boreholes (Wahnee et al, 2000; Zaman et al, 2003). The mined Pb came from galena (PbS) and the Zn came from sphalerite (ZnS) (e.g., Wahnee, 2000).

Environmental Problems Associated with Chat

Chat in its bulk form raises serious human health and ecological concerns due to its elevated concentration of heavy metals, particularly Pb. Some of the many harmful effects of Pb exposure are: 1.) damage to developing nervous tissue, 2.) mutations (birth defects). 3.) cancer, and 4.) in large doses, Pb exposure can result in death (Hoffman et al, 1995). According to a 1993 Indian Health Service study, approximately 35% of children tested at the Tar Creek Superfund Site had elevated blood lead levels (10 ug/dL or greater) above thresholds dangerous to human health (EPA, 1997). Due to extensive residential remediation and health education efforts, the percentage of children with elevated blood Pb levels at the Tar Creek Superfund Site has declined since 1995. According to the Ottawa County Lead Poisoning Prevention Program (OCLPPP), data collected in 1996 show that 31.2% of children aged 1 to 5 had elevated blood Pb levels; data collected in 2003 show that 2.8% of children aged 1 to 5 had elevated blood Pb levels (ATSDR, 2005). Children are most at risk of suffering neurological damage from Pb because they have developing nervous tissue and children are more susceptible to Pb poisoning than adults because children have a rapid metabolism (Squibb, 2004; Barbalace, 2004).

The chat piles at Tar Creek literally encompass residences and communities providing a hazardous attraction to both children and adults. Exposure to mine tailings is especially likely in Picher and Cardin where many homes are within 250 ft of tailings (ATSDR, 2005). The main route of Pb exposure for children is from ingestion of Pb contaminated soil by hand-to-mouth action during play, especially in children age 6 and younger (ATSDR, 2005). The upper aquifer and surface waters at Tar Creek are contaminated with mine drainage containing iron (Fe), sulfate, Zn, Pb, and Cd. An uncontaminated deeper aquifer is used as the primary drinking water source.

In addition to environmental concerns, there is an imperative need to increase the number of paved roads in Ottawa County because in the past unpaved roads have been graded in chat gravel (ODEQ, 2005). Driving over the chat gravel may lead to air pollution problems and eventual settling of chat dust into newly remediated residential properties (USGS, 2004). The Oklahoma Department of Transportation (ODOT) currently uses only a small percentage (20%) of washed (i.e., size fractionated, non-raw) chat in surface course and base course asphalt pavements (ODEQ, 2005; Zaman et al, 2003).

Benefits of Increased Chat Use in Asphalt

Benefits of increasing chat use in asphalt include: 1) reduced road construction costs, 2) economical production of high quality roads (increased skid resistance and reduced rut potential), 3) accelerated removal of exposed chat from the Superfund Site, 4) reduced generation of chat dust in the air, and 5) a source of income to those who sell chat (Zaman et al, 2003).

Study Objectives

The two main environmental objectives of this study were: (1) to develop Hot Mix Asphalt (HMA) Superpave designs that optimize the use of raw chat from the Tar Creek Superfund site for both surface and base mixes; and (2) to determine the effect of weathering on these mix designs, relative to the release of Pb, so that the Department of Environmental Quality (DEQ) would be able to conduct human health risk analyses. Aggregates for blending with chat were obtained from locally available sources so as to provide economic benefits to the people of Ottawa County. The mix design formulation was based on engineering properties such as volumetrics, strength and stability. The effect of weathering was evaluated by examining the performance of the mix when subjected to Asphalt Pavement Analyzer (APA) rut testing under dry and submerged (wet) conditions, retained strength (to account for moisture-induced damage) and grinding (to simulate milling). Environmental tests, including determination of total metals (EPA 2004a) and Toxicity Characteristic Leaching Procedure (TCLP; EPA 2004b), were performed to ensure that the use of the asphalt product will be environmentally responsible when applied in highway pavements and when removed during milling and reused for surfacing or recycling operations. The goals of chat asphalt mix production are to reduce the residual chat pile size and decrease dust due to chat gravel roads.

Two environmental-related hypotheses were developed for this study. The first hypothesis is that the leaching of Pb, Zn, and Cd from chat will be reduced as a result of encapsulating the raw chat in HMA. The second hypothesis is that the percentage of raw chat can be maximized in both the surface HMA design and base HMA design and also conform to DEQ requirements for allowable Pb, Zn and Cd concentrations.

Methods

Metal Analyses

All asphalt, chat aggregate, and non-chat aggregate collected in this study were subjected to TCLP (EPA method 1311). The importance of this metal leaching test is to reveal the soluble phase of a sample and the soluble constituents of a sample made available to organisms for uptake, to help predict the geochemical effects of a "flush" of material, to quantify toxic inputs due to mobilization of contaminants, and to help one assess risk and make management decisions based upon the risk (Townsend et al, 2002). Furthermore, Total Metals Concentrations (TMC) for all asphalt, chat aggregate, and non-chat aggregate samples were determined using EPA method 6010. After acid digestion, inductively coupled plasma-atomic emission spectrometry (ICP) was used to determine TMC. ICP is aimed at determining trace elements, including metals, in solution (EPA, 2004c).

Collection of Chat and Non-Chat Aggregate

The Kenoyer North (KN) chat pile was the sole source of chat for the asphalt designs because it provided a worst case scenario in that it was characterized in previous studies as having relatively high metal concentrations (Datin and Cates 2002), has an appropriate particle size distribution, and is readily accessible (Zaman et al, 2003). The chat was sampled at 20 locations across the working face of the KN stockpile, determined from a traverse across one or more faces of the pile (Datin and Cates, 2002). Chat grab samples were collected at each location and labeled KN-1 through KN-20. Chat collected from KN-1 through KN-20 were combined together (composited) and then size fractionated using U.S. Standard sieves. Also, non-chat aggregates were used for blending with chat to produce the chat asphalt core samples, including: limestone (1/2 inch (1.27 cm), 1 ½ inch (3.81 cm), and screenings) and manufactured sand. The limestone and manufactured sand were obtained from a local quarry (APAC-Oklahoma, Vinita, OK). Grab samples of the non-chat aggregates were collected. The size fractionated (composited) samples, non-size fractionated (grab) samples, and non-chat aggregate samples were submitted to Sherry Labs (Tulsa, OK) for analysis of Pb, Zn, and Cd, using TCLP and TMC. A randomly selected 10% of the samples were analyzed for arsenic (As), barium (Ba), chromium (Cr), mercury (Hg), selenium (Se), silver (Ag), copper (Cu), and iron (Fe) using TCLP and TMC. However, those results are not reported in this paper.

Formation of Chat Asphalt Samples

Chat asphalt samples were generated using Superpave hot mix asphalt (HMA) design methodology. Unwashed chat was used in the design in order to incorporate all the fines possible. Initially, three designs of base mix (BM) were created using 30% chat (BM30), 50% chat (BM50), and 70% chat (BM70) and three designs of the surface mix (SM) were generated as 40% chat (SM40), 60% chat (SM60), and 80% chat (SM80). Six replicates of each BM and SM design were made. Also, two replicates of both the BM and the SM were created that contained no chat aggregate (called BM0 and SM0, respectively); BM0 and SM0 are blanks so as to test for Pb, Zn, and Cd concentrations in the asphalt binding agent. All SM and BM asphalt samples were subjected to both weathering and engineering property tests to analyze the structural integrity of the asphalt. This laboratory research project focuses on conducting the environmental tests on the chat asphalt: simulated dry rutting, simulated wet rutting and simulated milling. The environmental tests are discussed below.

