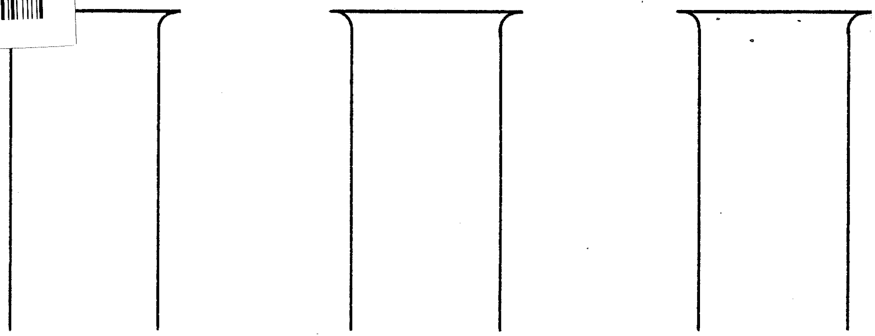
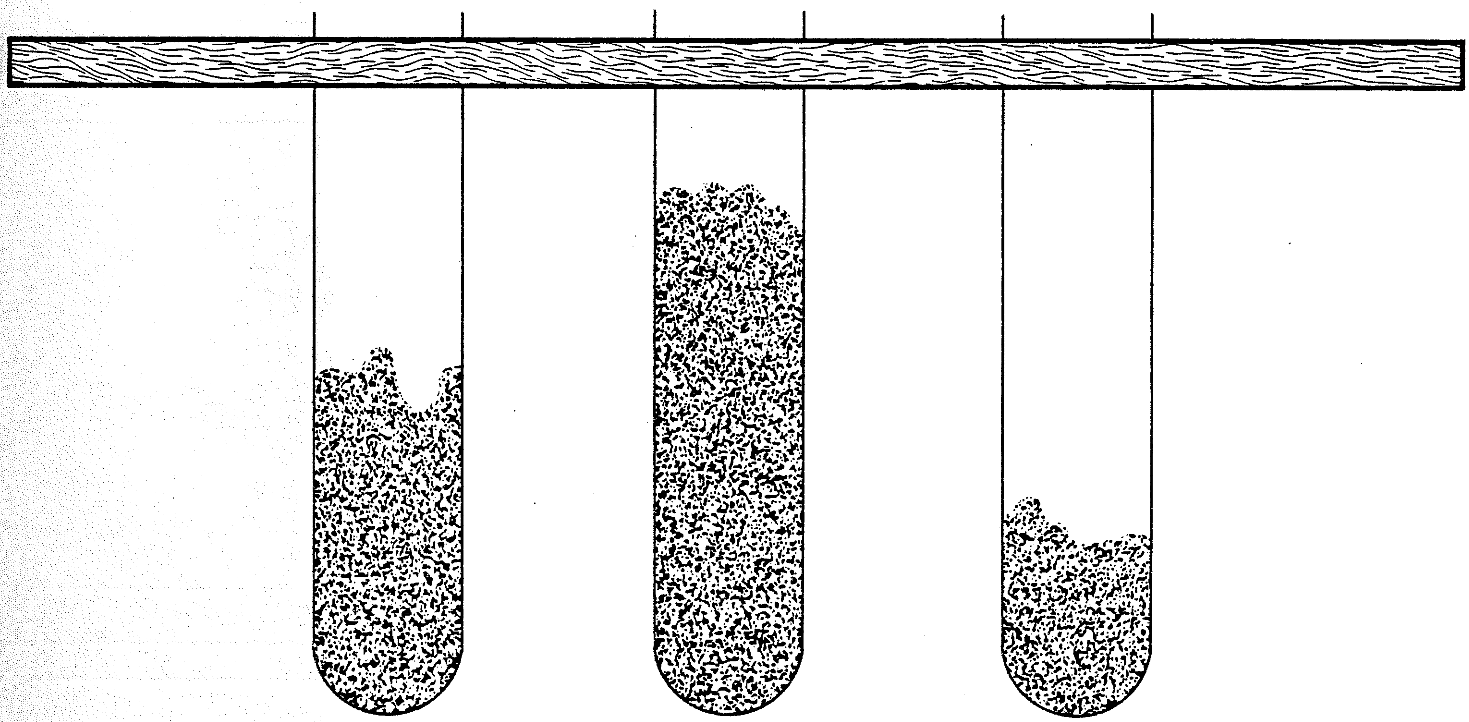


ANALYSIS OF SLUDGE ASH FOR USE IN ASPHALT, CONCRETE, FERTILIZER AND OTHER PRODUCTS



October 1982

Final Report
of the
Study Conducted by Enviroscience, Inc.,
for the
Metropolitan Council of the Twin Cities Area

ANALYSIS OF SLUDGE ASH
FOR USE IN
ASPHALT, CONCRETE, FERTILIZER
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Final Report
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Metropolitan Council of the Twin Cities Area

By

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2021 East Hennepin Avenue
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Publication No. 12-82-103

FOREWORD

This report was prepared for the Metropolitan Council by the Minneapolis consulting firm of Enviroscience, Inc. The report compiles the results of a study conducted by Enviroscience on the technical and economic feasibility of using sewage sludge ash in a number of products, primarily asphalt and concrete.

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SUMMARY

USES OF SLUDGE ASH: GENERAL CONCLUSIONS

Sludge ash, the residue remaining after incinerating sewage sludge, would likely be feasible as an additive to asphalt and concrete and as a possible source of recoverable minerals. However, additional information and testing are needed to make a conclusive determination.

Sludge ash is not feasible as a filler in asphalt shingle mixes, as an additive to fertilizer products, refractory brick and concrete block, and for use in treating the acid drainage from mines.

BACKGROUND

Sludge is the mud-like material left over after most of the water has been removed from sewage during treatment. Sludge is burned, producing ash, to reduce its volume.

Sludge that is burned by the Metropolitan Waste Control Commission (MWCC) at the Pig's Eye sewage treatment plant in St. Paul produces about 100 tons of ash each day. The ash is slurried (mixed with water) and then flushed into holding ponds, or lagoons. The Seneca plant in Eagan, the only other MWCC facility that burns sludge, buries its ash at the plant site. However, disposal space for sludge ash is dwindling.

To meet the need for additional disposal facilities, the 1980 Minnesota Legislature ordered the Metropolitan Council to find a suitable disposal location for sludge ash (Minn. Stat., sec. 473.153, subd. 1). In mid-1981, the Council began to study alternative uses of sludge ash in the hope of reducing or eliminating the need for on-land disposal of the ash. In 1982, the legislature required that, before the Council selects a disposal site, it must evaluate uses for the MWCC's sludge that would reduce the need for a disposal facility "to the greatest feasible and prudent extent" (Minn. Stat., sec. 473.153, subd. 6a).

In the fall of 1981, the Council investigated uses of sludge ash made by sewage treatment plants around the country. The Council found that almost all plants that incinerate sludge dispose of the ash in landfills or lagoons. One plant was found that sells the ash to a mineral recovery firm. This investigation, along with a review of current literature on sludge ash uses, showed that mixing ash in asphalt or concrete appears to be the most feasible use for the ash.

In May 1982, the Council hired the Minneapolis consulting firm of Enviroscience, Inc., to assist in studying possible uses for sludge ash. The purpose of study was to determine the technical and economic feasibility of using sludge ash in a number of products, mainly asphalt and concrete road mixes. The consultant also examined the environmental impacts of using ash at asphalt- and concrete-making plants and in asphalt and concrete products.

STUDY RESULTS

The various sizes of ash particles from the Pig's Eye plant are not precisely known because new sludge incinerators have just begun operation. However, grinding equipment is available to provide finer particles or more uniform sizes, if such processing is necessary for more effective use of the sludge.

Is sludge ash a hazardous waste? An extraction-procedure toxicity test showed that sludge ash would not be classified as a hazardous waste under standards of the U.S. Environmental Protection Agency. Under proposed hazardous waste regulations of the Minnesota Pollution Control Agency, the ash may have to be evaluated for toxicity to humans from oral, inhalation or skin contact. However, it is extremely unlikely that it would be classified a hazardous waste.

The study found that environmental problems appear to be minimal if sludge ash is transported, stored and handled in enclosed spaces and in a dry form.

The following discussion describes the potential uses of sludge ash explored by the Council and Enviroscience, Inc., and conclusions reached to date.

IN ASPHALT ROAD MIXES

Preliminary tests completed by the Minnesota Department of Transportation (Mn/DOT) indicate that the use of sludge ash in asphalt road mixes is feasible. However, additional testing is needed to demonstrate the durability and wear of sludge ash-amended asphalt pavement under field conditions. The Council has requested Mn/DOT to fund a demonstration project using sludge ash in asphalt on a local road project. A division of Mn/DOT, the Local Road Research Board (LRRB) has approved funding for such a project, subject to the approval of the state transportation commissioner. However, the LRRB has concerns about the potential liability for the road should the experiment fail. The Council or the MWCC may have to post a bond before Mn/DOT undertakes the demonstration project.

In general, asphalt mix producers were receptive to using sludge ash in their mixes, provided it is economically feasible and approved by Mn/DOT. Asphalt plants in the Metropolitan Area could use a full year's supply of ash (36,000 tons) produced by the Pig's Eye treatment plant, assuming all sludge is incinerated. However, the asphalt plants operate approximately seven months a year (May through November) and are inactive during the other five months. Because of the short asphalt production season and limited dry-ash storage capacity at the Pig's Eye plant, ash produced during the late fall, winter and early spring would have to be landfilled, used in other products or stored for future use.

The economic feasibility of using sludge ash at asphalt plants depends primarily on the distance of the those facilities from the Pig's Eye treatment plant and the quantity of asphalt produced. The asphalt producer benefits by adding sludge ash to asphalt mix because 1) it is substituted for aggregate otherwise used, thereby saving $1.25 to $3.50 per ton; and 2) it saves drying costs of 75 cents to $1 per ton because the ash is already dry. However, the MWCC may have to provide an economic incentive for asphalt producers to use the sludge ash in their mixes to offset other costs in using the ash material. Nevertheless, the cost of using sludge ash in asphalt for seven months a year and landfilling over the remaining five months is less expensive than landfilling for 12 months.

IN CONCRETE

Using sludge ash in concrete appears to be technically feasible, but state and national engineering specifications would have to be changed to permit the addition of sludge ash to concrete. Additional testing is needed to determine the compatibility of sludge ash with other additives in concrete and determine the long-term durability of the ash-amended concrete. In addition, Mn/DOT would have to approve the use of ash in concrete for highway projects. The Council is discussing with the MWCC the possibility of using ash-amended concrete in construction of the East Battery sewage treatment facilities at the Pig's Eye plant.

IN ASPHALT SHINGLES

Preliminary tests indicate sludge ash is not suitable for use as a filler in asphalt shingle mixes. Additional work is being done by GAF Corp., Minneapolis, to determine if the ash is suitable as an abrasive to be applied to the backsides of shingles to prevent them from sticking together when they are bundled. The results should be available later this year.

IN FERTILIZER

Sludge ash has little potential use in fertilizer products. There were few responses from various fertilizer companies, and those indicated no interest in using sludge ash in fertilizer products.

MINERAL RECOVERY

Mineral recovery from sludge ash appears to be feasible, based on a preliminary evaluation of its chemical composition and physical characteristics by a firm experienced in the technique. The firm will evaluate the sludge ash processing system at the Pig's Eye treatment plant when its new sludge incinerators are fully operational.

IN REFRACTORY BRICK

The use of sludge ash in the production of refractory brick is not suitable because of the high percentage of alkalies in the ash.

IN CONCRETE BLOCK

Using sludge ash in concrete blocks is not suitable because the ash particles are too fine.

IN TREATING ACID DRAINAGE FROM MINES

The ash produced from the new sludge heat-treatment facilities at the Pig's Eye plant is not effective in precipitating the heavy metals present in acid mine drainage. The old ash produced by incinerating sludge conditioned with lime and ferric chloride, now stored in lagoons at the Pig's Eye plant, is effective and could be used for such a purpose.

NEXT STEPS

The Council's work on sludge ash abatement will continue into 1983. Under discussion with Mn/DOT is a demonstration project that would use ash-amended asphalt on a city, county or state road. The details of this project will be worked out this winter with the MWCC, Mn/DOT and the affected local units of government. The Council will keep the Minnesota Asphalt Pavers Association informed of its progress on such a demonstration project.

The Council plans to pursue the potential for using sludge ash in concrete. Preliminary test data will be reviewed with Mn/DOT in the near future, and discussions have begun with the MWCC about the possibility of using ash-amended concrete in future road construction at the Pig's Eye treatment plant. It may be possible to incorporate an ash-concrete demonstration project with the proposed ash-asphalt demonstration project. In addition, the Council will conduct an economic analysis of using sludge ash in concrete.

The new sludge incinerators at the Pig's Eye treatment plant recently began operation. Canadian Waste Technology, Inc., which has been involved in mineral recovery operations at the Toronto sewage treatment plant, will be invited to evaluate the Pig's Eye plant's facilities, if the firm is still interested in pursuing recovery of metals from the sludge ash when these facilities are fully operational.

I INTRODUCTION

A. BACKGROUND

In 1980, the Minnesota Legislature enacted the Waste Management Act, which required state and local governments to deal with the increasing quantities of solid waste, sewage sludge ash and hazardous waste throughout the state. Under the provisions of the Act, responsible government bodies were required to begin looking for landfill sites on which to dispose of the various types of wastes, but then - before choosing any sites - determine how much of it could be recycled or processed.

In accordance with the 1980 Act, the Metropolitan Council has been examining ways to reduce the amount of sewage sludge ash that has to be disposed of in metropolitan area landfills, and hence reduce the landfill capacity required. The Metropolitan Council has encountered considerable opposition in its consideration of potential landfill sites in the seven-county area. Hence, the Council has actively been exploring a number of potential ways to put sewage sludge ash to use and help reduce the volume that would otherwise have to be landfilled in the metropolitan area.

The Metropolitan Waste Control Commission's Metropolitan Plant in St. Paul is expected to generate between 50 and 100 tons per day of ash by the incineration of sewage sludge when additions and modifications are completed on the sludge conditioning, incineration and ash handling systems. These improved systems will increase sludge treatment capacity and reduce the need for chemical conditioning of the sludge. Although more efficient methods are being used to condition and dewater the sludge before incineration, an ash residual still remains after incineration. Presently, the incineration ash is pumped in a slurry form to a lagoon, from which the excess is hauled to landfills. It is becoming increasingly difficult to site new landfills, and existing landfill area is dwindling. Enviroscience, Inc., was contracted by the Metropolitan Council to conduct a study on alternative uses for sludge ash.

B. PURPOSE

The purpose of this study is to determine the potential use of the sludge ash in a number of products, including asphalt road mixes, concrete, concrete block, fertilizer, and asphalt shingle mixes. In addition, mineral recovery from sludge ash and treatment of acid mine drainage using sludge ash will be evaluated. The evaluation of the potential use of sludge ash in these products includes:

1. Evaluation of the sludge ash characteristics and variability.

2. Examination of the requirement for additional ash processing such as grinding.

3. Preliminary economic analysis for the use of sludge ash in asphalt road mixes.

4. Preliminary determination of potential environmental impacts.

5. Determination of the general acceptance of the use of sludge ash in these products.

6. Preliminary evaluation of mineral recovery from sludge ash and evaluation of sludge ash for treatment of acid mine drainage.

II CONCLUSIONS AND RECOMMENDATIONS

The principal findings and indications of this study are outlined below in the form of a series of specific conclusions and recommendations. As noted elsewhere in this report, a number of the conclusions and recommendations are based directly upon the inputs received from the Metropolitan Council Staff, The Minnesota Department of Transportation and other sources. Enviroscience has carefully reviewed such inputs received from others and has, in addition, developed its own conclusions and recommendations on the basis of its own data collection and analysis.

A. CONCLUSIONS

Conclusions derived from this study are presented below in terms of the following categories:

1. General
2. Use of sludge ash in asphalt road mixes
3. Comparison of (2) vs. landfilling
4. Use in road base aggregate
5. Use in concrete
6. Use in asphalt shingles
7. Use in fertilizer
8. Mineral recovery
9. Use in refactory brick
10. Use in concrete blocks
11. Precipitation of heavy metals.

1. GENERAL

1. The actual particle size distribution of sludge ash obtained from the St. Paul Metropolitan Plant's ash handling facilities is, as yet, unknown. It is anticipated that 70-85% of the sludge ash will pass a #200 sieve.
2. Grinding equipment is available to provide finer particles or more uniform size distribution for the effective use of sludge ash if warranted.

3. According to the results of the Extraction Procedure (EP) Toxicity Test, the sludge ash would not be classified as a hazardous waste. Under the proposed MPCA Hazardous Waste Regulations, the ash may have to be evaluated for oral, dermal and inhalation toxicity.

4. Environmental problems appear to be minimal if sludge ash is transported, stored, and handled in a dry state within a closed system.

2. USE IN ASPHALT ROAD MIXES

5. In general, asphalt mix producers in the Twin Cities Metropolitan area were receptive to the use of sludge ash, subject to (1) proof that it is economically feasible and (2) acceptability to MnDOT and other agencies that issue specifications regarding its use.

6. From a technical viewpoint, sludge ash can be stored, handled, transported and used at asphalt mix plants with relatively little difficulty. In several instances, the equipment is already in place at asphalt plants for using mineral filler. The physical properties of sludge ash can be made to approximate those of ordinary mineral filler.

7. Sludge ash can be readily transported in tanker trucks, in an enclosed, environmentally protected condition, from the Metropolitan Plant in St. Paul to several plants in the Twin Cities Metropolitan area. The sludge ash can be pneumatically fed into storage silos and the asphalt mix production process.

8. Economic feasibility of using sludge ash at asphalt plants is primarily a function of <u>transportation distance</u> and <u>annual plant production of road mix.</u>

9. The use of sludge ash provides direct benefits to the asphalt mix production process by (1) acting as a substitute for aggregate otherwise used, thereby saving $1.25 - 3.50/ton, and (2) saving dryer costs of $.75 - 1.00/ton because the sludge ash is already dry.

10. Addition of sludge ash to asphalt road mixes (specifications 2331 and 2361) resulted in a significant increase in stability; reduction of percent void volume and percent cold water abrasion; and increase in the workability of the mix.

11. Asphalt plants in the Twin Cities Metropolitan area operate approximately seven months a year (May - November) and are inactive during the other five months (December - April).

12. Sludge ash may have a potential use to improve the properties of asphalt road mixes in areas where the available aggregate is round and unstable.

13. A seven months supply of sludge ash (21,000 tons) generated at the Metropolitan Plant can be used at the 13 asphalt production plants considered in the Twin Cities Metropolitan area. At concentrations of 1.8 - 2.4% of sludge ash used in total asphalt road mix production, the 13 metropolitan area plants could conceivably utilize 29,000 - 39,000 tons of sludge ash per year.

14. Because of the limited asphalt production season and limited dry ash storage at the St. Paul plant, ash produced during the late fall, winter and early spring would have to be landfilled, used in other products or stored for future use.

15. For sludge ash use representing 1.8% of each asphalt plant's annual volume of total road mix, the net cost per ton of using sludge ash (considering cost credits) ranged from $2.25/ton to $17.49/ton, based on data for 13 asphalt plants.

16. For sludge ash use representing 2.4% of each asphalt plant's annual volume of total road mix, the net cost per ton of using sludge ash (considering cost credits), ranged from $1.85/ton to $14.54/ton, based on data for 13 asphalt plants.

17. To furnish enough economic incentive for asphalt producers to use the sludge ash in their mixes, the Metropolitan Waste Control Commission would have to pay a higher cost than the net cost.

3. LANDFILLING VS. USING SLUDGE ASH AT ASPHALT PLANTS

18. Estimated costs for landfilling sludge ash from the Metropolitan Plant in St. Paul are approximately $34 - 52/ton, based on calculations by the Metropolitan Council Staff.

19. On a 7-month basis (the operating season for asphalt plants in this region), the cost comparison of (1) using sludge ash in asphalt road mixes vs. (2) landfilling the same material, shows that alternative (1) is substantially less expensive: $120,000 - 170,000 for alternative (1) vs $716,000 - 1,096,000 for alternative (2).

20. On an entire year basis, the cost comparison of (1) using sludge ash in asphalt plants for seven months and landfilling over the remaining 5 months, vs. (2) landfilling for 12 months, shows that alternative (1) is significantly less expensive: $660,000 - 980,000 vs. $1,244,000 - 1,905,000.

4. USE IN ROAD BASE AGGREGATE

21. Sludge ash has a potential use in road base aggregate or as a fill material, subject to an improved determination of its properties through testing.

5. USE IN CONCRETE

22. Preliminary test results indicate that sludge ash did not meet ASTM: C618 specifications for use of mineral admixtures in concrete. In order for sludge ash to be used as a cement replacement in concrete, these specifications would have to be modified.

23. Preliminary tests indicate that sludge ash could be used at a 5% cement replacement (based on cement weight) and at a 2% batch weight replacement (based on entire mix) of fine aggregate without adverse effects to the compressive strength. At a 4% batch weight replacement of the fine aggregate, the compressive strength decreases significantly.

24. As a fine aggregate replacement, the combined ash and fine aggregate would have to meet the size gradation specified in ASTM: C136. The most critical requirement would be that no more than 5% of the material can pass a #200 sieve. This would generally limit a fine aggregate replacement by sludge ash to less than 2% based on

total batch weight.

25. Replacement of the coarse aggregate by sludge ash can only be considered if a suitable pelletizing process is available which can reconstitute the sludge ash particles into aggregate having adequate size and strength.

26. The material costs for cement, fine aggregate and coarse aggregate are $68, $3 and $6 per ton respectively. Greater potential cost savings would be obtained by a partial replacement of the cement by fly ash rather than a partial replacement of the aggregate material; however, much less sludge ash could be used in the mix.

27. The use of sludge ash in concrete would be dependent upon economics and acceptance by the engineering community. Specifications for concrete mixes would have to be changed to allow addition of sludge ash (including ASTM: C618).

6. USE IN ASPHALT SHINGLES

28. Preliminary test results conducted by GAF Corporation on the use of sludge ash as a filler in asphalt shingle mixes indicated that the bulk density is too low and the viscosity of the mix containing 60% sludge ash is too high. A sludge ash bulk density of 32 pcf (pounds per cubic foot) was obtained compared with a desired bulk density of 60–80 pcf. The viscosity of the sludge ash mix was 30,000 centipoise compared with a desired viscosity of 2,000–10,000 centipoise. At the time this report was written, GAF was grinding the sludge ash to a smaller particle size to determine how much bulk density and viscosity would change.

29. Besides use as a filler, another possible use of sludge ash in asphalt shingle manufacture would be as an abrasive applicant to the back sides of the shingles to prevent them from sticking together when they are bundled.

7. USE IN FERTILIZERS

30. Test information indicates that the available nutrient levels in sludge ash are very low. Without extensive processing to convert phosphorus to more usable form, acceptance of sludge ash in fertilizer products is expected to be low.

31. Responses to inquiries made to various fertilizer companies (producers, blenders or large distributors) were very limited in number and indicated no interest in using sludge ash in fertilizer products.

32. Potential environmental problems in using sludge ash in fertilizer products involve the presence of heavy metals, particularly cadmium, chromium and lead.

8. MINERAL RECOVERY

33. Mineral recovery from sludge ash appears to be feasible, based on the preliminary evaluation of chemical composition and characteristics by a firm experienced in this application.

9. REFRACTORY BRICK

34. Use of sludge ash for refractory brick is unsuitable because the percentage of alkalies in the ash is too high.

10. CONCRETE BLOCKS

35. Use of sludge ash for concrete blocks is unsuitable because the ash is too fine for this use.

11. PRECIPITATION OF HEAVY METALS FROM ACID MINE DRAINAGE

36. Sludge ash that has undergone heat treatment is not effective in precipitating heavy metals from acid mine drainage.

B. RECOMMENDATIONS

Recommendations based upon the results of this study are presented below in terms of the following categories:

1. General
2. Use of sludge ash in asphalt road mixes
3. Use in road base aggregate
4. Use in concrete
5. Use in asphalt shingles
6. Mineral recovery.

1. GENERAL

1. Particle size distribution analysis should be made as soon as the new sludge ash handling facilities become operational at the Metropolitan Plant. Periodic chemical analysis should also be conducted to determine the variability of the chemical constituents in the ash.

2. The need for grinding equiment should be evaluated once the sludge ash handling facilities become operational.

3. The sludge ash should be evaluated to determine whether this material would be classified as a hazardous waste under oral, dermal and inhalation toxicity criteria in the proposed MPCA Hazardous Waste Rules.

2. USE IN ASPHALT ROAD MIXES

4. Approval should be obtained from the Minnesota Department of Transportation (MnDOT) for the use of sludge ash in asphalt mixtures used in asphalt binder courses.

5. Evaluation of trial sections of roads containing asphalt/sludge ash mixtures should be initiated in order to provide the base for MnDOT approval of such mixtures for use on asphalt wear courses.

6. Further study should be directed toward the effectiveness and economics of storing sludge ash over the five-month winter season for use during the seven-month asphalt road mix production season.

7. Further study should be made of asphalt operations outside the Twin Cities Metropolitan area (eg, Frontenac, Rochester) to determine their potential needs for using sludge ash to compensate for unstable properties of aggregate used in road mixes.

8. Contacts should be made among asphalt producers, representatives of the Metro Council, and MWCC to negotiate the use of sludge ash in asphalt mixes. The negotiations could include the amount of sludge ash that could be used by each producer and the costs which would have to be paid by the MWCC.

3. USE IN ROAD BASE AGGREGATE

9. Additional contacts should be made with producers of road base aggregate to explore further the technical and cost feasibility of using sludge ash in road bases or as fill material. Testing of aggregate samples should be performed on a cooperative basis with interested companies.

4. USE IN CONCRETE

10. Contacts should be made with members of ASTM to determine if ASTM: C618 can be changed to allow some maximum percentage use of sludge ash in concrete mixes.

11. MWCC should request that concrete containing sludge ash be used for non-critical structures such as sidewalks and parking lots for the new East Battery expansion. The performance of this concrete can be observed after several freeze-thaw cycles.

12. Additional tests should be run on concrete containing sludge ash, including freeze-thaw durability, alkaline reactivity, dry shrinkage and abrasion resistance.

13. After further testing has been completed, contacts can be made with concrete manufacturers to determine what costs would have to be paid by the MWCC to enable producers to utilize sludge ash in concrete mixtures.

5. USE IN ASPHALT SHINGLES

14. Contact should be made with GAF Corporation to follow-up on its testing results regarding the use of sludge ash as a filler in asphalt shingle mixes. A partial replacement of the limestone dust filler in the asphalt mix can also be considered along with the use as an abrasive applicant to the backsides of the shingles.

6. MINERAL RECOVERY

15. Further study should be performed to determine in detail the technical and economic feasibility of mineral recovery from sludge ash. The study should also consider possible methods for ultimate disposal of the residual material.

III STUDY PROCEDURE

The Enviroscience proposal submitted to the Metropolitan Council outlined four basic tasks to be performed during the study:

1. Task 1: Analyze the results of the MnDOT lab work

2. Task 2: Investigate and describe the potential for ash storage at the Metro plant

3. Task 3: Recommend a quality control system at the treatment plant to ensure consistency of ash quality and characteristics

4. Task 4: Conduct a feasibility study to determine whether the asphalt and concrete production facilities in the Metropolitan area can use the ash in their products.

A work program and schedule were developed by Enviroscience to provide for the performance of all required project tasks and the preparation of the draft and final study reports. The work program included the following project tasks:

1. Review available data from MWCC, MnDOT and Twin City Testing relating to the physical and chemical characteristics of the sewage sludge material, its hazardous properties and its compatibility with concrete and asphalt road mixtures.

2. Review sludge and ash handling procedures, ash variability, ash storage and quality control as they relate to the Metropolitan Waste Control Commission's operation at the Metropolitan Plant.

3. Determine the feasibility for grinding the sewage sludge ash to a size gradation compatible with its possible uses in asphalt and concrete mixes.

4. Determine the additional data, if any, required for use of sewage sludge ash in asphalt mixes.

5. Determine the additional data, if any, required for use of sewage sludge ash in concrete mixes.

6. Identify the location of local asphalt and cement/concrete producers in the Metropolitan area.

7. Prepare questionnaire and mail to asphalt producers (contacts to concrete producers were held up because sufficient information was not yet available).

8. Review questionnaire responses and make arrangements to visit medium to large asphalt producers in the Metropolitan area.

9. Visit asphalt producers and analyze interview data to determine their potential capability to use sludge ash.

10. Summarize results of asphalt producer survey.

11. Project use of sludge ash in asphalt mixes, based upon review of available data (projected use in concrete mixes was held up because of insufficient information).

12. Evaluate environmental problems in transporting and storing sludge ash or using it in asphalt and concrete materials (this task was deemphasized because it was determined that the sludge ash could be transported from the Metro Plant to the asphalt plants in tanker trucks that greatly reduce its exposure and release to the environment).

13. Identify methods and costs for transporting sewage sludge ash to asphalt (or concrete) mix production facilities.

14. Identify methods and costs for storing and handling sewage sludge ash at asphalt (or concrete) production facilities.

15. Evaluate other possible uses of sludge ash, including fertilizer mixes; asphalt shingles, concrete block, refractory brick, treatment of acid mine drainage, and mineral recovery.

16. Summarize results of the study and prepare preliminary draft report.

17. Incorporate review comments from Metropolitan Council Staff and prepare final version of study report.

IV SLUDGE AND ASH HANDLING FACILITIES

A. SLUDGE TREATMENT

The sludge ash is generated by the incineration of primary and waste activated sludge at the St.Paul Metropolitan Plant. A schematic of the sludge treatment processes at the Metropolitan Plant is shown in Exhibit 1. The waste activated sludge from the activated sludge process is thickened with flotation thickeners, and compressed air is used to concentrate the solids by floating the solids to the top of the tank. The thickened sludge is withdrawn from the top of the thickener, and the supernatant is withdrawn from the bottom. The sludge from the primary clarifiers is thickened in the gravity thickeners, where the thickened sludge is withdrawn from the bottom of the tank.

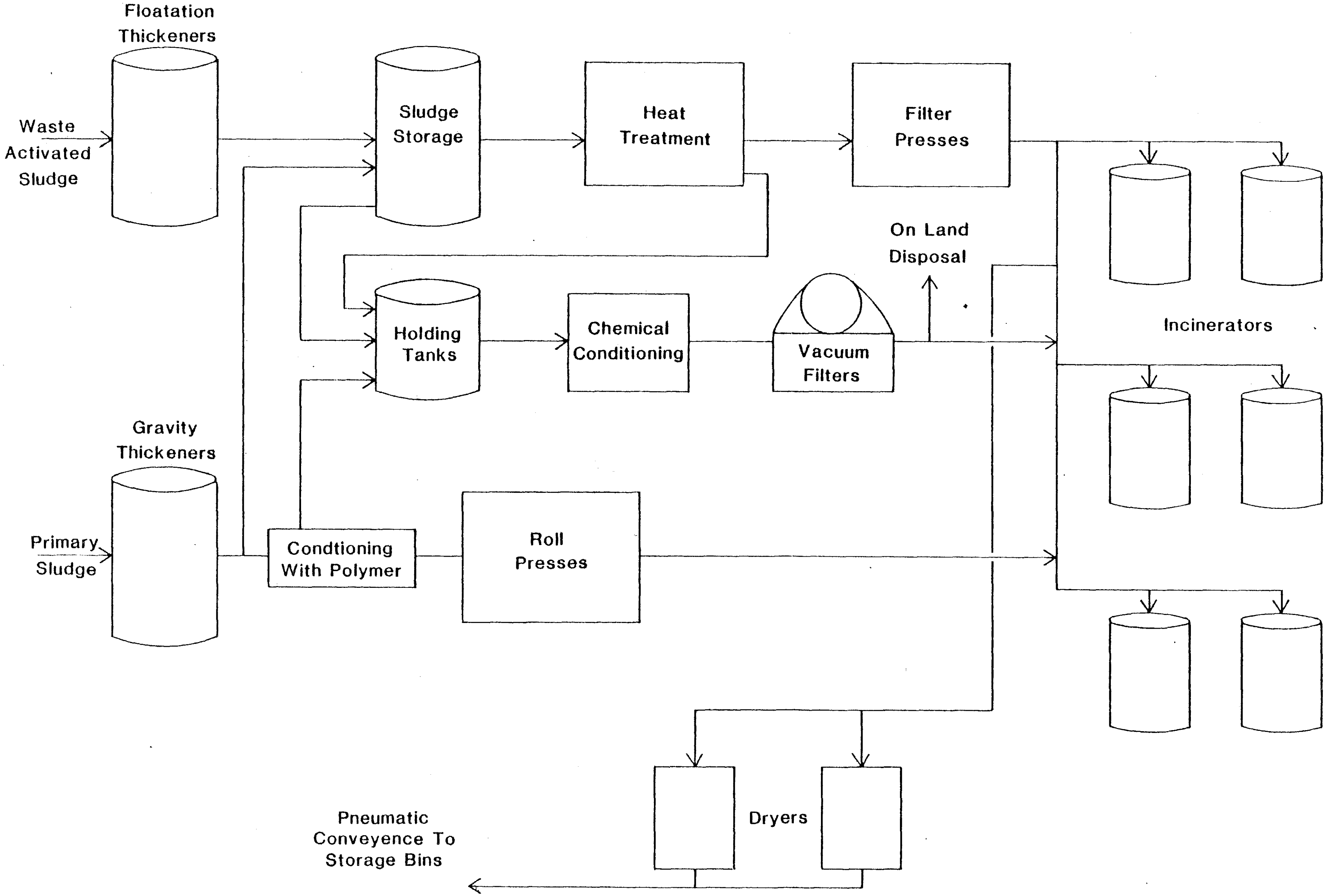
Some of the thickened primary sludge is blended with the waste activated sludge (approximately 75% waste activated and 25% primary) in sludge storage tanks. The blended sludge is kept aerated and mixed in the storage tank to prevent the sludge from going septic. The majority of this blended sludge will undergo heat treatment using both high temperature and pressure to increase the dewaterability of the sludge. The conditioned sludge will be dewatered to 45–50% solids content using filter presses. This dewatered sludge can be incinerated without the use of auxiliary fuel.

The primary sludge which is not blended with the waste activated sludge can be dewatered using the roll presses. Polymers are added to condition this sludge prior to dewatering. This sludge will contain about 35% solids and will generally be incinerated.

Portions of the sludge from the sludge storage tank, heat treatment decant underflow sludge and primary sludge can be sent to holding tanks. From these tanks the sludge would be chemically conditioned using lime and ferric chloride and dewatered to about 20–25% solids content using vacuum filters. Most of this sludge will be applied to land, and the amount of sludge dewatered using this method will depend upon farmer demand and the handling capacity of the filter and roll presses.

Although the majority of the dewatered sludge will be sent to the incinerators, a portion of the dewatered sludge from the filter and roll presses can be sent to sludge dryers for further reduction in the moisture content. The dried sludge will be stored and, when needed, used as a supplemental fuel source for the incinerators, or marketed as a heat-dried sludge.

EXHIBIT 1
SLUDGE HANDLING



The amount of sludge incinerated, versus the amount of sludge spread on land, will depend upon the BTU's required to process the sludge.

The capacity of the two ash storage silos is about 1,260 tons. Based upon the expected sludge production, about 14 to 21 days of storage are provided. The other six storage silos will be used for dry sludge storage and will generally not be available to store ash.

D. POTENTIAL GRINDING

Because the ash conveying and handling facilities have not been completed, the particle size distribution which can be obtained from these facilities must be estimated. A detailed discussion on particle size distribution is included in Section V,C. It is anticipated that additional grinding of sludge ash will not be required for utilization of this material in asphalt road mixes and concrete. The cam crushers are specified to reduce the size of "clinker" material so that 90% is less than 1/4". In addition, the screw conveyors used to transport the ash from the reclaiming units to the storage silos and to transport the ash from the storage silos to the loading stations should result in the breakup of clumps which may form in the ash.