Simulated Dry Rutting

An Asphalt Pavement Analyzer (APA) simulated the weathering process of rutting (whereby a tire runs over the same spot repeatedly) under both dry conditions and wet conditions. Prior to dry rutting any HMA samples, the APA was cleaned with naphthalene and deionized water. The samples were then rutted while being held in place by molds. Immediately following rutting, a template was laid down that divided the rutting table into three parts labeled: template area "A" (157.5 in^2), template area "B" (157.5 in^2), and template area "C" (130.27 in^2). Using Pb wipe kits and the guidelines developed by the U.S. Department of Housing and Urban Development (HUD), each section of the template was separately wiped with a "Huggies Original™" baby wipe. First the template was wiped in a side to side motion and then in a top to bottom motion. Next, the wipe was folded such that the contaminated side was facing inward and the contaminated wipe was aseptically inserted into a labeled, 50-ml, non-sterilized, polyethylene centrifuge tube (HUD, 1995). Template area "D" was a blank and was considered to be 0 in^2. The samples were sent to Sherry labs and analyzed for Pb, Zn, and Cd and for the other metals (on a randomly selected 10% of the samples) using TCLP and TMC (Zaman et al, 2002 and Zaman et al, 2003).

Simulated Wet Rutting

The APA was used to simulate the accelerated weathering that would occur if roads were subjected to wet, saturated conditions. Following wet rutting, the water in the drainage basin was filtered to remove any dust or gravel generated during wet rutting.

Prior to beginning a wet rutting, all inside components of the APA, including the water holding basin, were cleaned with naphthalene and deionized water. Then, the water holding basin was sealed using rubber plugs and/or caulking.

Water could not be pumped into the basin because the HMA samples would become contaminated, thus, deionized water was manually heated on hot plates to a minimum temperature of 147.2˚F (64˚C) and poured into the raised water basin until the HMA samples were submerged under ½ inch (1.27 cm) of water. The initial temperature of the water was measured. Rutting was initialized once the air temperature in the chamber stabilized at 147.2˚F (64˚C). After rutting stopped, the final air and the final water temperatures were measured.

Prior to rutting, a filter paper holder wais devised from two Plexiglas sheets in order to hold a sheet of 50-μm glass fiber filter paper in place while water was draining out of the water basin. The filter paper holder, containing a new sheet of filter paper, was dropped down into the water drainage shaft. After wet rutting commenced, the caulked outflow plug in the water basin was pulled to allow water to drain from the basin and flow through the filter paper, thus allowing sample collection.

After the water basin was drained of as much water as possible, the doors of the chamber were closed and the air heaters were turned to 180˚F (82.2˚C) for 6 hours so that remaining water evaporated. After the bottom of the basin and the rutting table were dry, Pb wipe sampling is conducted using as described above using "Huggies Original™" baby wipe, following the HUD guidelines (HUD, 1995), and using the following templates: area "A" (157.5 in^2), area "B" (157.5 in^2), area "C" (130.27 in^2), area "E" (796.06 in^2) and area "F" (5.41 in^2). Like the dry rut samples, template area "D" is considered to be 0 in^2 because "D" is a blank. Thus, "D" was not used in data analysis. Furthermore, "E" is the area of the circular filter paper that filtered the water draining from the rut machine basin.

The Pb wipes and the filter paper were folded so that contaminated side faced inward and were then aseptically inserted into a new, 50-ml, polyethylene, centrifuge tube. All wipe samples and filter paper samples were sent to Sherry Laboratories for analysis of Pb by TMC.

Simulated Milling

To simulate the milling process (the recycling of a previously paved road), HMA specimens were cut with an asphalt saw. First, the asphalt saw was thoroughly cleaned with tap water and then deionized water and allowed to dry. The chamber floor of the asphalt saw was lined with new aluminum foil used to cover the asphalt saw's entire chamber floor in order to give dust a surface on which to fall. Three replicates of each HMA design were randomly selected for milling. The HMA specimen was cut five consecutive times, without cooling water, to generate the needed minimum amount (100g) of sample to perform environmental analyses. The dust was allowed to settle for three minutes between consecutive cuttings of the HMA specimens. Once the dust settled, the aluminum foil sheets were removed from the floor of the saw and transferred to new Ziploc™ bags. New aluminum foil was laid down before each HMA replicate was cut. All milled samples were analyzed for Pb, Zn, and Cd concentrations using TCLP and TMC tests. Additionally, 10% of the milled samples are analyzed for the other metals (Zaman et al, 2002 and Zaman et al, 2003).

Collection of Unweathered HMA

The unweathered HMA specimens were prepared by cutting at least a 100-g piece from the bottom (unrutted side) of two randomly selected replicates of the chat asphalt samples using the asphalt saw. The asphalt saw was first cleaned in the same manner as described above before cutting any samples. Cooling water was used to cut the unweathered HMA specimens. The samples were packaged in new Ziploc™ bags. Sherry Laboratories analyzed unweathered HMA for TMC and TCLP concentrations of Pb, Cd and Zn and for the other metals on approximately 10% of the samples.

Results

No guidelines exist for metals concentrations in asphalt. According to EPA (2004c) the action level for Pb in soil is 400 μg/g (400 mg/Kg). If action levels are exceeded then remedial action is recommended by the EPA. According the EPA D-codes (maximum concentration of contaminants for TCLP), Pb is listed as D008 and the TCLP regulatory level for Pb is 5.0 mg/L (University of Iowa, 2004). All TCLP figures in the following section have a horizontal reference line indicating the TCLP regulatory limits for Pb. Only the results for Pb are reported in the following subsections because Pb is the metal of highest concern to human and environmental health.

According to engineering tests that were conducted on all the HMA designs, BM40 and SM80 were selected as the optimal HMA designs for paving a future test road. The results of the engineering tests are presented in a companion poster.

Environmental Tests on Bulk Raw Chat

TMC. Fourteen of the 20 chat samples collected from Kenoyer North chat pile and analyzed using TMC had Pb concentrations exceeding the EPA soil Pb action limit. The samples taken from KN-4, KN-7, KN-9, KN-12, KN-18, and KN-19 contained Pb concentrations below the EPA soil Pb action limit (Fig. 1). KN-1 had the greatest Pb concentration at 1,090 mg/kg, and the average Pb concentration was 484 mg/kg.

TCLP. Of the 20 Kenoyer North bulk chat samples tested using TCLP analyses, KN-1 had the highest Pb concentration at 20.7 mg/L (Fig. 2). TCLP Pb concentrations for the Kenoyer North chat pile averaged 8.38 mg/L. All of the locations traversing the outer face of the Kenoyer North chat pile yielded samples with Pb concentrations greater than the Pb TCLP regulatory limit, except for KN-7, KN-9, KN-15, and KN-18.

Environmental Tests on Non-Composite Size-Fractionated Raw Chat

Non-composite raw chat was sampled from the randomly selected KN-6 and KN-11 sites, size-fractionated, and analyzed via TMC and TCLP. The samples were organized according to U.S. Standard Sieve Size as KN-6-4, KN-6-10, KN-6-40, KN-6-80, KN-6-200, KN-6-PAN and KN-11-4, KN-11-10, KN-11-40, KN-11-80, KN-11-200, and KN-11-PAN, with the last number in the sample identification representing the sieve size.

TMC. The total metals analyses of non-composited, size-fractionated raw chat from KN-6 and KN-11 yield the data presented in Fig. 3. There was a trend of Pb concentrations in the chat increasing as particle size becomes finer (amount passing a U.S. Standard Sieve Size increases) for both KN-6 and KN-11. Thus, the greatest concentration of Pb was in the fines. All samples, except for KN-6-4, KN-6-10, KN-11-4, KN-11-10, and KN-11-40, exceeded the EPA soil Pb action limit. KN-6-PAN and KN-11-PAN had both the greatest Pb concentrations at 3,470 mg/Kg and 2,520 mg/Kg, respectively.

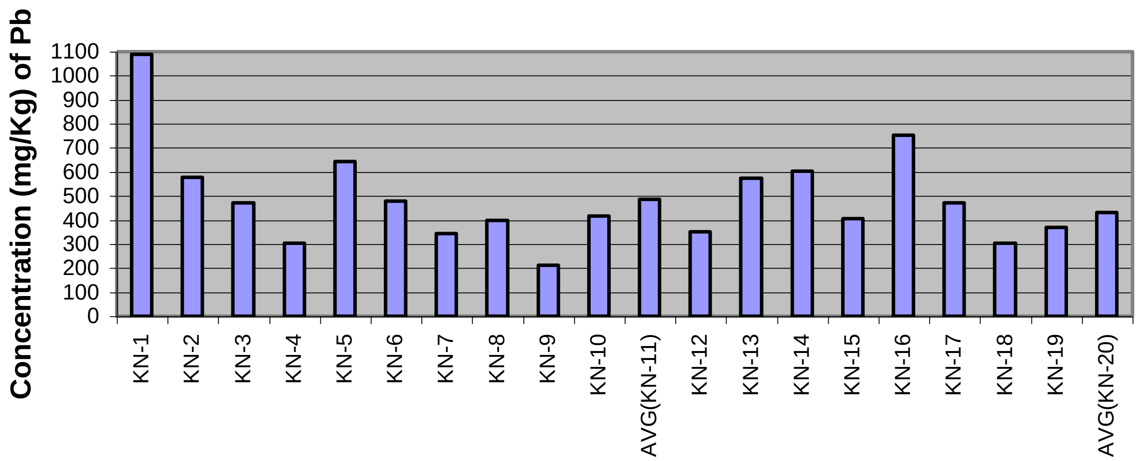

Figure 1. Total concentrations of Pb in bulk raw chat samples from the Kenoyer North pile.

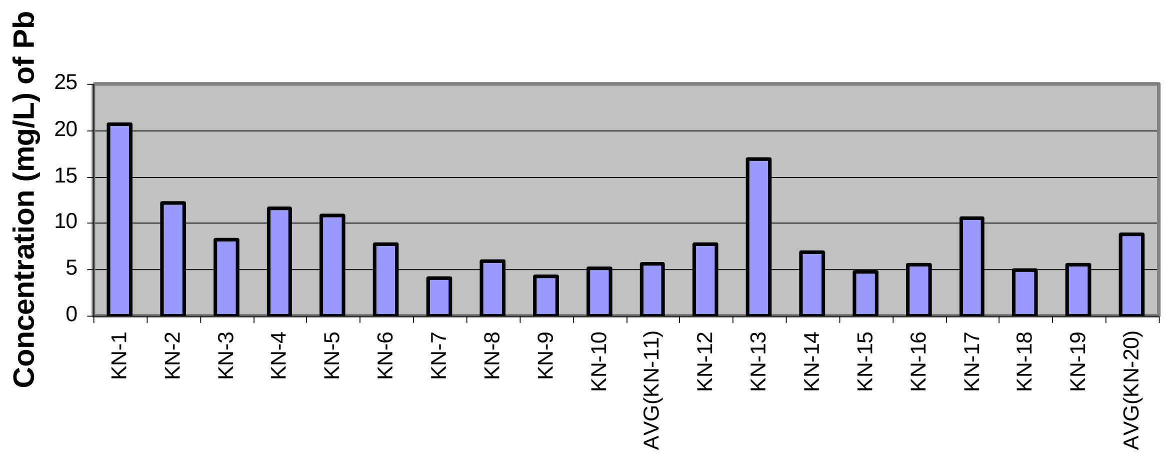

Figure 2. TCLP concentrations of Pb in bulk raw chat samples from the Kenoyer North pile.

TCLP. The TCLP data for non-composite, size fractionated chat sampled from KN-6 and KN-11 are presented in Fig. 4, showing trends wherein the concentration of Pb in the chat increases as the size fraction of the chat decreases (U.S. Standard Sieve Size decreases) for both KN-6 and KN-11. Samples KN-6-40, KN-6-80, KN-6-200, KN-6-PAN, KN-11-80, KN-11-200, and KN-11-PAN exceeded the Pb TCLP regulatory limit. The Pb concentration is greatest in KN-6-PAN at 113 mg/L and KN-11-PAN at 34.7 mg/L. The greatest total Pb concentrations and the greatest leachable Pb concentrations are in the finest material.

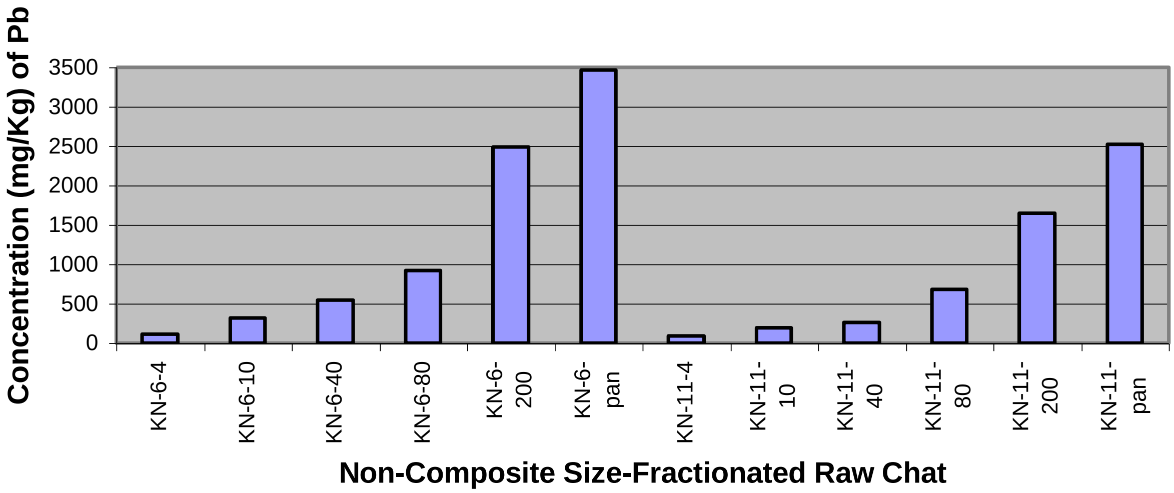

Figure 3. Total Pb from size-fractionated chat samples collected at sites KN-6 and KN-11 at the Kenoyer North pile.