If finer particles are required for the use of sludge ash, grinding equipment can be provided. The grinding equipment selected should be able to handle abrasive materials because of the high silicon, iron and aluminum oxides in the ash (roughly 50%). One manufacturer, Bepex Corporation (Minneapolis, MN), sells a vibrating tube mill (termed "Vibracron") for size reduction of hard and abrasive materials. Depending on machine settings or machine selection, the finished particle size can be selected. Using equipment of this type, the ash material can be processed so that 100% would pass a #200 screen. Suitable grinding equipment should also be available through other manufacturers.

The best location for the grinding equipment would be in the "400 area" of the Metro Plant along the screw conveyor system between the storage silos and the ash loading stations. The equipment needed for reducing the particle size of sludge ash would include the grinding machine, dust collector and bag house, electrical controls and required connection piping. Table 1 contains preliminary capital and operating costs for this equipment. These costs were based on a "Vibracron" unit with a 3.3 tons per hour capacity.

TABLE 1
PRELIMINARY COST ESTIMATE FOR ARTICLE-SIZE REDUCTION

CAPITAL COST

V24/5 "Vibracron" Mill	$130,000
Dust Collection System	30,000
Electrical Control and Connection Piping	20,000
Installation	20,000
SUBTOTAL	$200,000
10% Contingencies	20,000
TOTAL ESTIMATED CAPITAL COST	$220,000

OPERATING COST

Power Cost	$ 25,000/yr.
Maintenance Cost	20,000/yr.
TOTAL ESTIMATED OPERATING COST	$ 45,000/yr.

Note: Estimates based on a V24/5 "Vibracron" mill.

V SLUDGE ASH CHARACTERISTICS AND QUALITY CONTROL

A. CHEMICAL COMPOSITION

Table 2 presents data on the chemical composition of the sludge ash, excluding certain low concentrations of heavy metals. As can be seen from the table, the sludge ash is highest in silicon oxide (27.03%) followed by calcium oxide (20.97%), phosphorus pentoxide (20.20%), aluminum oxide (14.36%), and iron oxide (8.22%). The applicability of the ash material, in terms of its chemical composition, in asphalt and concrete products will be discussed in subsequent sections of this report.

Because of the limited amount of ash data, the variability in chemical composition of the sludge ash can only be estimated by observing the variability in the sludge cake. Of the major chemical components in the ash shown in Table 2, only the variability of phosphorus can be determined by observing it's contentrations in the sludge cake.

The following data was obtained from the Metropolitan Waste Control Commission's Quality Control Section:

Phosphorus data for 1981, press cake conditioned by heat treatment.

Average	27,860 mg/kg
Minimum	7,000 mg/kg
Maximum	106,000 mg/kg
Standard deviation	8,450 mg/kg
Number of samples	267
Volatile solids	61.5%

Phosphorus data for 1st quarter of 1982, press cake conditioned by heat treatment.

Average	29,820 mg/kg
Minimum	18,790 mg/kg
Maximum	46,600 mg/kg
Standard deviation	5,740 mg/kg
Number of samples	87
Volatile Solids	64.5%

TABLE 2
CHEMICAL COMPOSITION OF SLUDGE ASH SAMPLES

Component		Percent by weight
Silicon Oxide (SiO_2)		27.03%
Aluminum Oxide (Al_2O_3)		14.36
Iron Oxide (Fe_2O_3)		8.22
Subtotal	49.61	
Sulfur Trioxide (SO_3)		0.84
Calcium Oxide (CaO)		20.97
Magnesium Oxide (MgO)		3.21
Barium Oxide (BaO)		0.297
Strontium Oxide (SrO)		0.018
Phosphorus Pentoxide (P_2O_5)		20.20
Titanium Dioxide (TiO_2)		2.85
Moisture Content		0.086
Loss on Ignition		0.20
Available Alkalies as Na_2O		0.516
Available Sodium Oxide as Na_2O		0.305
Available Potassium Oxide as K_2O		0.320
Total Alkalies as Na_2O		0.882
Total Sodium Oxide (Na_2O)		0.467
Total Potassium Oxide (K_2O)		0.631
TOTAL CHEMICAL COMPOSITION		99.29%

Note: Analysis based on tests performed by Twin City Testing, April 1982.

Assuming that the carbon content would be lost by incineration and no loss in phosphorus would occur, the estimated average and standard deviations for phosphorus pentoxide in the ash would be:

Based on 1981 data

Average	16.6% as P_2O_5
Standard deviation	5.0%

Based on 1st quarter 1982 data

Average	19.2% as P_2O_5
Standard deviation	3.7%

If concentrations of the phosphorus pentoxide within ash samples followed a normal distribution, approximately 67% of the phosphorus pentoxide concentrations would be within $\pm$ one standard deviation from the average. The phosphorus pentoxide concentration obtained for the analysis of ash (Table 2) was 20.2%, which was within one standard deviation of the estimated averages obtained from 1981 and 1982 data.

If the ash material is to be used in asphalt or concrete products, ash samples should be analyzed on a regular basis.

Analysis of the ash should include silicon oxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO), phosphorus pentoxide (P_2O_5), available alkalies (as Na_2O), magnesium oxide, moisture content, and loss on ignition.

B. HAZARDOUS WASTE ANALYSIS

The Minnesota Pollution Control Agency has existing (Reference 2) and proposed (Reference 3) rules for the classification of hazardous waste. Under the existing rules the waste can be classified as hazardous waste if:

1. The concentrations of specified toxic materials in the waste exceed those concentrations in list 1. The concentrations are on a dry weight basis.

2. The concentrations in leachate, from a standard leachate test procedure, exceed the concentrations shown on list 2.

3. The waste can be classified as toxic through oral, dermal, and inhalation testing.

Under the proposed rules, list 1 will be dropped, and classification as a hazardous waste will depend on leachate concentrations using the EP Toxicity Test and on oral, dermal, and inhalation toxicity testing.

Two ash samples were analyzed to determine their concentrations of the list 1 toxic materials. This data is shown in Table 3. Lead concentrations in ash samples 1 and 2 exceed the MPCA limit shown in list 1 for the existing rules. Total chromium concentrations, not chromium (VI) concentrations, were· determined for the sludge ash. Although the total chromium concentrations for the ash are high, it cannot be determined from this data if the chromium (VI) limits shown in list 1 would be exceeded. Under the proposed rules (Reference 3), the critieria shown in Table 3 will no longer be used for hazardous waste classification.

An Extraction Proceedure (EP) Toxicity Test was also run on the two sludge ash samples. Basically, the EP test procedure includes:

1. Adding deionized water to the material
2. Agitating and adjusting the pH to 5 using acetic acid
3. Further agitating followed by adjustment of pH to 5 and addition of more water
4. Filtering and analyzing the filtrate.

The results of the analysis of the filtrate for ash samples 1 and 2 are shown in Table 4. The leachate obtained from the digestion of the ash samples was below the EPA limit for all parameters. The EPA limits shown in Table 4 will be used in the proposed MPCA Hazardous Waste Regulations. Under these guidelines the ash would not be classified as a hazardous waste.

Under the present and proposed regulations, the ash would have to be evaluated for oral, dermal and inhalation toxicity. Tests using laboratory rats and rabbits to determine the specific toxicity of a waste are rarely conducted. Generally, LD50 (lethal dose concentrations at which 50% of the test animals die) data for specific toxic materials contained in the waste can be obtained from literature sources. Using dosages and concentrations of toxic materials in the waste, it can be estimated whether or not the LD50 values from literature sources for oral, dermal and inhalation toxicity would be exceeded. It is unlikely that LD50 concentrations would be exceeded for sludge ash; nevertheless, this evaluation excercise may still have to be conducted to satisfy the MPCA.

TABLE 3
CONCENTRATIONS OF TOXIC MATERIALS IN HEAT-TREATED ASH
(mg/kg dry weight basis)

Component	MPCA Limit (List 1)*	Sample No. 1	Sample No. 2
Arsenic	500	15.4	18.6
Beryllium	20	2.4	1.6
Cadmium	500	31.2	7.5
Chromium (VI)	1,000	2,742**	3,935**
Copper		3,858	
Lead	600	1,012	820
Mercury		0.009	
Nickel	10,000	586	525
Selenium		0.52	
Silver		198	
Thallium		32	
Zinc		3,860	
Total PCB	500	0.1	

* Limits established by rule 6MCAR S 4.9002 B.1 of the Minnesota Pollution Control Agency.
** Total Chromium.

Note: Analysis based on tests performed by Metropolitan Waste Control Commission, February 1982.

TABLE 4

RESULTS OF EXTRACCTION PROCEDURE TOXICITY TEST ON SLUDGE ASH

Component	EPA Limit* (mg/l)	Ash Sample No. 1 (avg. of four tests, in mg/l)	Ash Sample No. 2 (mg/l)
Inorganic Compounds			
Arsenic	5.0	0.073	0.337
Barium	100.0	0.127	0.252
Cadmium	1.0	0.004	0.003
Chromium	5.0	0.073	0.490
Lead	5.0	0.011	0.005
Mercury	0.2	< 0.0002	< 0.0001
Selenium	1.0	0.015	< 0.002
Silver	5.0	< 0.0001	< 0.0002
Organic Compounds			
Endrin	0.02	< 0.00001	< 0.001
Lindane	0.4	0.00012	< 0.001
Methoxychlor	10.0	< 0.0004	< 0.001
Toxaphene	0.5	< 0.00003	< 0.005
2,4-Dichlorophenoxy-acetic acid	10.0	0.0047	< 0.5
3,4,5-Trichlorophenxy-prophionic acid	1.0	< 0.00002	< 0.5

* Limits established by CRF Vol. 45, No. 98, page 33122, May 19, 1980, of the U.S. Environmental Protection Agency.

Note: Analysis based on tests performed by Metropolitan Waste Control Commission, February 1982.

C. PARTICLE SIZE DISTRIBUTION

Since the ash conveyance system at the Metro Plant is not yet operational, the particle size distribution obtained from the ash handling facilities described in Section III is not known. Based upon a past grain size distribution analyses for ash obtained from chemical conditioned sludge (see Exhibit 3), and considering the type of ash conveying systems that will be installed, the following is an estimate of the grain size distribution for the sludge ash:

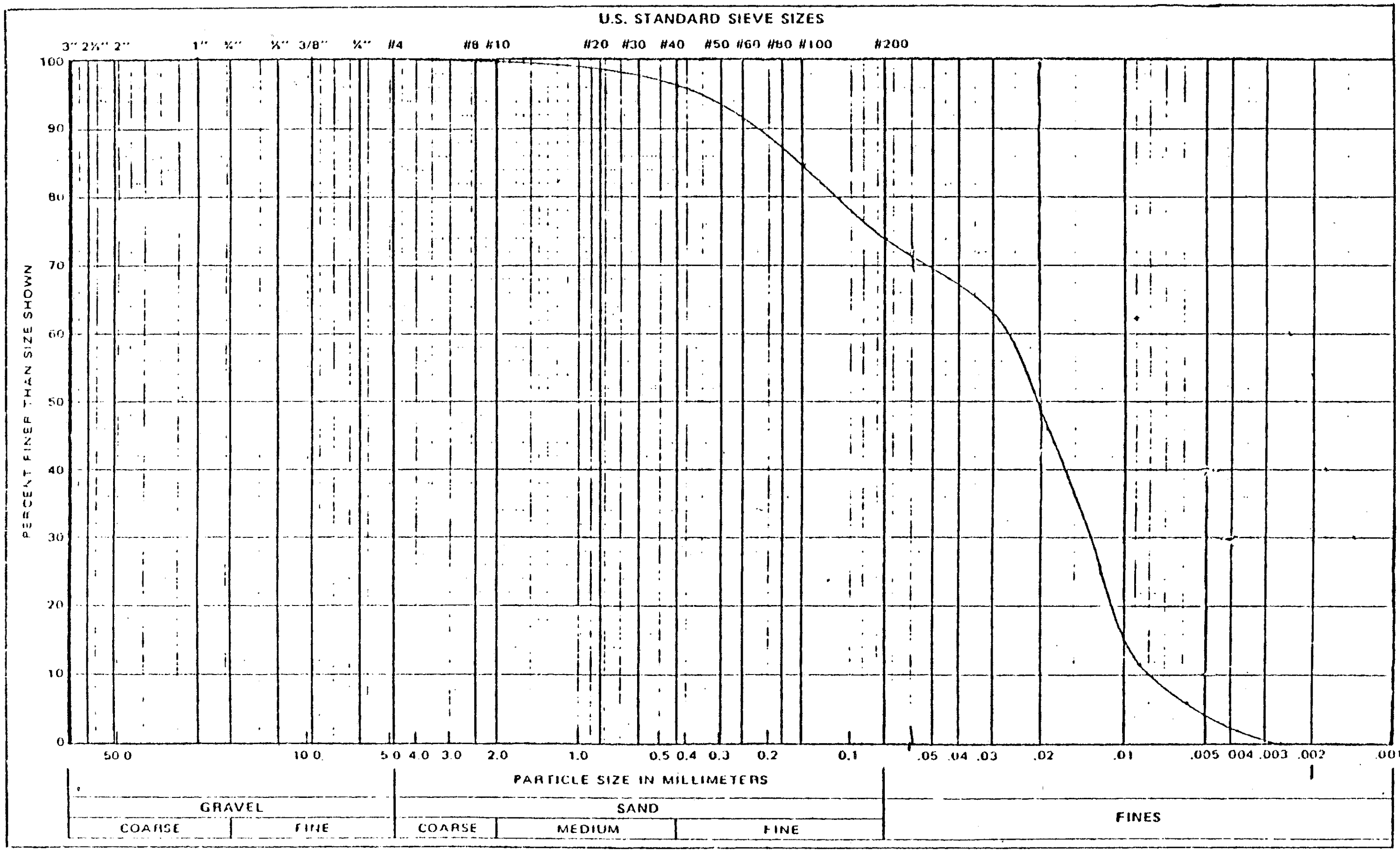
- 70–85% passing #200
- 10–20% sand (2.0 - .06 mm)
- 65–80% silt (.06 - .002 mm)
- 0–10% clay (<.002 mm)

As discussed in Section IV, D, grinding equipment can be installed to reduce and to obtain a more uniform particle size. Grinding should only be considered if it significantly enhances the use of the sludge ash in construction materials. The cost of grinding would have to be offset by the enhanced economic value of the sludge ash.

When the new ash handling facilities are operational, particle size distribution analyses should be conducted on the ash obtained from the system. Judgements as to whether further grinding equipment would be required can be made when there is no more information available on particle size and after consultation with manufacturers who may use the ash in their products. Periodic tests to determine particle size distribution should also be run to evaluate the variability in the size distribution.

EXHIBIT 3

PARTICLE SIZE GRADATION*



* Gradation Conducted on Dried, Chemical-Conditioned Ash Sample From Ash Storage Lagoons. Analysis Performed by Twin City Testing, November, 1981.

VI USE OF SLUDGE ASH IN ASPHALT ROAD MIXES

A. GENERAL

One projected use of the sludge ash would be as a mineral filler in asphalt road mixes. In the Metropolitan Area there is an estimated 4 to 6 million tons of asphalt applied to roads each year. Given this volume, there would be a good potential for utilizing sludge ash for this use. The Minnesota Department of Transportation conducted preliminary tests to evaluate the use of sludge ash in asphalt road mixes. Since the test results appeared promising, Enviroscience made contacts with asphalt road mix producers during July, 1982. Plant visits were made to discuss the feasibility of using sludge ash and to determine what equipment or modifications would be needed. After these visits a preliminary analysis was made to determine the economic feasibility of utilizing sludge ash in asphalt mixes.

B. MINNESOTA DEPARTMENT OF TRANSPORTATION TEST RESULTS

The Bituminous Testing Laboratory for the Minnesota Department of Transportation made up mixes conforming to specificications 2331 and 2361, using different aggregate concentrations and sludge ash concentrations. In general, the sludge ash was added as a mineral filler and was not used to reduce the amount of asphalt oil in the mixes. The amount of sludge ash, the aggregate gradation and the aggregate source and contractor are shown in appendix 1.

The sludge ash used in these tests was obtained by the incineration of heat conditioned sludge in the pilot scale furnace. The ash contained clumps of particles which could be easily crushed. These clumps are not expected to be as prevalent in the ash obtained from the new ash handling facilities. During initial tests, asphalt mixes were prepared using sludge ash containing clumps of ash particle material. A gradation analyses indicated that 82% of the ash passed a #80 sieve. Other mixes containing sludge ash were made up of sludge ash which had been pulverized so that 100% was passing a #80 sieve. This ash particle size is expected to be more representative of the particle size which would be obtained from the new ash handling facilities.

The asphalt mixes were tested for stability, percent void volumes and percent cold water abrasion. The stability of a mix is a measure of its resistance to flow and is determined as the maximum load that a test specimen can reach while being loaded at a specified constant rate. Percent void volume is a measure of the air voids within the mix. The cold water abrasion test is used to determine the relative durability of bituminous moisture to water abrasion. The percent loss in the test specimen is measured after a cylinder containing the specimen and cold water has been rotated using a test machine.

In general, better results were obtained for the pulverized sludge ash than for the unpulverized ash. The following is a summary showing the average results for adding pulverized ash to 2331 and 2361 mixes:

Mix Specif-ication	Percent Sludge Ash	Average Percent Asphalt Content	Average Stability[1] (lbs)	Average Voids[2] (%)	Average CWA[3] (%)
2331	0	5.5	686	4.4	6.3
	2	5.5	1,109	4.0	4.8
	3	5.5	1,491	3.7	4.9
2361	0	6.1	1,770	7.0	4.5
	3	6.1	2,527	5.0	3.9

As can be seen from the above data, addition of sludge ash resulted in a significant increase in stability. Reduction of percent void volume and percent cold water abrasion was also apparent by addition of sludge ash. It must be pointed out that the control mixes (containing no sludge ash) had values of stability, void volume and cold water abrasion which were within Minnesota Department of Transportation specifications for these parameters. Addition of sludge ash, however, does appear to improve these mix parameters and increase the workability of the mix.

No reduction of asphalt oil content was attempted for mixes containing sludge ash. The mixes already contained low oil content and Mn/DOT personnel would not recommend any oil

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[1] ASTM D 1559 Resistance to Plastic Flow of Bituminous Mixtures using Marshall Apparatus.

[2] ASTM D 2041 Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures

[3] MnDOT's Cold Water Abrasion Test

reduction. However, in mixes that require the use of higher asphalt contents, the amount of asphalt may be reduced by the utilization of sludge ash.

C. ASPHALT PLANT OPERATION AND PRODUCER CONTACTS

1. DESCRIPTION OF PLANT OPERATION

A. PUGMILL

The pugmill plants that were evaluated were all batch mix plants, although continuous pugmill plants are also in existence. Exhibit 4 shows a schematic for a pugmill batch plant. The cold aggregate storage bin and feeder unit stores the aggregate and accurately feeds the required amount of each size to maintain constant balance of aggregate in the gradation unit. The aggregate is conveyed from the cold aggregate storage bins to the dryer. The aggregate flows continuously through the dryer where it is dryed by direct contact with the flame and hot gasses. The hot gasses containing fumes are vented to the air pollution control equipment consisting of a wet scrubber or bag house and an exhaust gas stack.

The dried aggregate is conveyed by bucket elevators to the gradation control unit, which separates and stores the dried aggregate. Vibrating screens in the gradation unit separate aggregate which is stored in bins underneath the screens. Oversized aggregate is rejected. Aggregate is released in predetermined order from the hot bins into a weigh hopper in proportions required to make up a batch. If sludge ash or another mineral filler is to be added, it would be pneumatically conveyed from the storage silo into the weigh hopper containing the aggregate. The amount of sludge ash added would be automatically controlled with the addition of the aggregate.

An asphalt weighing bucket is used to weigh the proper amount of asphalt oil needed for the batch. When the pugmill is cleared and ready for the next batch, the gates to the weigh hopper are opened and the aggregate and mineral filler, if used, are dumped into the pugmill. The asphalt oil is added to the material in the pugmill and the batch is thoroughly mixed before it is loaded onto a waiting truck.

B. DRUM MIX

The other general type of plant which was visited was a drum mix plant, a schematic of which is shown in Exhibit 5. This type of plant continuously produces an asphalt mix during its operation. Cold aggregate storage and feed hoppers feed aggregate at the proper gradation into the front end of a dryer-drum mixer. The aggregate comes in contact with the flame

EXHIBIT 4
ASPHALT PUGMILL MIX PLANT

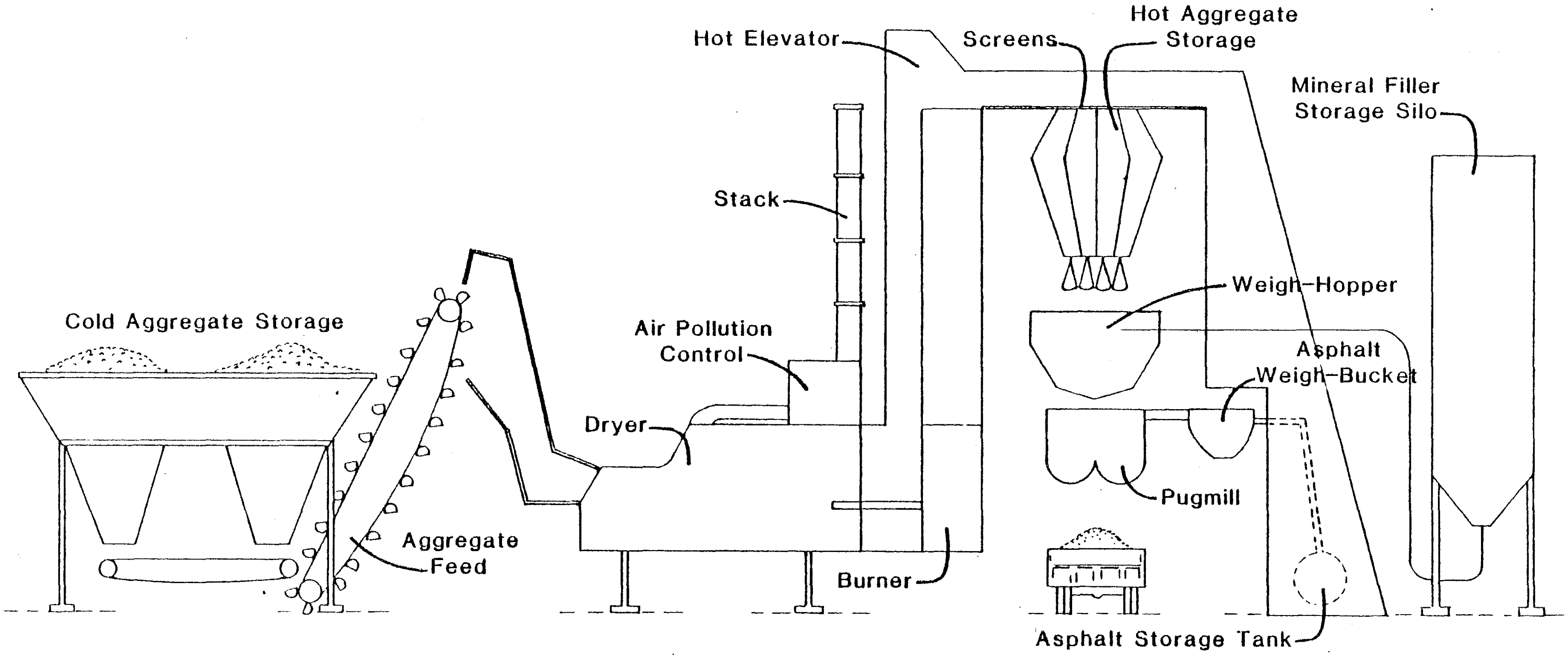
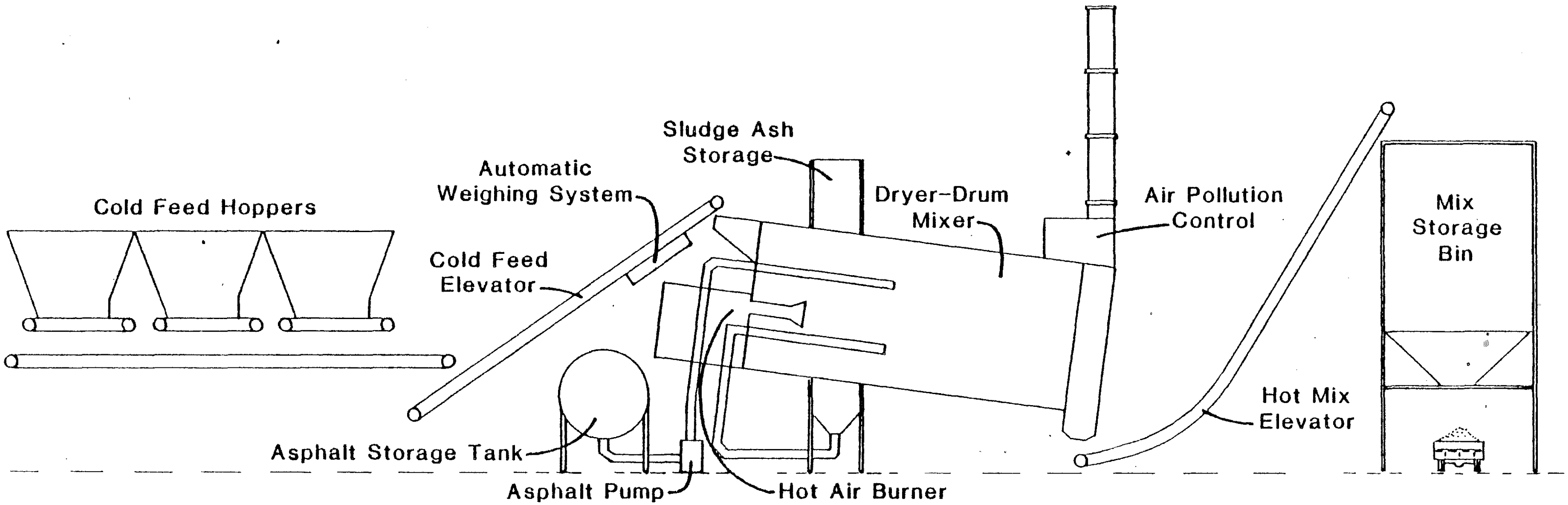


EXHIBIT 5
ASPHALT DRUM MIX PLANT



and hot gasses in the dryer section of the mixer. The dry aggregate is sprayed with hot asphalt in the center portion of the mixer, and the asphalt mix is thoroughly mixed in the latter section. Exhaust air from the dryer-drum mixer is conducted through the air pollution control equipment (wet scrubber or bag house). The asphalt mix is finally conveyed to the asphalt mix storage bin.

The sludge ash would have to be injected into the drum mixer near the injection point for the hot asphalt oil. Adding the sludge ash at this point should result in the "capture" of the ash particles by the asphalt oil.

C. REQUIRED ASH STORAGE AND FEED SYSTEMS

Ash storage and feed systems would be similar to mineral filler systems used at asphalt plant facilities. The location for the addition of the sludge ash into the mix was discussed in the previous sections. For a pugmill plant a pressurized silo can be used, and ash is injected onto the weighing scale using a pressurized line attached to the silo. When the controller calls for the addition of sludge ash, an automatic valve can be opened until the required weight of sludge ash has been deposited onto the scale. The silo would be pressurized by an air compressor which would be controlled by pressure sensors and controllers.

For batch operations a gravity silo and a weighing system for the sludge ash could also be used. Ash can be deposited directly from the silo onto a weighing scale until a predetermined amount of ash has been obtained. The ash would then be blown into the pugmill using an air compressor.

For the drum mix facilities a continuous feed of sludge ash into the mixer would be required. A vane feeder would continuously pull ash from the silo and feed it into an air stream which is directed into the drum mixer. A blower would be required to provide the air flow for conveying the sludge ash. The ash feed rate would be controlled by adjusting the rate on the vane feeder.

2. CONTACTS WITH ASPHALT PRODUCERS IN THE METROPOLITAN AREA

Two mailing lists were prepared for making initial contacts with asphalt producers in the Twin Cities Metropolitan Area. One list contained those member firms of the Minnesota Asphalt Pavement Association (MAPA) that are located in the Metropolitan Area; and another list was based on telephone directory information. Separate cover letters and response forms (see Appendix 2) were prepared, for these two mailing lists. They were mailed, along with self-addressed stamped envelopes, on June 11, 1982 to the asphalt producer firms.

The responses received from the vast majority of the firms which produced asphalt mixes indicated that there was a potential for use of sludge ash in their mixes, and that they were interested in plant visits by the Enviroscience staff. In general, the non-producers of asphalt mix were not interested in using sludge ash in asphalt mixes.

For the plant visits, selection was made of seven asphalt producers that had annual production of at least 100,000 tons. These firms also provided good geographical distribution throughout the Twin Cities Metropolitan Area. The selected firms included the following:

1. Midwest Asphalt Corporation - 2 plants in Eden Prairie and New Brighton; total annual production 100,000 tons.

2. McNamara - Vivant Contracting Company - 1 plant in Apple Valley, annual production 200,000 tons.

3. Bituminous Roadways Inc. - 2 plants in Minneapolis (Cedar Ave.) and Inver Grove Heights; total annual production 150,000 tons.

4. Tower Asphalt Inc. - 1 plant in Lakeland; annual production 150,000 tons.

5. Total Asphalt Construction Company - 1 plant in St. Paul; annual production 200,000 tons.

6. Hardrives Inc. - 2 plants in Plymouth and Shakopee; annual production 200,000 tons.

7. Commercial Asphalt Company - 4 plants in Maple Grove, Burnsville, Newport, and Rosemount; total annual production 625,000 tons.

Telephone calls were made to the senior members of these firms who had signed the response forms received during the mail survey. Plant visits were arranged and conducted during the first half of July, 1982.

Prior to making the plant visits, the Asphalt Plant Interview Form, shown in Appendix 2 was devised. This form provided for entry of responses to a series of basic questions relating to the following:

1. Plant type, condition and outlook

2. Production rates and capacity

3. Material stockpiling purchases

4. Possible storage and feeding of sludge ash

5. Pollution control equipment

6. Overall plant operation

The form also provided for entry of additional comments not covered by standard questions.

Also prepared was a handout item, entitled "Sludge Ash Data Sheet", which presented a summary of basic sludge ash characteristics and available MnDOT test results. This data sheet, shown in Appendix 2, was useful for briefing the person(s) interviewed during the plant visits. Half-pint bottle samples of sludge ash (as simulated in the laboratory) were also brought along on plant visits; they proved to be of considerable interest to the persons interviewed.

The completed interview forms obtained from the asphalt plant visits are presented in Appendix 3. Exhibit 6 shows the location of the asphalt plants which were visited. Presented below are descriptive summaries of the information obtained during the visits regarding:

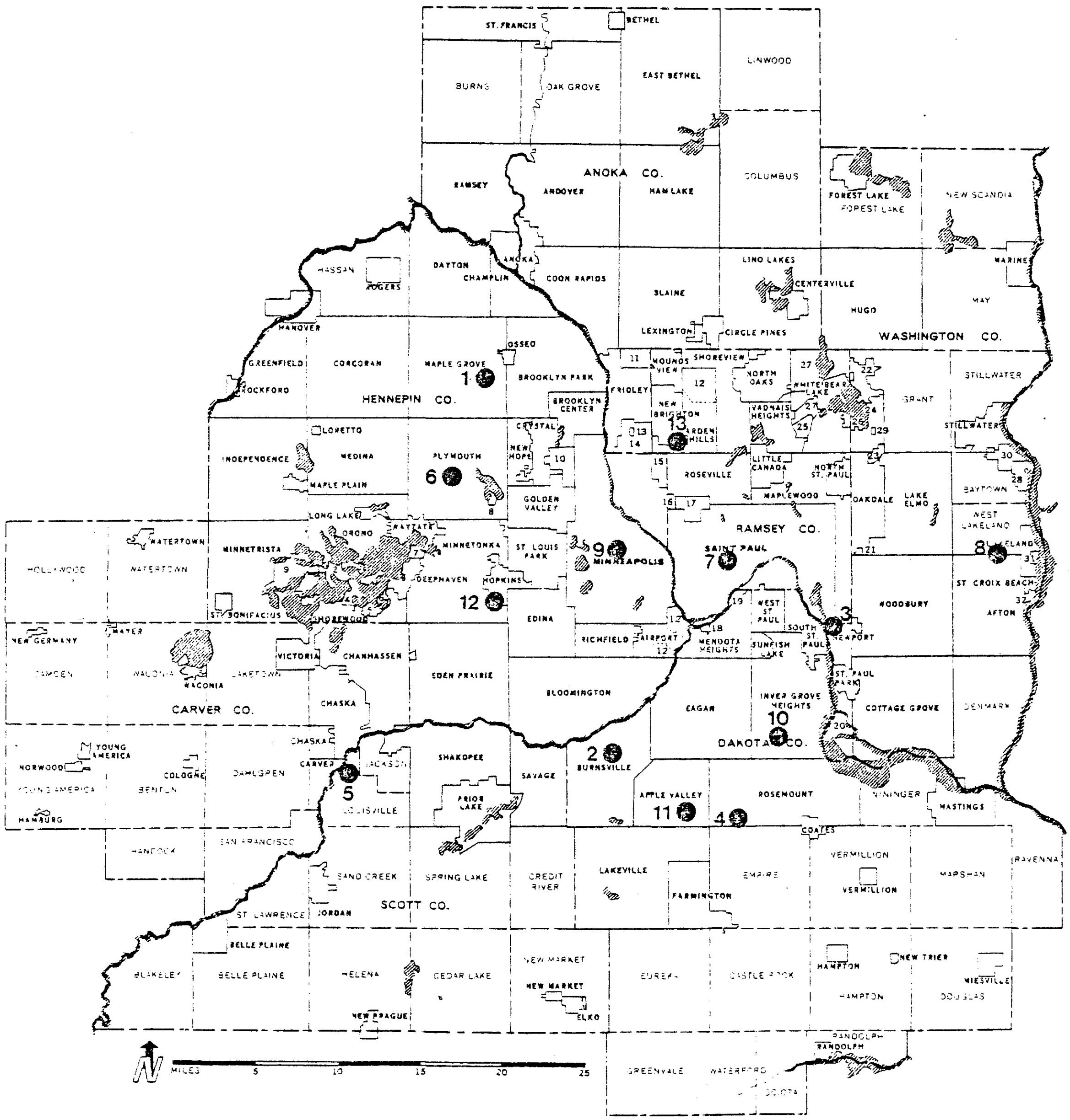
1. Plant type
2. Annual Production
3. Sources of aggregate
4. Stockpiling practices
5. Storage of mineral filler
6. Possible use of sludge ash as mineral filler
7. Possible use of sludge ash in road base aggregates
8. Possible effects of using sludge ash on production times

The names of the firms have been shortened in these descriptive summaries.

A. PLANT TYPE AND PRODUCTION

Midwest has two batch plants in Eden Prairie and New Brighton, with production evenly divided at about 50,000 tons per year apiece. Bituminous has two plants, a batch plant at 2825 Cedar Ave., Minneapolis and a relatively new continuous drum mixer plant in Inver Grove Heights; annual production at these two plants is 60,000 and 90,000 tons, respectively. McNamara - Vivant, Tower and Total have large batch (pugmill) plants, each producing in the range of 100,000 - 200,000 tons/year. Hardrives has two continuous drum mixer plants, each producing about 100,000 tons per year. Commercial has four continuous drum mixer plants in the Metropolitan Area; these plants each produce asphalt road mixes in the range of 100,000-250,000 tons per year.