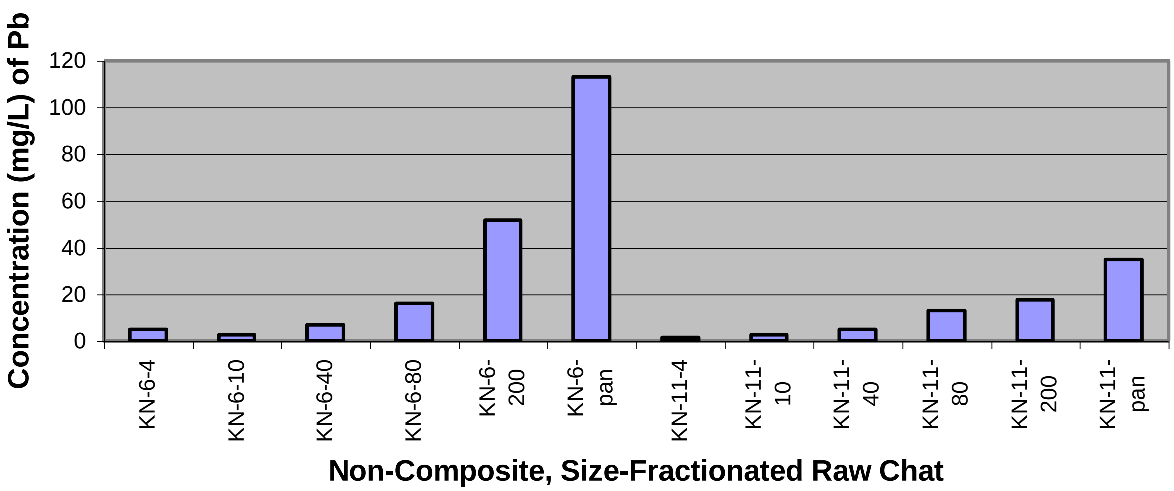

Figure 4. TCLP Pb concentrations for size-fractionated chat samples collected at sites KN-6 and KN-11 at the Kenoyer North pile.

Environmental Tests on Composite Size-Fractionated Chat

Bulk raw chat was composited and size-fractionated to form samples identified as comp-4, comp-10, comp-40, comp-80, comp-200, and comp-PAN. Samples were analyzed via TMC and TCLP. The number at the end of the sample name indicates the size of the U.S. Standard Sieves.

TMC. TMC results for composite size-fractionated chat showed mean concentration of Pb demonstrating a trend of increasing as the U.S. Standard Sieve Size decreases (Fig. 5). The greatest average Pb concentration was in comp-PAN at 5,105 mg/Kg. All samples exceeded the EPA action limit for Pb except for comp-4 and comp-10.

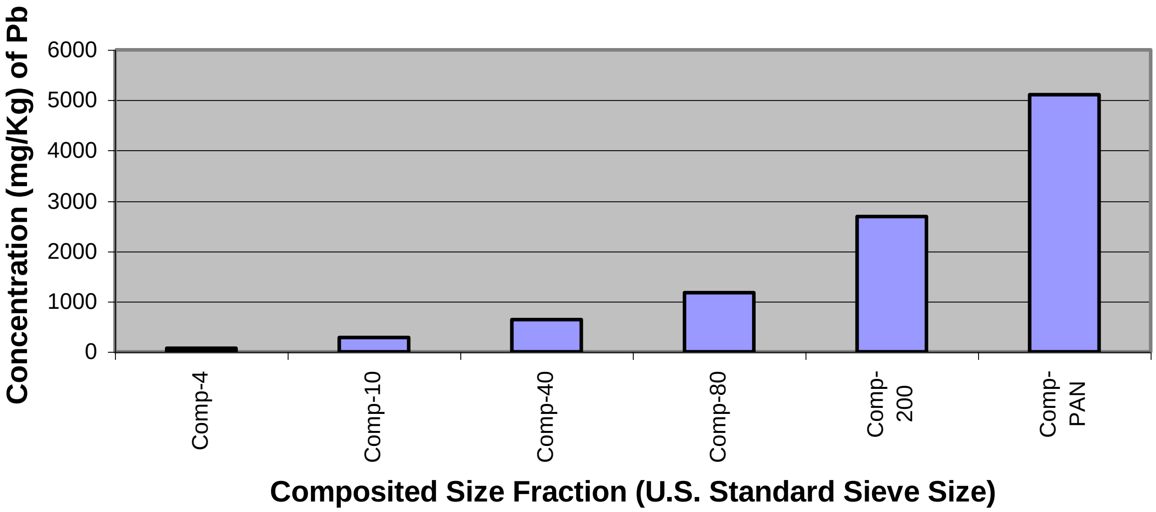

Figure 5. Total Pb concentrations for composite size fractionated chat samples.

TCLP. Fig. 6 shows results of TCLP analyses for Pb on comp-4, comp-10, comp-40, comp-80, comp-200, and comp-PAN. Mean Pb concentrations increased as the size fraction decreased. The greatest average Pb concentration was found for comp-PAN at 93.5 mg/L. All samples exceeded the TCLP regulatory limit for Pb, except for sample comp-4.

Environmental Tests on Size-Fractionated Non-Chat Aggregate

The size fractionated non-chat aggregate materials were limestone and sand. The limestone aggregate were labeled VR-3/8, VR-0.5, VR-0.75, VR-1.25, VR-1.5, and VR-screen, VR-sand and VR-manu. sand (manufactured sand). The size-fractionated non-chat aggregate was analyzed via TMC and TCLP metals concentrations.

TMC. The result of the total metals analysis of the size-fractionated non-chat aggregate is presented in Fig. 7. The greatest Pb concentration is in VR-sand at 1.4 mg/Kg. None of the non-chat aggregate exceeded the EPA action limit for Pb.

TCLP. Results of TCLP analyses of the size-fractionated non-chat aggregate are displayed in Fig. 8. All size fractions had Pb concentrations below the 5.0 mg/L threshold. As anticipated, none of the non-chat aggregate exceeded the TCLP regulatory limit for Pb.

Environmental Tests on Unweathered HMA

The unweathered HMA (UHMA) samples were labeled BM0, BM30, BM40, BM50, BM70, SM0, SM40, SM60, and SM80 with the number representing the percentage of chat contained in the sample. The UHMA samples were subjected to TMC and TCLP analyses.

TMC. TMC results for the UHMA samples are shown in Fig. 9. Total Pb concentrations did not exceed 25.45 mg/Kg in any HMA design (BM30 had greatest Pb concentration at 25.45 mg/Kg). Moreover, none of the UHMA designs exceeded the EPA Pb action limit. SM0 and BM0 had the lowest Pb concentrations (each at 1.25 mg/kg). Since the Pb concentrations were near detection in the UHMA designs that contained no chat (BM0 and SM0) it can likely be concluded that the asphalt binder does not significantly contribute to Pb concentrations in the asphalt.

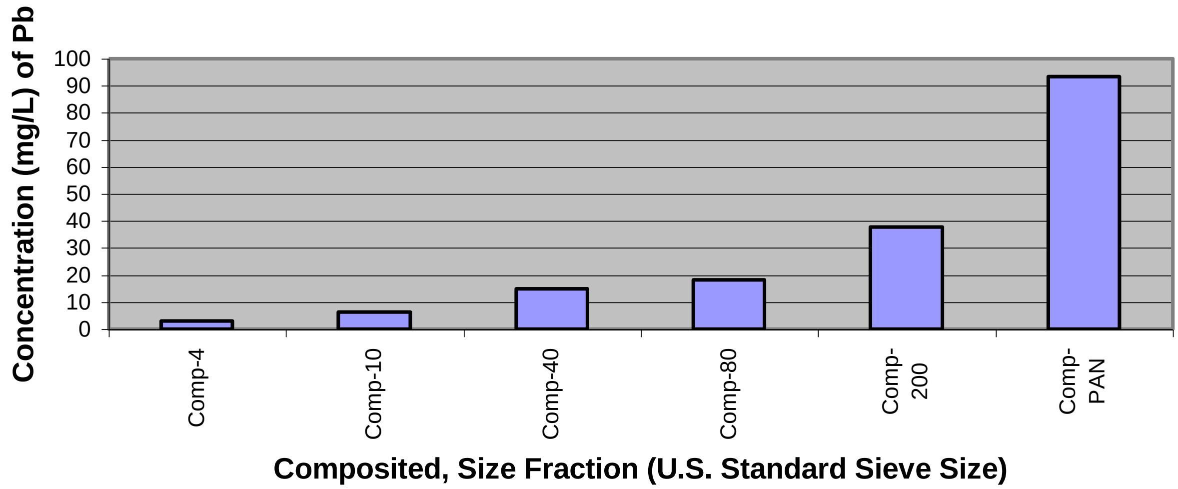

Figure 6. TCLP Pb concentrations for composite size fractionated chat samples.

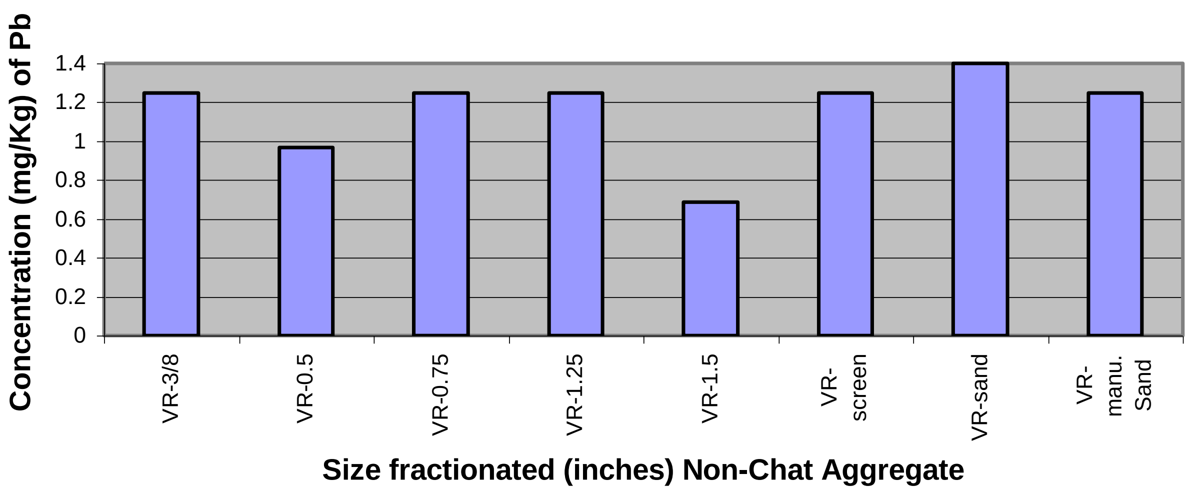

Figure 7. Total Pb concentrations for non-chat, size-fractionated aggregate samples.

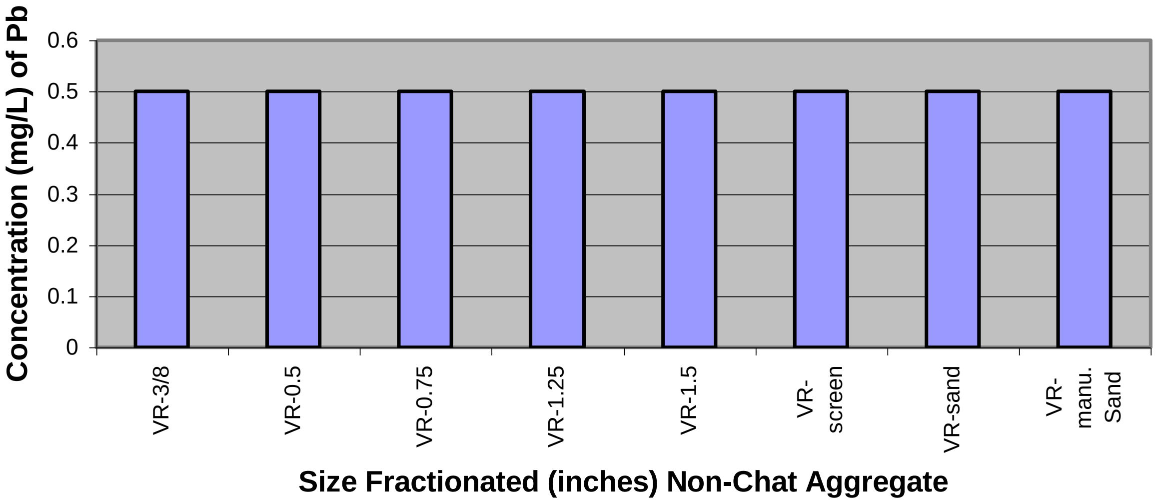

Figure 8. TCLP Pb concentrations for non-chat aggregate samples.

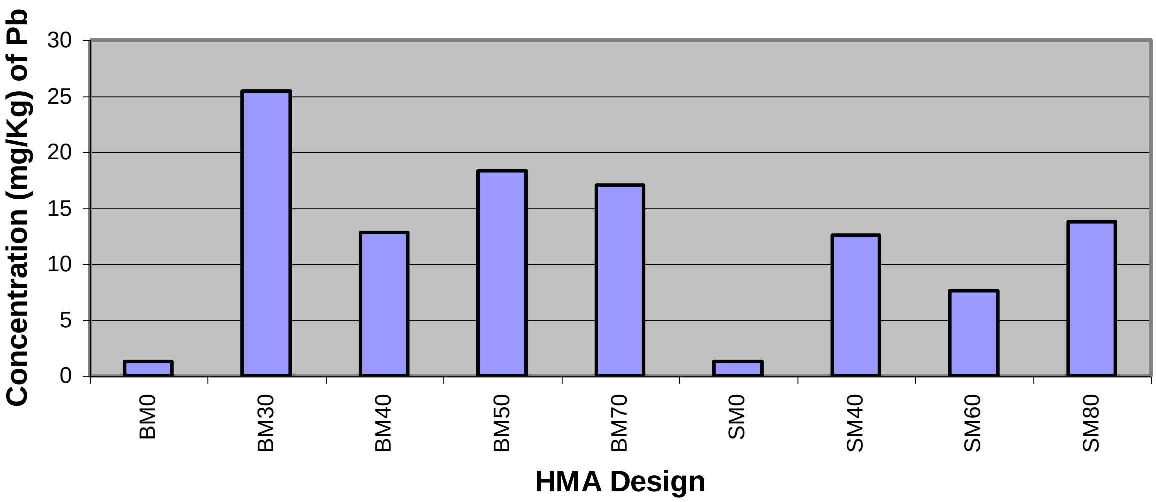

Figure 9. Total Pb concentrations for unweathered HMA samples.