ASPHALT PLANT LOCATIONS
EXHIBIT 6



TWIN CITIES METROPOLITAN AREA

1. Commercial Asphalt - Maple Grove
2. Commercial Asphalt - Burnsville
3. Commercial Asphalt - Newport
4. Commercial Asphalt - Rosemount
5. Hardrives - Louisville
6. Hardrives - Plymouth
7. Total Asphalt - St. Paul
8. Tower Asphalt - Lakeland
9. Bituminous Roadways - Minneapolis
10. Bituminous Roadways - Inver Grove Hieghts
11. McNamera-Vivianti Contracting - Apple Valley
12. Midwest Asphalt - Hopkins
13. Midwest Asphalt - New Brighton

B. SOURCES OF AGGREGATE

Midwest has its own off-site quarry in Chaska. McNamara - Vivant and Hardrives (both plants) do their own on-site mining. Tower has its aggregate trucked in from Barton's nearby quarry in the Lakeland area. Total and the Bituminous Cedar Avenue plant are supplied from outside sources. Commercial's plants at Maple Grove and Rosemount are located near the aggregate source; their plants at Newport and Burnsville require transport of aggregate in from other sources.

C. STOCKPILING PRACTICES

Aggregate stockpiling practices vary considerably. Midwest, Bituminous and Tower stockpile about a 1-1 1/2 month supply of aggregate. McNamara - Vivant and Hardrives mine their own aggregate at whatever rate is needed to maintain a working stockpile. Total pursues a very tight policy of inventory control. Commercial mines aggregate at two locations and maintains a low inventory at the two other locations.

D. STORAGE OF MINERAL FILLER

Mineral filler is stored in relatively small quantities by Midwest (both plants), McNamara - Vivant, Bituminous (Cedar Ave. plant only), and Total. Currently, Tower does not keep any mineral filler on hand. Hardrives and Commercial do not have any provisions for storing mineral filler.

Mineral filler storage units are in place at Midwest (20 ton units at both plants), McNamara - Vivant (35-40 ton unit), Bituminous/Cedar Ave. (20 ton units), Total (100 ton unit), and Tower (75 ton unit). During the interview, Tower expressed concern about plugging, clogging and bridging problems resulting from moisture pickup during longer-term storage of mineral filler.

E. POSSIBLE USE OF SLUDGE ASH AS MINERAL FILLER

Overall reaction to the idea of using sludge ash as a mineral filler additive in 1-3% concentrations ranged from mildly to moderately interested. Total was most positive of the firm's interviewed with regard to using sludge ash in asphalt road mixes. All persons at the asphalt plants interviewed were interested in getting more information as it becomes available. More definite information from MnDOT, Metro Council and MWCC is required regarding changes in specifications, and possible subsidies, before the asphalt plant operators can decide upon the use of sludge ash as a mineral filler in asphalt road mixes.

F. POSSIBLE USE OF SLUDGE ASH IN ROAD BASE AGGREGATE

Midwest and Bituminous both expressed interest in the possible use of sludge ash in road base aggregates, at concentrations of 15% Midwest and 5% Bituminous.

Follow up contacts were made with (1) Arsenal Sand and Gravel Co., which supplies aggregate to Bituminous Roadways, Inc., and (2) J.L. Shiely, a major supplier of road bases in the Metropolitan area. It was learned that Arsenal Sand and Gravel Co., operates on Federal arsenal property and is restricted, therefore, in terms of bringing in materials such as sludge ash to mix with other onsite road base materials.

The contact with J.L. Shiely revealed an interest on their part in discussing the idea of using sludge ash in road base mixtures; or as fill; however, the firm would first want to test the material's properties thoroughly to protect itself and its customers. Shiely does market a relatively inexpensive sand and gravel by-product that the sludge ash could conceivably be mixed with at 2-3% concentrations. This product, which is sold at $1.75 - 2.50/ton, meets class 5 specifications for road base material. If the sludge ash were to be used merely as fill, this type of product is sold at about $0.67/ton. Shiely's operation on Childs Road is located in close proximity to the St. Paul Metropolitan Plant.

G. EFFECT OF USING SLUDGE ASH ON PRODUCTION TIMES

Midwest and Total expressed specific concerns about the slowdown in production times resulting from the regular use of sludge ash as a mineral filler in road mix production. This factor may be quite important for plants working near the limit of their productive capacity. Consider, for example, Total's batch operation, which makes a 3 ton batch every 45 seconds, or 240 tons per hour, or 1,920 tons per 8-hour day. On a maximum production day (eg: 2,500 tons), accumulations of some seconds per batch (together with several seconds from time to time to resolve clogging problems) are very important, particularly for overtime (time and a half) operations. On a minimum production day (eg: 700 tons), some modest time slippage may not be too important.

Further discussion of the information obtained during the asphalt plant visits is presented in Section VI, D of this report, which deals with the economic factors associated with the transportation, storage and use of sludge ash at the 13 asphalt plants operated by the seven firms interviewed.

3. CONTACTS WITH ASPHALT PRODUCERS OUTSIDE THE METROPOLITAN AREA

Pursuant to a suggestion from MnDOT, contacts were made with two asphalt producing firms, one in Frontenac and the other in Rochester, MN. These operations are located about 50 miles southeast, and 70-75 miles south south-west of the St. Paul Metropolitan Plant. According to MnDOT, the aggregate used in the Rochester/Frontenac region is somewhat round and unstable and could possible benefit from the use of sludge ash as an additive.

Telephone contact was made with the president of Rochester Sand and Gravel; he is also a partner in the North Star Asphalt operation at Frontenac. Completed interview forms were received by mail and are presented in Appendix 3.

The North Star Asphalt operation at Frontenac is producing an estimated 200,000 tons in 1982; however, it was not in production during 1981. Two plants are used - one a pugmill and the other a drum mix facility. The plants and equipment are 8 years old and have a projected remaining lifetime of 7 more years. The aggregate are crushed onsite at relatively low cost. Mineral filler is not used and there are no storage units or feed equipment for handling it.

The Rochester Sand and Gravel plant is a 12-year old batch/pugmill operation, with a projected remaining lifetime of 6 more years. The Rochester operation produced 70,000 tons of asphalt mix in 1981 and is producing an estimated 85,000 tons this year. Over the years, production at the Rochester facility has varied from 70,000 - 190,000 tons/year. Aggregate is trucked into the plant at relatively high cost. Mineral filler is not currently being used; however, a 25-ton silo is in place at the plant, along with pneumatic feed equipment, that could be used for storing and handling sludge ash.

No detailed cost calculations were made for the two non-metropolitan area plants for the following reasons: (1) distances of 50 miles or more from the Metropolitan Plant in St. Paul, and (2) large year-to-year variability in production rates. The Frontenac facility did not operate at all during 1981, and the Rochester plant produced under 100,000 tons annually of asphalt road mix during 1981 and 1982. Although these two asphalt operations would not appear to be primary candidates for sludge ash use on a regular, high level basis, they could still conceivably serve as sludge ash users on a secondary basis. Furthermore, if it can be shown through testing that the sludge ash helps to compensate for the unstable material properties of aggregate mined in the Rochester/Frontenac region, then this could become an overriding reason for its use.

D. ECONOMICS

Initial definition was made of the significant factors that determine the economic feasibility of using sewage sludge ash in asphalt road mixes. Two broad categories were established: (1) the cost of transporting, storing, feeding and process controlling the sludge ash used at asphalt plants, and (2) the cost credits associated with substituting dry sludge ash for fine aggregate material and also by saving on drying costs during the production process.

1. TRANSPORTATION COSTS

The estimated costs of transporting the sludge ash from the MWCC Metropolitan Plant to potential asphalt plants were obtained by contacting a sample of firms that provide truck hauling services in the Twin Cities Metropolitan Area. No railroads were contacted because, with very rare exception, all aggregate that is transported into this metropolitan area's asphalt plants is trucked in.

The first firm contacted, W.&G. Rehbein of Centerville, is the contractor currently handling for MWCC (1) the removal of sludge from lagoons at the Metropolitan and Seneca plants, (2) its transport to the disposal sites, and (3) landfilling operations. The sludge is hauled in 23-24 ton trailers. Under the terms of the July, 1980 contract with MWCC, the following cost figures apply:

Loaded Mileage (one Way)	Incremental Rate Per Ton Mile ($)
0-10 miles	0.55
10-20 miles	0.32
20-30 miles	0.24
over 30 miles	0.20

Further contact with W.&G. Rehbein revealed that above figures had not changed very much, possibly by 5%, if at all. The cost estimates obtained from W.&G. Rehbein apply to a regular hauling truck, which could be covered with a tarpulin covering to help keep the sludge ash dry. The person contacted in this firm felt that a tanker truck was not necessary in order to haul the sludge ash in a dry condition from the Metro Plant to the asphalt plants.

Contact was also made with two firms that haul dry bulk cement in tanker trucks. One firm, Mitchell Transport Inc., of Burnsville, quoted the following rates for a tanker truck of approximately 25 ton capacity, allowing one hour each for loading and unloading:

Loaded Mileage	Cumulative Cost per Ton ($)
0–10	4.89
11–20	5.86
21–30	6.60
31–40	7.09
41–50	8.06

The other firm contacted, Ruan Transport Corp. of Burnsville, quoted the following rates for a 24–ton load, including allowances of one hour each for loading and unloading.

Loaded Mileage	Cost per Ton Mile ($)
0–10	0.42
11–20	0.42
21–30	0.42
31–40	0.42
41–50	0.42

Exhibit 7 shows a plot of the three transportation cost curves based on the information obtained from the three contracting firms. Curve A, representing the cost estimate obtained from Mitchell Transport Inc., was the one adopted for use in this study; it provides for the use of a tanker truck, including one hour each for loading and unloading.

2. STORAGE AND FEEDING COSTS

Contacts were made with a number of firms regarding storage silos and pneumatic equipment of a type that would be generally suitable for use at asphalt plants. Three basic categories of silo (and associated equipment) were examined:

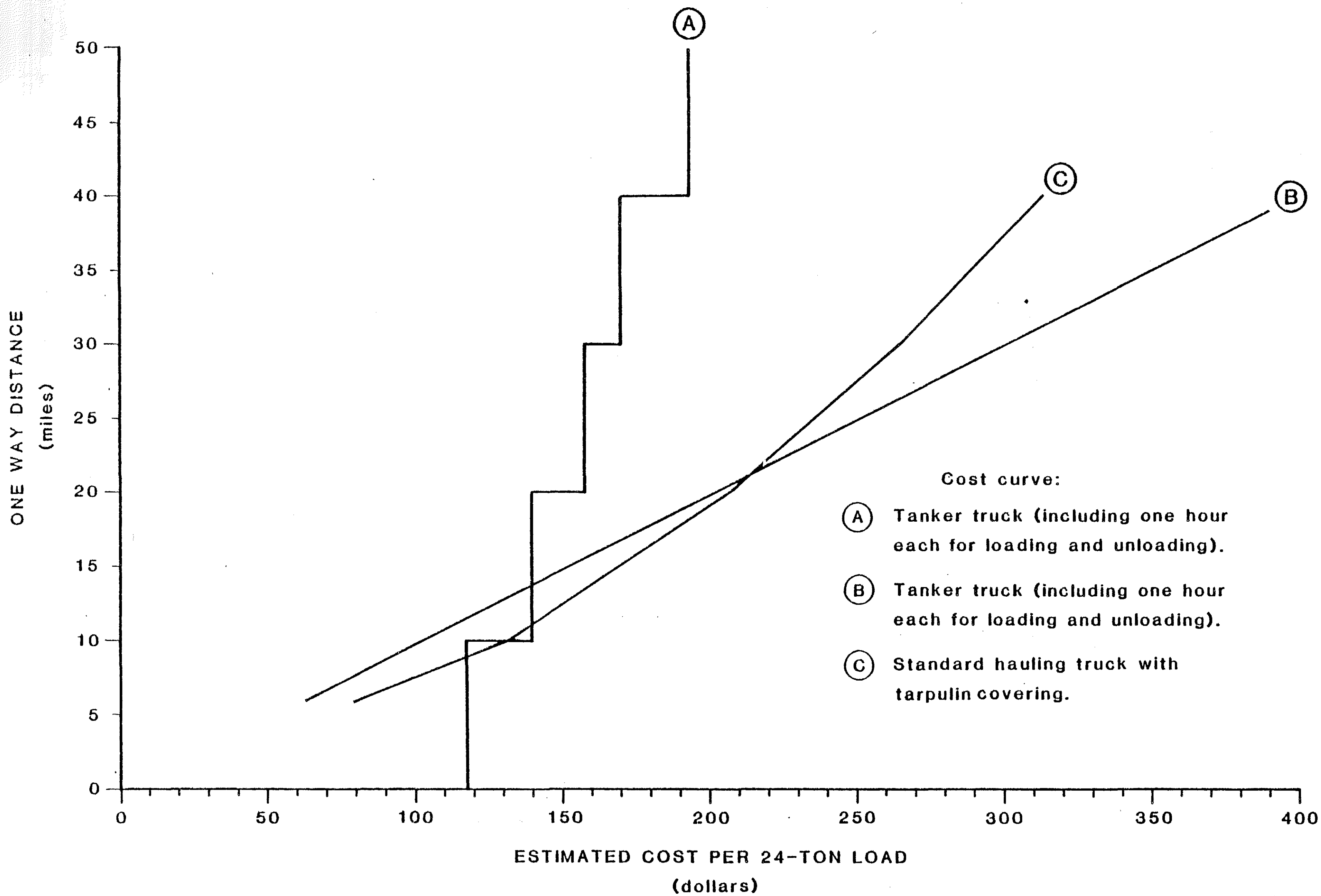
1. Batch process/smaller plant – a pressurized silo of approximately 2,000 ft^3 capacity that could hold about 45 tons of sludge ash assuming a bulk density of 45 lbs/ft^3.

2. Batch process/larger plant – a pressurized silo of approximately 4,000 ft^3 capacity that could hold about 90 tons of sludge ash.

3. Drum mixer/larger plant – a silo of approximately 4,000 ft^3 capacity that could hold about 90 tons of sludge ash.

The capital cost estimate determined for the three basic silos and associated equipment

Exhibit 7
ESTIMATED COSTS FOR TRANSPORTING 24-TON LOADS OF SLUDGE ASH FROM THE MWCC METRO PLANT TO ASPHALT PLANTS.



were as follows:

1. Batch/2,000 ft^3 - \$50,000, including piping, indicators, air compressor and installation.

2. Batch/4,000 ft^3 - \$67,000, including piping, indicators, air compressor and installation.

3. Drum mixer/larger plant - \$76,000, including blower, metering system and installation.

These capital costs were amortized over a 10-year period using an interest rate of 12 1/2%, as applicable for bonds that might be issued by the Metropolitan Council. On this basis, the annual capital costs of the silo/feed systems are as follows:

Capital Cost (\$)	Annual Cost (\$)
50,000	9,100
67,000	12,200
76,000	13,700

Estimates were prepared for the operation and maintenance costs of the storage and feed systems. These costs included the cost of electricity for operating the blowers or compressors, as well as the cost of manpower and spare parts for maintaining the silo/feed systems. The later cost was estimated on the basis of approximately one hour per day over the operating season. Total estimated operating and maintenance costs per plant fall within the range of \$4,000 - 6,000 per year, depending on the type and size of production operation.

3. PROCESS CONTROL COSTS

Another cost factor considered was the cost of necessary adaptations in the process control system to integrate the use of sludge ash into the overall control of the asphalt production. In some cases, the asphalt plant already had an automatic control system that could readily accommodate the use of sludge ash without addition or modification. In other instances, a capital outlay of \$10,000 was provided to automate the sludge ash handling, feeding and weighing operations within the overall process control system. This capital cost of \$10,000 was amortized over a 10-year period at an interest rate of 12 1/2% yielding an annual cost of approximately \$1,800.

4. COST CREDITS

Consideration was given to two types of cost savings that the asphalt plant operators could realize from the use of dry sludge ash in their production process. One cost credit involves the cost of the aggregate for which the sludge ash is to be substituted. For the asphalt plants examined in this study, this cost credit generally varied over a range from $2.50–3.50/ton; however, a value of $1.25/ton was reported by one firm Hardrives that mines its own aggregate at two asphalt plants.

The other cost credit considered was the saving in drying costs resulting from the substitution of dry sludge ash for no-dry aggregate in the production process. This cost credit was estimated to be within the range of $0.75–1.00/ton, depending on the type and scale of production operation.

5. OVERALL COST ANALYSIS

Exhibit 8 presents the cost analysis sheet that was used to calculate the various costs and credits for each of the asphalt plants examined during the study. The two major categories of costs and cost credits are further divided into the subcategories of transportation cost, storage/feed system cost, process control system cost, replaced aggregate cost credit, and aggregate drying cost credit.

The information gathered during the asphalt plant visits was used to complete the cost analysis sheets. Two sets of calculations were made: one based on the use of 3% sludge ash concentration in 80 percent of the volume of road mix produced at a given plant; the other using 3% sludge ash concentration in 60 percent of the volume of road mix producted. Both sets of calculations were performed because it cannot be clearly established at this time how much of the asphalt mix at the plants can utilize sludge ash (see Section VI F, "Projected Acceptance", for further discussion on the use of sludge ash in asphalt mixes). The 60 and 80 percent values provide a reasonable range of estimates for calculating the costs associated with the use of sludge ash at asphalt plants in the Twin Cities Metropolitan Area.

Table 5 presents a summary of costs and cost credits based on $^{3\%}/_{80\%}$ sludge ash use factors; Table 6 is based on $^{3\%}/_{60\%}$ use factors. The "$^{3\%}/_{80\%}$" sludge ash factor denotes its use at 3% concentration in 80% of the volume of road mix produced at a given plant; similarly, the "$^{3\%}/_{60\%}$" factor denotes use at 3% concentration in 60% of the road mix volume produced. For the 13 plants considered during the study, the tables summarize the annual costs and cost credits. Also shown in the tables are the approximate annual production of asphalt mixes at the plants, their distances from the Metro Plant, and the estimated annual use of sludge ash.