TCLP. Results of TCLP analyses conducted on UHMA are presented in Fig. 10. TCLP Pb concentrations were less than 5.0 mg/L in all UHMA samples, so Pb did not exceed the Pb TCLP regulatory limit in UHMA. These data indicate that mobility of Pb from the chat aggregate is negligible when the HMA remains unweathered. In addition, Pb concentrations are low in the UHMA designs that contain no chat (BM0 and SM0) so it is not likely that the asphalt binder significantly contributes to Pb contamination.

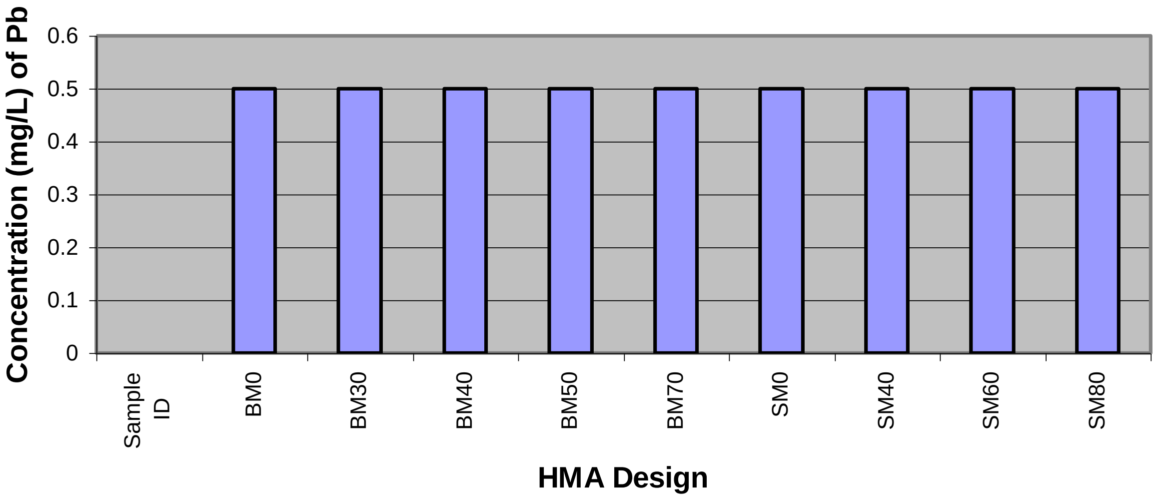

Figure 10. TCLP Pb concentrations for unweathered HMA samples.

Environmental Tests on HMA Weathered by Simulated Milling

The first type of weathering conducted on the HMA samples was weathering by simulated milling using the asphalt saw. The milled HMA samples are labeled BM30, BM40, BM50, BM70, SM40, SM60, and SM80 with the number representing the percentage of chat they contain. All samples were subjected to TMC and TCLP analyses.

TMC. Fig. 11 shows the results of the total metals analyses on the milled HMA samples. For the base mixes, a trend of Pb concentrations increasing as the percentage of chat in the HMA design increases is demonstrated. Of the base mixes, BM70 contained the highest Pb concentration at 343.33 mg/Kg. Of the surface mixes, the maximum Pb concentration was 395.7 mg/Kg and was found in SM80. None of the milled HMA contained Pb concentrations that exceed the EPA Pb action limit.

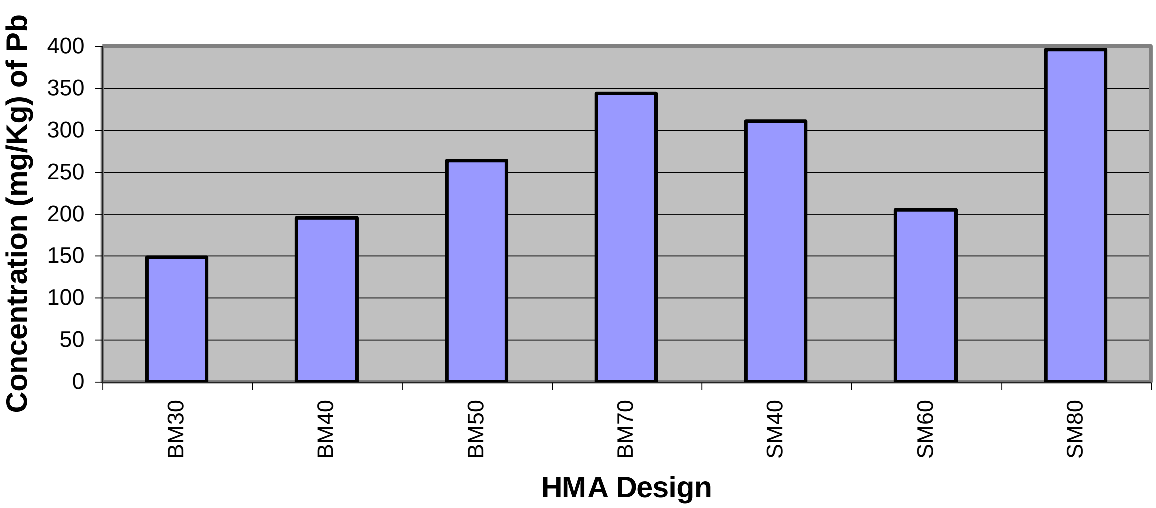

Figure 11. Total Pb concentrations for milled HMA samples.

TCLP. TCLP results for the milled HMA samples are reported in Fig. 12. Of the base mixes, BM50 contained the greatest Pb concentrations at 2.01 mg/L. The chosen base mix design, BM40, contained a Pb concentration of 0.852 mg/L, well below the Pb TCLP regulatory limits. For all the surface mixes, the optimal surface mix (SM80) had the greatest Pb, concentration at 0.465 mg/L, again not exceeding the Pb TCLP regulatory limits.

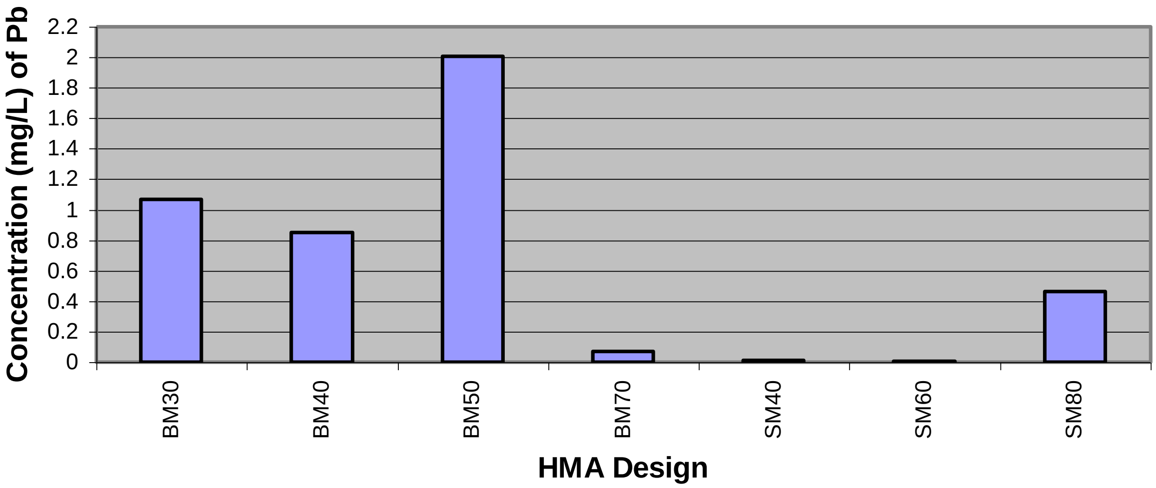

Figure 12. TCLP Pb concentrations for milled HMA samples.

Environmental Analyses of HMA Weathered by Dry Rutting

Pb wipe samples were collected for samples of each HMA mix design from of the APA after rutting and analyzed for total Pb concentrations. The concentrations from each template were summed. TMC is the only metal analyses conducted on the dry rutted samples.

TMC. Mean data, obtained from TMC, is reported in Fig. 13. For the base HMA designs, BM50 had the greatest Pb concentration at 77.27 mg/Kg. Of the surface HMA designs, BM60 had the greatest Pb concentration at 13.8 mg/Kg. Additionally, none of the dry rutted HMA samples exceeded the EPA Pb action limit concentration. Use of the optimal HMA designs based on engineering criteria (that is, BM40 and SM80) appears to be favorable in a way that minimizes the human health and environmental risks of Pb exposure.

Environmental Analyses on HMA Weathered by Wet Rutting

Only two of the HMA designs (BM50 and SM80) are wet rutted using the APA and analyzed for total Pb. Concentrations from each template were summed for wipe samples and used filter paper.

TMC. From the total Pb data, BM50wet demonstrated greater Pb concentrations than BM50; The SM80wet showed greater Pb concentrations than the SM80 (Fig. 14). The mean Pb concentration from BM50wet was 79.86 mg/Kg. The mean Pb concentration of SM80wet was 56.25 mg/Kg, while the mean Pb concentration of SM80 was 13.5 mg/Kg. According to these data, wet rutting weathers the samples more than dry rutting and therefore, produces greater amounts of lead. However, none of the wet or dry rutted samples exceeded the EPA action limit for Pb.

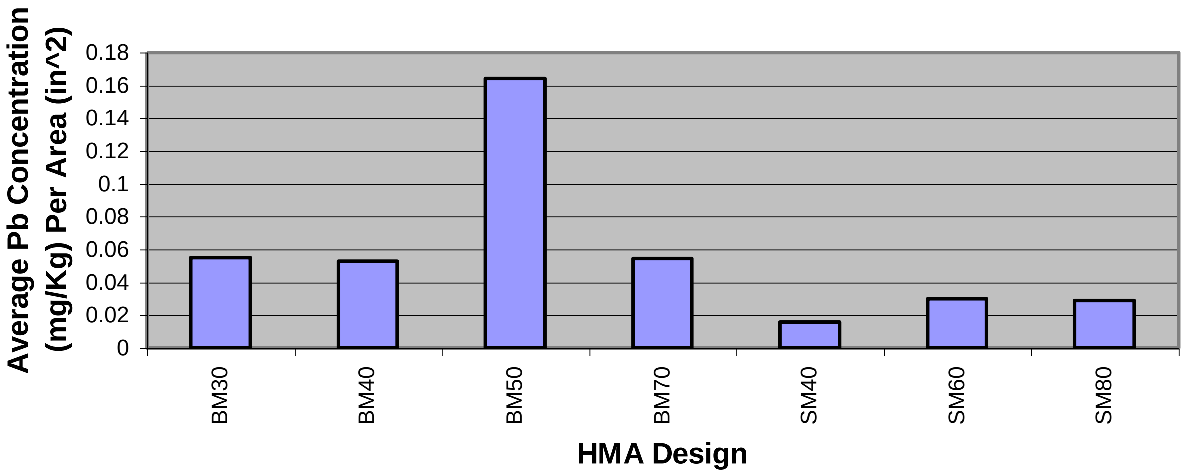

Figure 13. Total Pb for dry rutted HMA samples.

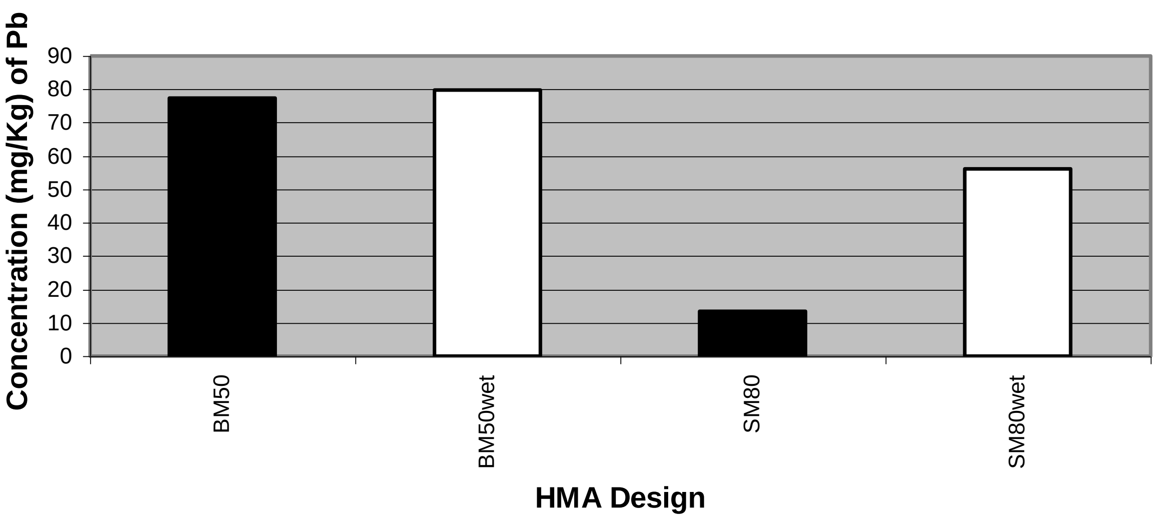

Figure 14. Total Pb concentrations obtained in wipe samples after wet and dry rutting of HMA.

Conclusions

Fourteen of the 20 samples collected from the Kenoyer North chat pile and analyzed for total metals had Pb concentrations above the EPA action level. Sixteen of the 20 samples had TCLP Pb concentrations above the TCLP regulatory limit. Since TCLP regulatory levels and EPA action limits for Pb were exceeded in the majority of bulk chat samples from Kenoyer North, raw chat represents a potentially hazardous material. Provisions for safe uses for chat, such as encapsulating the raw bulk chat in HMA, are needed.