EXHIBIT 8

COST ANALYSIS SHEET FOR SLUDGE ASH USED AT ASPHALT PLANTS

(Assuming that the sludge ash is delivered, stored and used in a dry condition)

COSTS

(1) Transportation

a) Mileage to Asphalt Plant

b) Total tons ash shipped

Truck________________

Railroad Car______________

c) Rate per ton mile________________

d) Total Transportation Cost $____________/yr

e) Other

(2) Storage and Feed System Cost

a) Capital Cost (2,000 or 4,000 cu ft silo) $__________________

includes: installation

feed system (batch or continuous)

air compressors or blowers

b) Amortized cost of silo (________years at ______% interest) $__________/yr

c) Maintenance Cost $__________________/yr

(3) Process Control System

a) Estimated cost of adaptations$___________________

b) Amortized cost of adaptations (_________years at_______% interest) $___________________/yr

c) Operating cost $____________________/yr

COST ANALYSIS SHEET (continued)

(4) Total Costs

a) Transportation

b) Storage and feeding

c) Process Control

COST CREDITS

(1) Cost of aggregate (delivered price at asphalt plant) $_______________/ton

$__________/ton x ____________tons = $____________________/yr

(2) Cost of drying replaced aggregate $_____________/ton x ___________tons

=$______________________/yr

(3) Reduction in pollution control costs $__________________/yr

(4) Replacement of filler $_____________/ton x ____________tons = $_______________/

(5) Total Cost Credits

a) Aggregate replacement

b) Drying reduction

c) Pollution cost reduction

d) Filler replacement

In the case of the more optimistic assumption of $^{3\%}/_{80\%}$ sludge ash use factors, Table 5 shows a very wide range in the annual net cost per ton of using sludge ash in the road mixes produced at the 13 asphalt plants. These net costs, which take into account the cost credits, vary over a very wide range: from $1.85 to $14.54 per ton. The most favorable unit net cost was estimated for Total Asphalt, which is favorably located in St. Paul just 8 miles from the Metro Plant, produces about 200,000 tons of asphalt mixes annually, and has a storage/feed system in place that can be regarded as already suitable for use with sludge ash. The least favorable unit net cost was estimated for the Hardrives/Shakopee Plant, which is approximately 45 miles from the Metro Plant, produces about 100,000 tons of asphalt mixes per year, and would require installation of a storage/feed system.

There are five asphalt plants which have unit net cost factors within the range of $6.61–8.31 per ton. There are seven plants at the high end of the distribution which have unit net cost factors ranging from $11.10 to $14.54 per ton. According to Table 5, the six asphalt plants with unit net cost factors of $8.31 or less per ton would be capable of using 25,800 tons per year of sludge ash, or an entire year's production of this material at the Metro Plant, based on a daily output of 70 tons.

Table 5 clearly shows the primary importance of <u>distance</u> from the Metro Plant and <u>annual production volume</u> in assessing the feasibility of sludge ash use at specific asphalt plants.

Table 6, which is based on a $^{3\%}/_{60\%}$ sludge ash use factor, demonstrates the sensitivity of the cost calculations to the amount of sludge ash that is actually used in the asphalt road mixes. The most favorable unit net cost (for Total Asphalt) increases only slighly from $1.85 (Table 5) to $2.25. Other unit net cost values increase somewhat more substantially. The five asphalt plants shown in Table 5 with unit net cost of $6.61 - 8.31 per ton have comparable values of $7.85 - 10.19 per ton in Table 6. Correspondingly, the unit net costs per ton would increase for sludge ash used in concentrations of less than 3% and in road mixes representing less than 60% of total production volume. At some point in such calculations, each asphalt plant considered would pass through a transition from economic feasibility to unfeasibility, depending on where the criteria are set in terms of the costs of disposing of the sludge ash by alternative means.

The cost estimates in Tables 5 and 6 are based on preliminary cost data and estimates for operation and maintenance costs. They can be used to generally compare the cost of using sludge ash in asphalt with the cost of alternative uses. In addition, the net cost per ton is based on estimated cost minus estimated credits for benefits. The Metropolitan Waste Control

TABLE 5

SUMMARY OF COSTS AND COST CREDITS FOR POTENTIAL USE OF SEWAGE SLUDGE ASH AT METRO AREA ASPHALT PLANTS

(3% concentration in 80% of road mix, by volume)

Company/ Plant	Approx. Annual Production of Asphalt Mixes (tons)	Approx. Distance from Metro Plant (miles)	Estimated Annual Use of Sludge Ash (tons)	ANNUAL COSTS Transportation	Storage & Feeding	Process Control	TOTAL	ANNUAL COST CREDITS Aggregate Replace	Drying Reduction	TOTAL	Annual Net Costs Minus Credits	Net Cost/ Ton of Sludge Ash
Midwest Asphalt Corp.												
- Eden Prairie	50,000	26	1,200	7,920	13,100	0	21,020	3,600	900	4,500	16,520	13.77
- New Brighton	50,000	19	1,200	7,030	13,100	0	20,130	3,600	900	4,500	15,630	13.03
McNamara - Vivant Contracting												
-Apple Valley	200,000	22	4,800	31,680	16,200	0	47,880	12,000	3,600	15,600	32,280	6.73
Bituminous Roadways												
-Cedar Avenue	60,000	14	1,400	8,440	13,100	1,800	23,340	5,040	1,080	6,120	17,220	11.96
-Inver Grove Hgts.	90,000	18	2,160	12,660	18,700	1,800	33,160	7,560	1,620	9,180	23,980	11.10
Tower Asphalt												
-Lakeland	150,000	15	3,600	21,100	16,200	0	37,300	10,800	2,700	13,500	23,800	6.61
Total Asphalt												
-St. Paul	200,000	8	4,800	23,470	4,000	1,800	25,270	16,800	3,600	20,400	8,870	1.85
Hardrives												
-Plymouth	100,000	31	2,400	17,000	18,500	1,800	37,300	3,000	1,800	4,800	32,500	13.54
-Shakopee	100,000	45	2,400	19,400	18,500	1,800	39,700	3,000	1,800	4,800	34,900	14.54
Commercial Asphalt												
-Maple Grove	250,000	39	6,000	42,500	19,700	1,800	64,000	15,000	6,000	21,000	43,000	7.17
-Burnsville	150,000	24	3,600	23,800	18,700	1,800	44,300	10,800	3,600	14,400	29,900	8.31
-Newport	125,000	9	3,000	14,700	18,500	1,800	35,000	9,000	3,000	12,000	23,000	7.67
-Rosemount	100,000	27	2,400	15,900	18,500	1,800	36,200	6,000	2,400	8,400	27,800	11.58

TABLE 6

SUMMARY OF COSTS AND COST CREDITS FOR POTENTIAL USE OF SEWAGE SLUDGE ASH AT METRO AREA ASPHALT PLANTS

(3% concentration in 60% of road mix, by volume)

Company/Plant	Approx. Annual Production of Asphalt Mixes (tons)	Approx. Distance from Metro Plant (miles)	Estimated Annual Use of Sludge Ash (tons)	ANNUAL COSTS Transportation	Storage & Feeding	Process Control	TOTAL	ANNUAL COST CREDITS Aggregate Replace	Drying Reduction	TOTAL	Annual Net Costs Minus Credits	Net Cost/Ton of Sludge Ash
Midwest Asphalt Corp.												
- Eden Prairie	50,000	26	900	6,020	13,100	0	19,120	2,700	680	3,380	15,740	17.49
- New Brighton	50,000	19	900	5,340	13,100	0	18,440	2,700	680	3,380	15,060	16.73
McNamara - Vivant Contracting												
-Apple Valley	200,000	22	3,600	23,760	16,200	0	39,960	9,000	2,700	11,700	28,260	7.85
Bituminous Roadways												
-Cedar Avenue	60,000	14	1,080	6,330	13,100	1,800	21,230	3,780	810	4,590	16,640	15.41
-Inver Grove Hgts.	90,000	18	1,620	9,560	19,560	1,800	30,920	5,670	1,220	6,890	24,030	14.83
Tower Asphalt												
-Lakeland	150,000	15	2,700	15,890	16,200	0	32,090	8,100	2,020	10,120	21,970	8.14
Total Asphalt												
-St. Paul	200,000	8	3,600	17,600	4,000	1,800	19,400	12,600	2,700	15,300	8,100	2.25
Hardrives												
-Plymouth	100,000	31	1,800	12,800	18,500	1,800	33,100	2,250	1,350	3,600	29,500	16.39
-Shakopee	100,000	45	1,800	14,500	18,500	1,800	34,800	2,250	1,350	3,600	31,200	17.33
Commercial Asphalt												
-Maple Grove	250,000	39	4,500	31,900	19,700	1,800	53,400	11,250	4,500	15,750	37,650	8.37
-Burnsville	150,000	24	2,700	17,800	18,700	1,800	38,300	8,100	2,700	10,800	27,500	10.19
-Newport	125,000	9	2,250	11,000	18,500	1,800	31,300	6,750	2,250	9,000	22,300	9.91
-Rosemount	100,000	27	1,800	11,900	18,500	1,800	32,200	4,500	1,800	6,300	25,900	14.39

Commission may have to pay a higher cost than the net cost per ton so that asphalt producers would have an economic incentive to utilize the sludge ash.

Another important consideration is that the asphalt plants surveyed generally operate from early May through late November, or about a seven month period. If sludge ash generated outside this time period is to be used in asphalt, it would have to be stored at the Metropolitan Plant. The projected storage at the Metropolitan Plant is 14 to 21 days, using the two storage silos designated for sludge ash. To utilize sludge ash generated from the start of December through the end of April, additional dry storage would have to be provided, or the ash would have to be stored outside and dryed before it is transported to asphalt producers. Therefore, unless additional storage is provided, only the sludge ash generated during the approximate seven-month (or 210 day) period that the asphalt plants are operating can be used in asphalt mixes. At a sludge ash generation rate of 100 tons/day, about 21,000 tons of sludge ash could be used annually in asphalt mixes.

6. COMPARISON WITH COSTS OF LANDFILLING SLUDGE ASH

A. COSTS OF LANDFILLING SLUDGE ASH

A preliminary estimate of the cost of landfilling sewage sludge ash was prepared by members of the Metropolitan Council staff. The cost estimate is based upon the disposal of 100 tons per day, or 36,500 tons per year, of sludge ash transported to a landfill from the Metropolitan Plant in St. Paul.

1. Capital Investment Costs

It was assumed that the capital cost of acquiring a 300-500 acre site and constructing a landfill facility would range from $5-10 million. The lower figure represents the estimate made by the Metropolitan Waste Control Commission in its 201 Study; the higher figure was recently estimated by Metropolitan Council staff. Much of the difference in cost reflects differing opinions regarding the usable depth and liner thickness. In addtion, it is possible that a smaller site could be purchased along with the option to buy additional adjoining land for expansion after, say, 10 years.

A rate of 10 percent interest on bonds over a 20 year period is assumed for financing the landfill acquisition and construction. The calculation of annual cost is as follows:

$5,000,000 x .11746 = $587,300 per year

$10,000,00 x .11746 = $1,174,600 per year

Based upon the disposal of 36,500 tons per year, the annualized capital costs are $16.09/ton and $32.18/ton.

2. Landfill Operation & Maintenance Costs

Based upon knowledge of comparable landfill operations, the Metropolitan Council Staff estimated that, the landfill operation and maintenance (O&M) costs would range between $8-10 per ton. On this basis, the annual O&M cost would total $292,000 - $365,000.

3. . Transportation Costs

For estimation purposes, the Metropolitan Council staff assumed a distance of 25 miles from the Metro Plant to the landfill. A unit cost of $.40 per ton mile was assumed, on the basis of available information. The resultant cost, therefore, is $10/ton for transporting the sludge ash to landfill disposal.

4. Total Costs for Landfilling Sludge Ash

The breakdown of total annual costs for landfilling sludge ash is as follows:

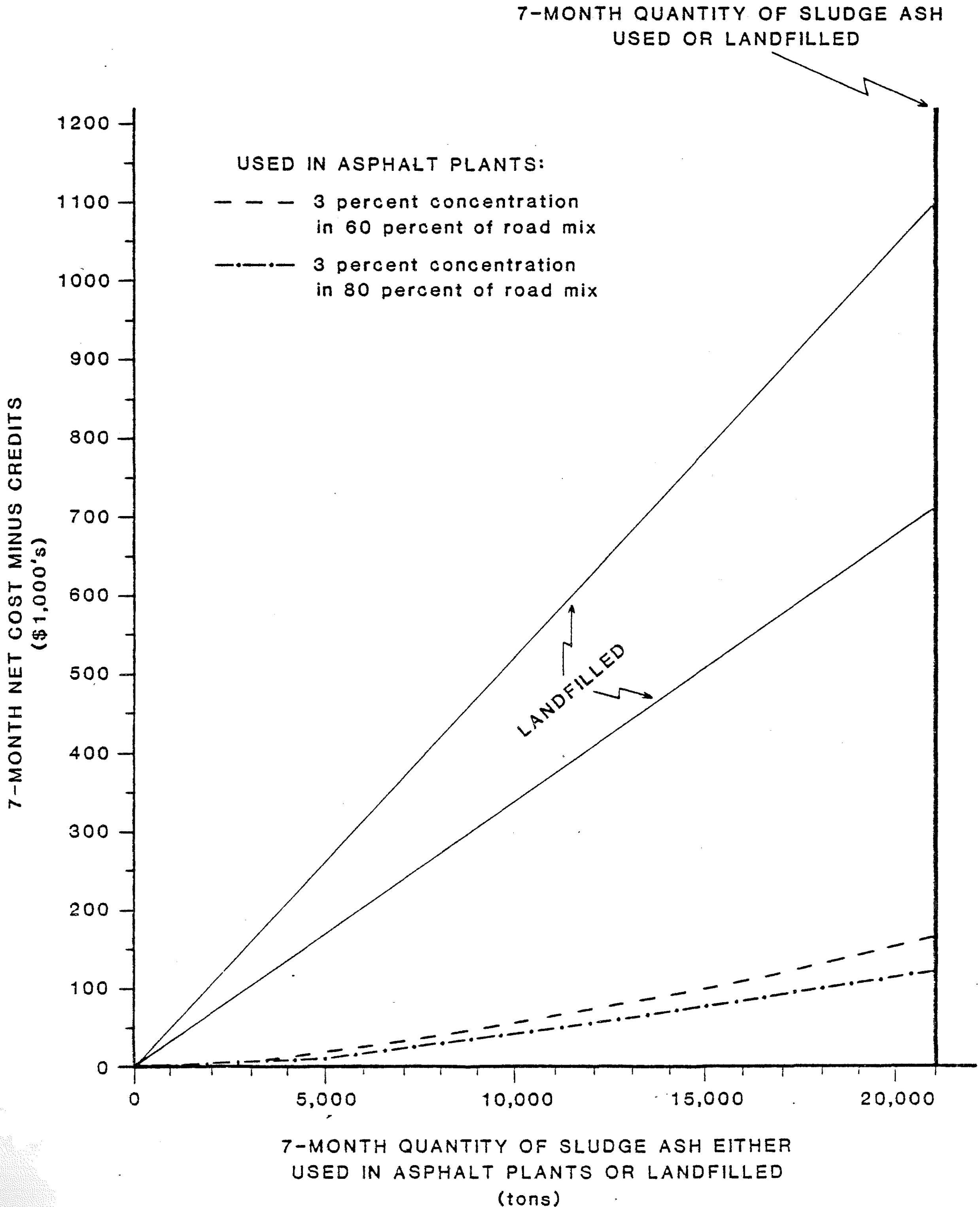
Capital investment	$587,300	$1,174,600
Operation & Maintenance	292,000	365,000
Transportation	365,000	365,000
Total Annual Costs	$1,244,300	$1,904,600
Cost Per Ton	$34.09	$52.18

B. COMPARISON OF COSTS OF USING SLUDGE ASH IN ASPHALT ROAD MIXES VS. LANDFILLING

The cost data presented previously provide the basis for comparing the costs of using sludge ash in asphalt road mixes vs. landfilling. Because of the seasonality of asphalt mix production in the Twin Cities Metropolitan area, two sets of cost comparisons have been developed: one covering the approximate 7-month period from May 1 to November 30, the other, for the entire year.

Exhibit 9 shows the cost comparison for the 7-month period. The cost data are plotted in terms of (1) 7-month quantity of sludge ash either used in asphalt plants or landfilled, and (2) 7-month net cost minus any applicable credits. The vertical line drawn at the value of 21,000 tons represents the approximate 7-month production of sewage sludge ash at the Metro Plant.

Exhibit 9
COMPARISON OF COSTS FOR USING SLUDGE ASH
AT ASPHALT PLANTS VS. LANDFILLING
(7-month asphalt plant operating season).



The "asphalt plant use" curves shown in Exhibit 9 were derived from the cost data presented in Tables 5 and 6. The cost data for the 13 asphalt plants considered were grouped in ascending order of net cost per ton of sludge ash, ie, from the least to the most expensive on a unit cost basis. This is reflected by the curves in Exhibit 9, which show an increasing slope as a function of larger quantity of sludge ash used. As discussed earlier with regard to Tables 5 and 6, two sets of cost data were derived in the study: one set referring to an assumed 3% concentration of sludge ash used in 80% of the road mix produced by the asphalt plants; the other set referring to an assumed 3% concentration of sludge ash used in only 60% of the road mix produced. These two cost data sets are reflected by the two lower curves in Exhibit 9.

The landfill cost curves for the 7-month period are also plotted in Exhibit 9. These curves are based upon the cost estimates made by Metropolitan Council staff.

The cost curves in Exhibit 9 show a considerably lower net cost for using the sludge ash in asphalt plants vs. landfilling it over the seven-month period: approximately $120,000 - 170,000 vs. $716,000 - $1,096,000.

Another cost comparison shown in Exhibit 10, was made on the basis of a entire year: (1) landfilling for 12 months vs (2) using in asphalt plants for 7 months and then landfilling over the remaining 5 months. According to the cost curves in Exhibit 10, the landfilling only option has an annual cost in the range of $1,244,000 - $1,905,000; the combined asphalt plant/landfill option has an annual cost in the approximate range of $660,000-$980,000. In the event that the combined asphalt plant/landfill option were adopted, it is possible that a smaller landfill site (with an expansion option) could be acquired and developed with some considerable saving on capital investment and operation and maintenance costs.