TMC and TCLP analyses of non-composite size-fractionated chat (collected from KN-6 and KN-11) demonstrated that Pb concentrations increased in chat as the particle size decreased. In other words, the greatest Pb concentrations are found in the finest materials. The fines pose the greatest risk to human health and the environment because the fines are more readily available for transport through the environment (by wind, water, etc.). Seven of the 12 non-composite, size-fractioned chat samples collected from KN-6 and KN-11 had Pb concentrations that exceeded the EPA soil Pb action limit and the TCLP Pb regulatory limit. All but two of the composite, size-fractionated chat samples exceeded the EPA action limit for Pb. All but one of the composite, size-fractionated chat samples exceeded the TCLP regulatory limit for Pb. These data reinforce the need to provide for safe uses of chat at the Tar Creek Superfund Site.

Total metals analyses conducted on the non-chat aggregate (limestone and sand) confirmed that Pb concentrations of Pb were below the EPA action limit for Pb. TCLP analyses confirmed that concentrations of Pb were below the TCLP regulatory limit. Therefore, Pb contamination of the HMA sample designs due to non-chat aggregate is unlikely.

The optimal HMA designs according to mechanical criteria were BM40 and SM80. All unweathered HMA designs had Pb concentrations below the TCLP regulatory level and below the EPA action limit for Pb. In the unweathered BM0 and the unweathered SM0 (which contained no chat aggregate), the Pb concentrations demonstrated that it is unlikely that the asphalt binder would contribute to any Pb contamination. When the asphalt remains unweathered, the asphalt binder encapsulates the Pb and reduces leaching from the samples better than in weathered samples.

Despite the weathering process of milling, none of the milled HMA had Pb concentrations exceeding the EPA Pb action limit. All milled HMA designs had concentrations of Pb below the Pb TCLP regulatory limits. Thus, it appears that despite the extensive weathering process of milling, Pb was still being encapsulated by the asphalt binder in a way that reduced the leaching of Pb into the environment.

Pb concentrations in the dry rutted HMA were all below the EPA action limit for Pb. Wet rutting did appear to more effectively produce higher Pb concentrations than dry rutting conditions, perhaps, because it is a more rigorous weathering process. Wet conditions may accelerate the weathering of HMA, thus releasing greater concentrations of Pb. However, despite the greater concentrations of Pb produced by wet rutting, Pb concentrations were still well below the EPA action limit for Pb, thus reaffirming that BM40 and SM80 meet the environmental needs for HMA to pave roads at the Tar Creek Superfund Site.

In summary, Pb EPA action levels and TCLP regulatory levels were not exceeded in the unweathered HMA, milled HMA, dry rutted HMA, or wet rutted HMA. Several recommendations for future environmental research are warranted, such as the following: (1) construction of a test road using BM40 and SM80 so that these laboratory results can be field tested, (2) soil sampling, over time, along the aforementioned test road, (3) air quality sampling, over time along the test road, (4) runoff water sampling for the test road, (5) milling of the test road (one year after the initial construction), and (6) water, soil and air quality sampling during and following milling of the test road.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Report to Congress: Tar Creek Superfund Site, Ottawa County, Oklahoma. http://www.atsdr.cdc.gov/sites/tarcreek/tarcreekreport-p3.html#figure1cont. Accessed: January 22, 2005.

Barbalace, K.L... 2004. Periodic Table of Elements: Element Lead (Pb). KBL Productions.com. http://environmentalchemistry.com/yogi/periodic/Pb.html. Accessed: April 25, 2004.

Datin, D.L., and Cates, D.A... 2002. Sampling and Metal Analysis of Chat Piles in the Tar Creek Superfund Site. University of Oklahoma. Norman, OK. p. 1-69.

EPA. 2004a. Method 1311: Toxicity Characteristic Leaching Procedure. 1992. http://www.epa.gov/epaoswer/hazwaste/test/pdfs/1311.pdf. Accessed: April 21, 2004.

EPA. 2004b. Method 1610: Inductively Coupled Plasma-Atomic Emission Spectrometry. 1996. http://www.epa.gov/epaoswer/hazwaste/test/pdfs/6010c.pdf. Accessed: April 21, 2004.

EPA. 2004c. Region 7. "Model Lead (Pb) QAPP". 2004. http://www.epa.gov/region7/qa/qamodel_pb.htm. Accessed: June 20, 2004.

EPA. 1997. Record of Decision: Residential Areas Operable Unit 2, Tar Creek Superfund Site, Ottawa County, Oklahoma. Dallas, TX. p. 1-69. http://www.epa.gov/earth1r6/6sf/pdffiles/tar-creek-rod-ou2-res.pdf.

Hoffman, D.J., Rattner, B.A., Burton, Jr., G.A., and Cairns, Jr., J... 1995. Handbook of Ecotoxicology. Lewis Publishers. Ann Arbor, Michigan. ISBN 0-87371-585-3. p. 1-755.

Oklahoma Department of Environmental Quality (ODEQ). 2005. Oklahoma Plan for Tar Creek. p. 1-39. http://inhofe.senate.gov/superfund1.pdf. Accessed: January 24, 2005.

Squibb, K... 2004. Applied Toxicology (NURS 735): Metals (Lead). http://aquaticpath.umd.edu/appliedtox/lead.pdf. Accessed: April 18, 2004.

Townsend, T.G., Jang, Y., and Tolaymat, T... 2002. Leaching Tests for Evaluating Risk in Solid Waste Management Decision Making. Department of Environmental Engineering Sciences. University of Florida. Gainesville, FL. http://www.floridacenter.org/publications/Leaching%20Report.pdf. Accessed: April 20, 2004.

University of Iowa. 2004. Appendix 1-(D Codes): Maximum Concentration of Contaminants for Toxicity Characteristic. http://www.uiowa.edu/~hpo/manuals/wastman/AppendixI.pdf. Date accessed: June 18, 2004.

U.S. Department of Housing and Urban Development (HUD). 1995. Appendix 13.1: Wipe Sampling for Settled Lead-Contaminated Dust. p. 1-7.

U.S. Geological Survey (USGS). 2004. Photographs of the Picher Mining District/Tar Creek Superfund Site. Ottawa County, OK. http://ok.water.usgs.gov/tarcreek/. Date accessed: April 22, 2004.

Wahnee, K., Coursey, K., Norton, A., Jefferson, M., Cogburn, M., Kimbro, M., Lipe, S., Rhoney, K., Biles, T., Pankop, A., Sprowls, M., Suiter, J., Shu-Mei, T., Gillespie, C., Athay, D., Wolfard, T., Alcazar, A., Stearns, C., and Pham, V. 2000. Development of Holistic Remediation Alternatives for the Catholic 40 and Beaver Creek, 2000. Spring 2000 Environmental Capstone Project. University of Oklahoma. p. 1-45.

Zaman, M., and Nairn, R.W. 2002. A Research Proposal on A Laboratory Study to Optimize the Use of Raw Chat in Hot Mix Asphalt for Pavement Application. University of Oklahoma. Norman, OK. p. 1-10.

Zaman, M., Nairn, R.W., and Knox, R.C. 2003. Quality Assurance Project Plan. A Laboratory Study to Optimize the Use of Raw Chat in Hot Mix Asphalt for Pavement Application. University of Oklahoma. Norman, OK. p. 1-38.