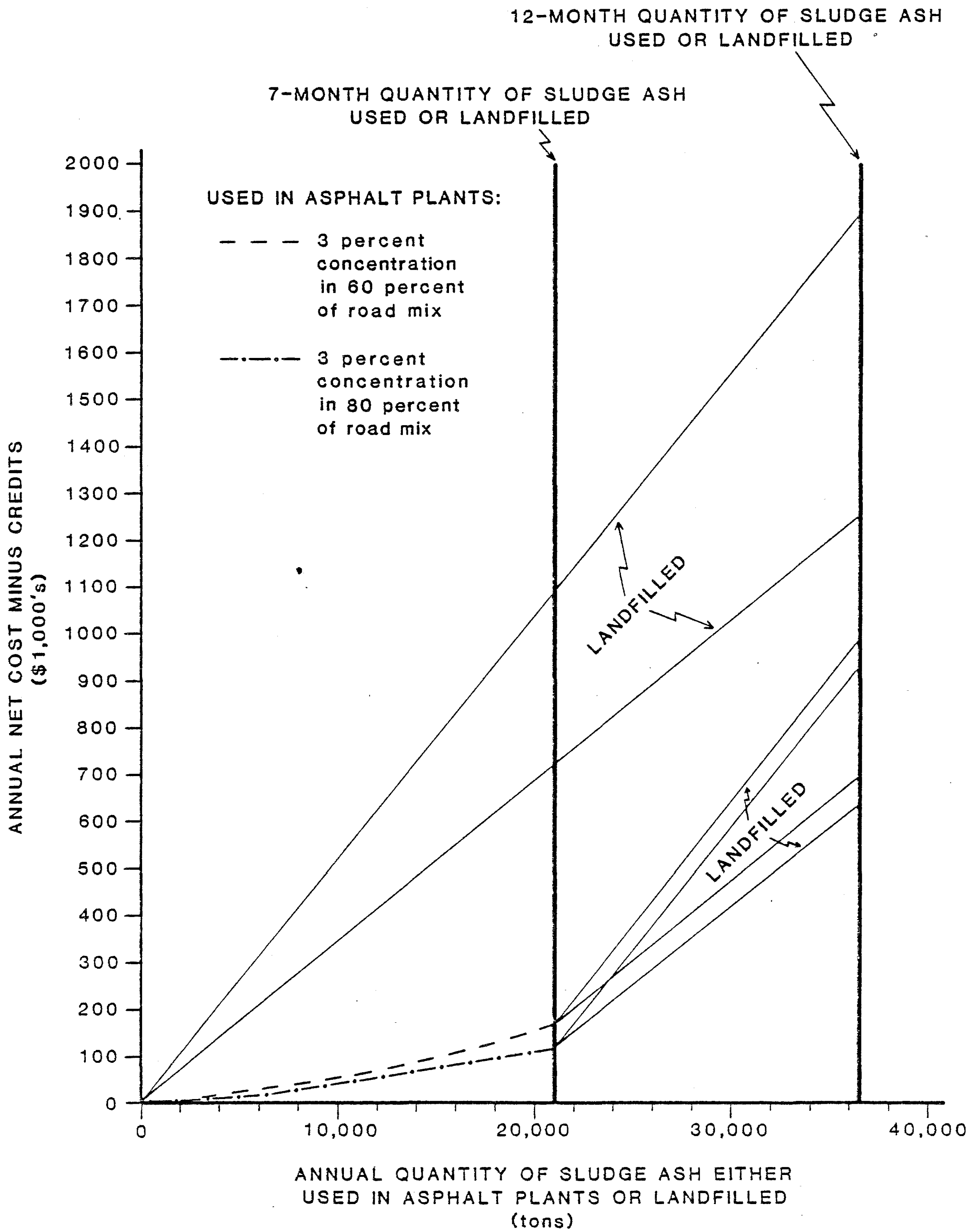
E. POTENTIAL ENVIRONMENTAL EFFECTS

Potential environmental problems that were considered were the loss of material while transporting to the asphalt plant, while storing the material and while injecting the material into the mill. In addition, there is the possibility of toxic heavy metals leaching from the asphalt once it has been placed in service.

The transportation of the sludge ash to the asphalt plant site should be conducted using a closed truck, the same or similar to trucks used to haul cement. The sludge ash would be blown into the storage silos at the asphalt plant using air injection equipment either on the

Exhibit 10

COMPARISON OF COSTS FOR USING SLUDGE ASH AT ASPHALT PLANTS AND LANDFILLING FOR REST OF YEAR VS. LANDFILLING THROUGHOUT ENTIRE YEAR.



truck or provided at the plant. From the silos the sludge ash would be air conveyed to the asphalt drum mixer or pugmill using air tubing or piping. If properly hauled during transportation and storage, very little ash should be lost to the environment.

The sludge ash would be injected near where the asphalt oil is injected so that the "capture" of the sludge ash particles will be high. The sludge ash will not be applied upstream of the dryer section where much of the material will be blown out to the air pollution control equipment (bag house or wet scrubbers). Sludge ash that is not "captured" in the mix near the injection of the asphalt oil will be removed by the air pollution equipment.

Addition of sludge ash to asphalt mixes may increase the particulate loading on the air pollution control system. If a bag house is used, the bags may have to be cleaned more often than if sludge ash was not added to the mix. For wet scrubbers, the flow rates may have to be adjusted to effectively remove the sludge ash particulate material in the exhaust gases. Although it is anticipated that the particulate material in the exhaust gas may increase slightly with the use of sludge ash, existing air pollution control equipment at asphalt facilities should remove this material to acceptable MPCA levels.

In the cold water abrasion tests performed by the Minnesota Department of Transportation (Section VI, B) the water used was analyzed for total and soluble heavy metals. The laboratory results are shown in Table 7. The asphalt mix used in the cold water abrasion tests had sludge ash contents of 2% and 3%. The concentrations of the total metals were much higher than the concentrations for the soluble metals, probably because of the high amount of particulate material that was sheared off the asphalt samples during the test. The concentrations for total metals were below the EPA limitations for safe drinking water in all but two cases. These results indicate that there would be very low concentrations of heavy metals in water which would leach through asphalt pavement containing sludge ash.

F. PROJECTED ACCEPTANCE

In general, asphalt mix producers in the Metropolitan Area were receptive to using sludge ash in their mixes. The two biggest concerns were that (1) using sludge ash in their mixes would have to be economically feasible and (2) mixes containing sludge ash would have to be acceptable to the Minnesota Department of Transportation or other agencies which would be releasing specifications for asphalt used in road construction or repair. The economic aspects of using sludge ash are discussed in a previous section. It would appear that there

TABLE 7

ANALYSIS OF COLD WATER ABRASION TEST WATER

(Tests Performed by MWCC, June, 1982)

Concentrations - ug/1

	Primary Drinking Water Standards*	2% Ash in Mix		3% Ash in Mix	
		Total	Soluble **	Total	Soluble **
Arsenic	50	11.8	1.0	4.8	1.0
Barium	1,000	100	0	144	1
Cadmium	10	4.5	0.1	4.3	0.1
Chromium	50	88.8	3.6	41.7	1.7
Lead	50	52	4.0	0.2	0.2
Mercury	2	0.2	0.2	0.2	0.2
Selenium	10	2	2	2	2
Silver	50	7.0	0.2	13.8	0.2

* CFR Vol. 40, No. 248, December 24, 1975, Page 59570

** 0.45 M filter

would have to be some kind of economic incentive or benefit to asphalt producers in order for them to use the sludge ash. For example, the Metropolitan Waste Control Commission might be asked to pay for all or some of the (1) cost of transporting the sludge ash to the asphalt plant, (2) storing the sludge ash at the plant site, and (3) plant operation in using the sludge ash.

The second major concern of plant operators was that the asphalt mixes containing the sludge ash would have to be accepted by the Minnesota Department of Transportation. In discussions with MnDOT personnel, they indicated that asphalt mixes containing up to 3% sludge ash would be suitable for binder courses. At this time, they would not allow the sludge ash to be used in asphalt mixes used for wear courses on roads although they may allow asphalt mixes containing sludge ash to be used in wear courses on road shoulders. Because cracking problems have been associated by Mn/DOT personnel with mineral filler, there is a concern that the use of sludge ash in asphalt wear courses may increase cracking. For the sludge ash to be approved for use in asphalt wear courses on roads, trial sections of roads may have to be paved with asphalt mixes containing sludge ash, and the wear on these sections would have to be compared with the wear on control sections where sludge ash was not used. It would probably take a number of years before the effectiveness of asphalt wear courses containing sludge ash could be evaluated using this method.

Restriction of the use of asphalt mixes containing sludge ash to non-wear courses, with possible exceptions of shoulder wear, would limit the use of sludge ash in asphalt road mixes. The majority of the mixes specified as 2341 and almost all of the mixes specified as 2361 are used in wear courses. The majority of the mixes specified as 2331 would be used in binder or non-wear courses. In very general terms, the majority of 2331 asphalt mix and a portion of the 2341 asphalt mix could utilize sludge ash. Further work and follow up studies should be conducted to investigate the use of sludge ash in asphalt wear courses.

Use of sludge ash in mixes having poor aggregate will increase the stability of the mix and may enable the reduction of asphalt oil content. Aggregate from the southeastern portion of the state is generally "well-rounded" which contributes to stability problems in the mix. The additional cost of transporting the sludge ash longer distances to asphalt plants using this type of aggregate would have to be balanced by improved balanced by improved quality of the mix and by cost savings such as the reduction of asphalt content in the mix.

VII USE OF SLUDGE ASH IN CONCRETE

A. GENERAL

Since approximately 5.5 million tons of concrete is used in the Metropolitan Area, the potential use of sludge ash in concrete mixtures was evaluated. Fly ash, obtained from coal burning power plants, has been used for a number of years as a partial cement replacement in concrete. Although sludge ash has some characteristics which are similar to fly ash, sludge ash has lower combined silicon oxide, iron oxide and aluminum oxide (50% for sludge ash compared with 75% for fly ash) and a high phosphorus pentoxide content which may limit its use in concrete. Because of the suspected low pozzolanic activity of sludge ash, very low percent replacements of the cement and fine aggregate in concrete mixes were considered.

To evaluate the use of sludge ash, a concrete testing program was conducted by Twin City Testing and Engineering Laboratories, Inc. (TCT). After test results were obtained, a meeting was held with staff from J.L. Shiely Company to discuss the potential of using sludge ash in concrete mixes.

B. TESTING RESULTS

Twin City Testing conducted tests to determine the pozzolanic activity of the sludge ash and to determine the feasibility of using the sludge ash as a partial replacement of the cement and fine aggregate in concrete. The detailed test results, as reported by TCT, are presented in Appendix 4. The testing for pozzolanic activity was conducted in accordance with ASTM: C-311-77. Control cubes containing cement and Ottawa sand and test cubes containing 35% (by volume) sludge ash, cement and Ottawa sand were crushed to determine their compressive strengths. Test cubes containing lime, sand and sludge ash were also tested for compressive strength. In addition, during this test the fineness, specific gravity, water requirement and soundness of the sludge ash were also evaluated. The results, shown in Appendix 4, indicated that the pozzolanic activity of the sludge ash did not meet ASTM: C618 specifications.

Trial concrete mixes were also prepared using the following:

1. A concrete batch without sludge ash.

2. A 5% cement replacement by weight with sludge ash.

3. Fine aggregate replacement using 2% of the total batch weight replaced by the sludge ash.

4. Fine aggregate replacement using 4% of the total batch weight replaced by the sludge ash.

Both the cement and aggregate were tested before mixing using the appropriate ASTM test procedures.

Nine compression cylinders were cast for each batch and were tested in sets of three at 3, 7, and 28 days. The detailed results are shown in Appendix 4. The average compression strengths (based upon the percent of control strength) for the batches are summarized below:

Compression Strengths (Control–100%)
Mix Number
(Corresponds to previous listing of mixes)

Time	1	2	3	4
3 Day Test	100.0	98.0	96.2	83.3
7 Day Test	100.0	98.5	99.6	65.2
28 Day Test	100.0	98.9	100.0	72.8

These results indicate that there is no significant difference in compression strength between batches 1, 2 and 3. For batch 4, containing 4% (by batch weight) replacement of the fine aggregate, the compression strength was significantly reduced.

The initial and final set times of the mixes increased with increasing amounts of sludge ash in the mix. These set times may effect the amount of construction crew time needed to remove concrete forms, which could result in higher installation costs for concrete containing sludge ash.

C. PROJECTED USE IN CONCRETE

Enviroscience and Metropolitan Council Staff met with representatives of J.L. Shiely Company to discuss the possible use of sludge ash in concrete mixes. Based upon the preliminary results shown in Appendix 4 and discussions at this meeting, possible uses of sludge ash in concrete include:

1. A partial replacement for the cement
2. A partial replacement for the fine aggregate
3. A partial replacement for the coarse aggregate
4. A partial replacement of both cement and fine aggregate.

1. PARTIAL CEMENT REPLACEMENT

Twin City Testing indicated that the sludge ash could be used up to a 5% replacement of the cement without adverse effects on compressive strength. One problem with this use is that the sludge ash does not meet the pozzolanic activity portion of ASTM: C618-80 which covers the use of miner admixtures in Portland Cement Concrete. However, the 5% cement replacement recommended by TCT is much lower than the 35% cement replacement called for in the pozzolanic activity test, ASTM: C311-77. To utilize the sludge ash as a cement replacement, changes in ASTM C618 may have to be made to allow a maximum replacement, say 5%, of cement by sludge ash.

The delivered price for cement is approximately $68.00 per ton. Five percent replacement of the cement in the mix would result in a cement savings of about $.95 per cubic yard of concrete. This cost savings would be offset by the cost of shipping the sludge ash to the concrete mix plant and storing the ash at the plant.

2. PARTIAL FINE AGGREGATE REPLACEMENT

Based upon the Twin City Testing results, a fine aggregate replacement using 2% of the total batch weight replaced by the sludge ash, did not effect the compressive strength of the concrete. Compressive strength significantly decreased for a 4% replacement (based on total mix weight) of the fine aggregate. The 4% replacement probably resulted in too many fines within the mix to obtain an adequate cement bond. Gradation of the fine aggregate is specified by ASTM: C136, which includes the requirements that 2%-10% of the fine material shall pass a #100 sieve and a maximum of 5% (3% for concrete subject to abrasion) shall pass a #200 sieve. The latter requirement would be the most critical regarding the replacement of fine aggregate with sludge ash.

Approximately a 1.8% (percent of total mix weight) replacement of the fine aggregate could be obtained based on the limitations of ASTM: C136 and the following criteria:

1. About 1.5% of the fine aggregate (before addition of sludge ash) passing a #200

sieve.

2. 75% of the sludge ash passing a #200 sieve.

This allowable percent replacement of the fine aggregate would vary depending upon the amount of fines in the aggregate and sludge ash.

The cost of the fine aggregate is $3.00/ton; and at 1.8% replacement, the aggregate savings would be approximately $.11 per cubic yard of concrete. The material cost savings would be lower for fine aggregate replacement than for cement replacement; however, the use of sludge ash per cubic yard of concrete would be almost three times greater for fine aggregate replacement than for cement replacement.

3. PARTIAL COARSE AGGREGATE REPLACEMENT

To utilize the sludge ash as a coarse aggregate replacement, a pelletizing process would have to be used to obtain a larger sludge ash particle size. Although a pelletizing process for sludge ash was not investigated during this study, a binding agent may be required to obtain the aggregate strength required by the sludge ash particles for use as larger aggregate in concrete. To utilize sludge ash as a partial replacement of the larger aggregate, ASTM specifications C33 and C136 would have to be met.

The cost of coarse aggregate is $6.00/ton and is expected to increase more rapidly than the cost of fine aggregate due to expected future shortages of large aggregate. Replacement of the larger aggregate by pelletized sludge ash (if technically feasible) would result in higher material cost savings than replacement of the fine aggregate. However, the cost of pelletizing the sludge ash may be prohibitive.

4. PARTIAL REPLACEMENT OF BOTH CEMENT AND FINE AGGREGATE

A partial replacement of both cement and fine aggregate would be limited by ASTM: C618 (pozzolanic activity) and ASTM: C136 (fine aggregate gradation). As previously discussed, ASTM: C618 would have to be changed so that sludge ash could be used as a partial cement replacement. ASTM: C136 would not have to be changed; however, it would essentially limit the replacement of the fine aggregate by the sludge ash. For this alternative, material cost savings between $.12 and $.95 per cubic yard of concrete, and sludge ash usages of between 26 and 72 pounds per cubic yard could be obtained.

D. PROJECTED ACCEPTANCE

According to representatives of J.L. Shiely Company, the use of sludge ash in concrete would depend upon acceptance by the engineering community and economics. Acceptance by the engineering community could include the inclusion of sludge ash in concrete specifications for larger projects and the alteration of ASTM: C618 to allow some percent replacement of the cement by sludge ash. The potential for sludge ash use would also be increased if Minnesota Department of Transportation (MnDOT) specifications for concrete could be written to allow certain uses of sludge ash. As a trial, the Metropolitan Waste Control Commission could require that sludge ash be used in concrete sidewalks and parking lots for the East Battery expansion project. The performance of the concrete containing sludge ash could then be observed after several freeze-thaw cycles. Additional tests, as recommended by Twin City Testing, could also be conducted including freeze-thaw durability, alkaline reactivity, dry shrinkage, and abrasion resistance.

Even if the use of sludge ash in concrete is accepted by the engineering community, there must be enough economic incentive for the concrete producers to utilize this material. Cement and aggregate savings by replacement with sludge ash have been discussed in the previous section. These savings will be offset by the shipping of the sludge ash to the plant, and the storage and handling of the material at the site. It is expected that the Metropolitan Waste Control Commission would have to subsidize the use of ash by paying for the transportation, storage and possibly, the handling of the ash.

Another economic consideration which could effect the use of sludge ash is set time. Testing results obtained by Twin City Testing indicated that the set time of the concrete increased with the increased percentage of sludge ash used in the mix. Increased set time could add to the installation cost of concrete by increasing the required crew time. Set times for concrete containing sludge ash can be decreased by the addition of non-chloride accelerators. These additives, however, are expensive and may add up to $3.00 per yard of concrete mix.

VIII USE OF SLUDGE ASH IN ASPHALT SHINGLES

A. GENERAL

Because mineral filler is used in asphalt shingle mixes, the use of sludge ash was considered as a possible replacement of the filler.

Asphalt mix generally contains two grades of asphalt oil (about 40-50% of the mix) and filler (50-60% of the mix). Limestone dust and silica sand are generally used as fillers in the asphalt mix. The asphalt mix, or coating, is applied to both sides of a saturated felt or glass mat. After coating, colored slate granuals are applied to the front of the sheet and a dusting of sand or sand talc is applied to the back of the sheet. For self adhesive shingles, adhesive strips are attached to the back before dusting with sand or sand talc. The shingles are then cooled, dryed and cut to the proper size.

Two asphalt shingle plants are located in the Metropolitan Area, GAF and CertainTeed. The GAF plant is located in North Minneapolis and the CertainTeed plant is located in Shakopee. Data sheets and samples of the sludge ash were sent out to representatives of both companies. GAF expressed an interest in conducting a testing program on the ash material, and at their request, additional ash material was sent to their research lab[4] in Wayne N.J. CertainTeed personnel expressed a concern that the phosphorus pentoxide content (P_2O_5) in the ash material was too high and could be formed into corrosive phosphoric acid. Enviroscience personnel contacted personnel from CertainTeed to point out that the pH of the ash when mixed with water was 6-7 and that the phosphorus pentoxide in the ash was relatively stable and non-reactive. CertainTeed still was not interested in conducting a testing program to evaluate the ash material for use in asphalt shignesl.

B. POTENTIAL USE

The potential uses for sludge ash would be as a filler in the asphalt mix and as a mating on the back sides of the shingles to prevent the shingles from sticking after they are bundled. The best use of the sludge ash, from the standpoint of quantity used and cost advantages, would be as a filler in the asphalt mix.

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[4] the contact person at the lab is Fred Sieling (201-356-3000)

Preliminary tests were conducted by GAF using the sludge ash sent to them. The ash was obtained from incinerating the heat treated sludge in the pilot scale furnace and had chemical characteristics similar to those shown in Table 2. GAF obtained a bulk dry density of 32 pcf (pounds per cubic foot) which was lower than the expected bulk dry density of 40-45 pcf which should be obtained for the ash when the incineration equipment is operational. As a filler material, GAF would like to have a 60-80 pcf bulk density, minimum density acceptable to them is 50 pcf. GAF also tested the viscosity of the asphalt mix containing 60% sludge ash by weight. The viscosity of the mix was about 30,000 centipoise which is much higher than a desired viscosity of 2,000-10,000 centipoise. An excessive viscosity would prevent the mix from spreading properly on the felt or glass mat.

These tests indicate that the bulk density is too low and viscosity is too high for the ash which was tested, to be used as a filler. During the time this report was written, GAF personnel were grinding the material to 80-90% passing #200 to determine how much the bulk density and viscosity would change. However, even with the smaller particle size, the viscosity may still be too high to be used as a filler. Other alternatives should still be considered are the use as a partial replacement of the limestone filler in the mix and as a coating on the back sides of the shingles.

IX USE OF SLUDGE ASH IN FERTILIZER MIXES

A. GENERAL

Because of its high lime (CaO) and phosphorus pentoxide (P_2O_5) content, sludge ash was considered for use in fertilizers. Further testing was conducted to determine the amount of extractable phosphorus and other minerals which could be obtained from the ash and to determine the calcium carbonate equivalent of the material. After obtaining these results, a number of fertilizer blenders, producers and distributors were contacted to determine if they had an interest in utilizing this material.

B. CHARACTERISTICS RELATED TO USE AS FERTILIZER

The primary chemical constituents of the sludge ash (from Table 2) which are related to its use as fertilizer include the following:

Parameter	%
Calcium Oxide	20.97
Magnesium Oxide	3.21
Potassium Oxide	.63
Phosphorus Pentoxide	20.2

This analysis of the sludge ash indicates relatively high concentrations of lime and phosphorus pentoxide which, available for plant uptake, would be of some value as a fertilizer.

To determine the available nutrients in the ash, a sample was submitted to the Department of Soil Science at the University of Minnesota. This department ran tests which are commonly used by the industry and the following results were obtained:

Extractable Potassium	183 ppm[5]
Extractable Calcium	2,757 ppm
Extractable Magnesium	432 ppm
Extractable Sodium	70 ppm
Extractable Manganese	14 ppm

[5] parts per million

Calcium carbonate equivalent	8.51%
Brady's #1 phosphate	6,740 ppm (as phosphorus)

The extraction was conducted using 1N ammonium acetate for the potassium, calcium, magnesium, sodium and manganese analyses and was conducted using .03N ammonium fluoride for Brady's #1 phosphate.

These tests indicate that the available nutrient levels in the ash are very low. The total lime percent in the ash is around 20%, whereas the calcium carbonate equivalent of that lime is only 8.51%. The phosphorus pentoxide content is also around 20% (8.8% as phosphorus), whereas the available phosphorus is 0.67%. The phosphorus within the ash was highly oxidized during incineration and very little would be available for plant uptake.

There are methods available to treat the phosphorus in the ash with sulfuric acid to convert it to a more available form. These methods should be further investigated, and cost estimates for processing the ash should be determined.

C. FERTILIZER COMPANY CONTACTS

Fertilizer companies were sent information on sludge ash along with a brief questionnaire. These items are shown in Appendix 5. The companies, listed below, that were contacted included fertilizer producers, blenders, and large distributors.

Cenex Service Center
Inver Grove Heights

Cominco American Inc.
Minneapolis

Farm Service Cooperative
New Brighton

Farmland Industries, Inc.
St. Paul

Howe Inc.
Minneapolis

Midwest Feed and Seed
South St. Paul

Multi-Marketing International
Minneapolis

Land O'Lakes
Minneapolis

Peavy Company
Minneapolis

Cargill Inc.
Wayzata

Only two responses were received to the letters that were sent out. One response was from Howe Inc., which is a fertilizer producer and distributor. This firm would not be interested in using this material mainly because of reasons which are listed below. The second response was obtained from Farmland Industries Inc. This firm only distributes ready-mixed materials and would not be able to handle the sludge ash. Follow-up phone calls were made to several of the fertilizer companies listed above with no positive response for using sludge ash.

D. POTENTIAL ENVIRONMENTAL EFFECTS

The main potential environmental problem in utilizing the sludge ash as a fertilizer would be the heavy metals, particularly cadmium, chromium and lead. These metals could limit the amount of ash that could be spread on agricultural lands. Procedures similar to those used to determine the amount of sewage sludge which can be applied on land, would also have to be used for applying sludge ash on land.

E. PROJECTED ACCEPTANCE

Without extensive processing to extract the phosphorus and therefore convert it to a more useable form, the acceptance of the sludge ash for use as a fertilizer is expected to be low for the following reasons:

1. The available phosphorus and the calcium carbonate equivalent of the ash (less than 1% available phosphorus and about 8.5% calcium carbonate equivalent) is relatively low. There is very little fertilizer value in the sludge ash.

2. In the dry form the sludge ash would be difficult to apply since it would tend to blow around. Usually dry fertilizer is granulated so that it can be applied in the dry state. Liquid fertilizer consists mainly of water, a clay (non-abrasive filler) and nutrient salts which have been blended in. The ash may be too abrasive as a filler in liquid fertilizers.

3. As discussed previously, the presence of heavy metals, particularly cadium, lead

and chromium, could limit the amount of ash which can be applied to land, or correspondingly, limit the use of ash as a fertilizer.

X USE OF SLUDGE ASH IN CONCRETE BLOCK, REFRACTORY BRICK, FOR TREATMENT OF ACID MINE DRAINAGE AND MINERAL RECOVERY

The Metropolitan Council staff investigated the potential for sludge ash use in the manufacture of concrete block and refractory bricks. A sample of ash was sent to A.P. Green Refractories Company for its evaluation to determine the ash could be used in making refractory brick. The company determined that the percentage of alkalies in the ash was too high, rendering it unsuitable for their use (see letter in Appendix 6).

The Metropolitan Council staff also contacted Anchor Block Company in North St. Paul to determine whether the ash could be used in making concrete blocks. Anchor Block said that the ash was too fine a material for use in blocks.

The U.S. Department of the Interior, Bureau of Mines, was interested in testing the potential of sludge ash to neutralize and precipitate heavy metals from acid mine drainage. The Bureau's preliminary testing revealed that the sludge ash obtained from sewage sludge that was conditioned with lime and ferric chloride is effective in precipitating heavy metals and additional testing will continue. However, sludge ash obtained from the sewage sludge that has undergone heat-treatment was not effective in precipitating heavy metals. Table 8 shows the Bureau of Mines' test results. (see letter from Bureau of Mines, Appendix 7).

Samples of sludge ash obtained from both the lime and ferric chloride conditioned sewage sludge and heat-treated sewage sludge were sent to Canadian Waste Technology Inc. CWT specializes in mineral recovery from ash and other waste products and in solidification of hazardous wastes. CWT has contracts for removal of sludge ash with the municipal wastewater plants in Toronto and Hartford, Connecticut.

CWT evaluated the chemical composition and characteristics of the sludge ash to determine the feasibility for mineral recovery. CWT has indicated it is very interested in using the sludge ash and would like to do additional testing and evaluation of the treatment plant.

However, CWT would prefer to inspect the Metropolitan Plant in St. Paul after the new incinerators come on line; this is expected to occur in early 1983. If the company determines that mineral recovery is feasible, it would be interested in making a long-term contract for sludge ash removal similar to its contracts with the Toronto and Hartford treatment plants.

TABLE 8

REMOVAL OF HEAVY METALS BY
PRECIPATION WITH ALKALINE MATERIALS

(Preliminary Test Results From the U.S.
Department of the Interior, Bureau of the Mines)

Material Tested	Dosage, g/l	Metal Concentrations mg/l		
		Cu	Mn	Zn
Lime conditioned fly ash	1.21	<0.10	5.7	<0.10
	2.05	<0.10	0.39	<0.10
	4.15	<0.10	.06	<0.10
	0.62	<0.13	12.0	3.6
Coal incineration fly ash	0.625	<0.10	0.46	<0.10
	1.27	<0.10	.06	<0.10
	0.27	0.22	13.9	6.9
Untreated head sample		10.8	15.1	12

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XII ACKNOWLEDGMENTS

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- Tower Asphalt Co./Mr. Bob Springer
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- Hardrives Inc./Mr. Barton Lund and Mr. Dan Ramer
- Commercial Asphalt Co./Mr. Brad Olson and Mr. Richard Peterson
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- TRANSPORTATION SERVICES
- W.G. Rehbein Bros./Mr. Tom Bell
- Mitchell Transport Inc./Mr. Dan Haffner
- Ruan Transport Corp./Gail Bendt

XIII. APPENDICES

APPENDIX A. MINNESOTA DEPARTMENT OF TRANSPORTATION (Mn/DOT) ASPHALT TESTING RESULTS

APPENDIX B. ASPHALT PRODUCER/CONTACT AND EVALUATION SHEETS

Cover Letter
Response Form
Data Sheet
Interview Form

APPENDIX C. COMPLETED INTERVIEW FORMS (Shown in Volume II)

APPENDIX D. RESULTS OF CONCRETE TESTS

APPENDIX E. FERTILIZER PRODUCER CONTACT SHEETS

Cover Letter
Response Form
Data Sheet

APPENDIX F. LETTER FROM A.P. GREEN REFRACTORIES COMPANY

APPENDIX G. LETTER FROM U.S. DEPARTMENT OF INTERIOR

APPENDIX A

AGGREGATE GRADATIONS

T.M. No.	Aggregate No.	%Sludge Ash	3/4"	5/8"	1/2"	3/8"	#4	#10	#40	#200	Aggregate Source	Aggregate Contractor
81301A	81752	0	100	100	95	86	66	55	23	5	Barton	Total Asphalt
81301B	81751 & 52	1	100	100	95	86	66	55	24	6	@ Lake-	"
81301C	81751 & 52	2	100	100	95	86	67	56	24	6	land	"
81301D	81751 & 52	3	100	100	95	86	67	56	25	7	"	"
82006A	82008	0	100	98	92	83	65	56	23	4	Pit #9008	C.S.
82010A	82006 & 08	2	100	98	92	83	66	57	25	6	"	McCrossan
82010B	82006 & 08	3	100	98	92	83	66	57	25	6	"	"
82009A	82009	0	100	98	90	80	64	52	21	3	Barton	Total Asphalt
82011A	82009 & 06	2	100	98	90	80	65	53	23	5	@ Lake-	"
82011B	82009 & 06	3	100	98	90	81	65	53	23	5	land	"
	82010		100	100	100	95	17	4	1	0	J.L.	Total Asphalt
82013A	82011	0	100	100	100	100	95	68	23	3	Shiely	"
	Composite 30%										@ St.	
	(010) & 70% (011)		100	100	100	98	72	49	16	2	Cloud	"
82014A	82010, 11, 06	2	100	100	100	99	72	50	18	4	"	"
82014B	82010, 11, 06	3	100	100	100	99	72	50	19	5	"	"
	82013		100	96	89	82	68	56	17	3	Elk River Pit	H. & S.
82019F	82014	0	100	99	98	96	91	86	42	2	Anoka Pit	Asphalt
	82015		100	97	81	61	22	13	7	2	Elk River Pit	"
	Composite 40%		100	97	89	80	61	52	22	2		
	(013) 30% (014)											
	30% (015)											
82025A	82013, 014, 015											
	& 06	2	100	97	89	80	62	53	23	4	Elk River Pit	"
82025B	82013, 014, 015											
	& 06	3	100	97	89	80	62	54	24	5	Elk River Pit	"

<u>Sludge Ash</u>
TM 81301 - 82% passing #80 Sieve Sp. Gr. 2.972
All other T.M. 100% passing #80 Sieve. Sludge pulverized to 100% passing #80 sieve. Hydrometer analysis of pulverized material: 71% Silt 16% Clay.

BITUMINOUS MIXTURE PROPERTIES

T.M. No.	Aggregate No.	Spec.	% Sludge Ash	Asphalt Content	Sp. Gr.*	Density * (lbs/ft^3)	Stability * (lbs)	Voids ** (%)	CWA *** (%)
81301A	81752	2331	0	5.2	2.373	147.9	1273	5.0	4.5
81301B	81751 & 52	2331	1	5.2	2.381	148.4	1482	4.9	4.1
81301C	81751 & 52	2331	2	5.2	2.377	148.1	1510	4.7	3.9
81301D	81751 & 52	2331	3	5.2	2.374	148.0	1680	5.9	3.3
$81301D_1$	81751 & 52	2331	3	4.8	2.354	146.7	1690	6.7	----
$81301D_2$	81751 & 52	2331	3	5.0	2.358	147.0	1559	5.8	----
82006A	82008	2331	0	5.6	2.321	144.7	662	4.7	7.5
82010A	82008 & 06	2331	2	5.6	2.347	146.3	1157	4.2	5.7
82010B	82008 & 06	2331	3	5.6	2.363	147.3	1463	3.4	5.3
82009A	82009	2331	0	5.2	2.380	148.3	815	4.3	5.0
82011A	82009 & 06	2331	2	5.2	2.388	148.8	1262	4.2	4.1
82011B	82009 & 06	2331	3	5.2	2.412	150.3	1777	3.1	3.7
82013A	82010 & 11	2361	0	6.1	2.292	142.9	1770	7.0	4.5
82014A	82010, 11, & 06	2361	2	6.1	2.332	145.3	2287	5.6	3.2
82014B	82010, 11 & 06	2361	3	6.1	2.344	146.1	2527	5.0	3.9
82019F	82013, 14 & 15	2331	0	5.7	2.307	143.8	581	4.2	6.3
82025A	82013, 14, 15 & 06	2331	2	5.7	2.345	146.2	907	3.6	4.7
82025B	82013, 14, 15 & 06	2331	3	5.7	2.349	146.4	1232	4.6	5.7

* ASTM D 1559 Resistance to Plastic Flow of Bituminous Mixtures using Marshall Apparatus.

** ASTM D 2041 Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures.

*** Mn/DOT's Cold Water Abrasion Test.

APPENDIX B

Enviroscience, Inc.
CONSULTING ENGINEERS

HENNEPIN SQUARE BUILDING
2021 EAST HENNEPIN AVENUE
MINNEAPOLIS, MN 55413

(612) 379-7242

June 29, 1982

Gentlemen:

Our firm, Enviroscience, Inc., was recently hired by the Metropolitan Council to study the feasibility of using sludge ash from the Metro Plant at St. Paul as a fertilizer or as an additive to fertilizer mixes. Our firm specializes in consulting studies which involve the fields of environmental and civil engineering.

An important part of the Metropolitan Council study is to contact fertilizer producers and blenders in the metropolitan area to determine their potential interest in using the sludge ash material (60-90 tons/day) as a fertilizer or fertilizer additive.

The ash as produced by the incineration of sludge at the Metro Plant is a fine (primarily the size of fine sand and silt), granular material having a specific gravity of about 2.8.

The attached chemical analysis sheet gives a breakdown of the major constituents in the sludge ash. The extractable phosphorus, potassium, calcium, magnesium, manganese and sodium are also shown in the table along with the equivalent calcium carbonate. In general, although the total phosphorus pentoxide is high, the available (or extractable) phosphorus is relatively low.

We would appreciate your answering the few brief questions in the enclosed form and returning it to us the self-addressed stamped envelope. We would greatly appreciate your prompt response so that we can evaluate whether this material would have a use in fertilizer. Your response to the questions on the enclosed form in no way obligates your company to use sludge ash.

If you would like additional information at this time regarding the study, please call myself or Isaac Yomtovian at (612) 379-7242. Thank you in advance for your assistance.

Sincerely,

Richard M. Anthony, P.E.
Vice President

RMA/njk

Enclosures

RESPONSE FORM

(Please fill out and return to Enviroscience, Inc., in the self-addressed return envelope)

Name of Firm: ______________________________

Person Filling out Form: ______________________________
(name)

____
(title)

Basic type of asphalt production process: pugmill __________ drum mix __________

Approxmiate number of tons of asphalt mix produced:

__________ tons per __________
(day, week, month or year)

Are you currently using mineral filler or other additives in your asphalt mixes? yes __________ no __________

Would you like to receive more detailed technical information regarding the properties of test samples which have incorporated sludge ash into asphalt mixes? yes __________ no __________

Do you think that the sludge ash would have a possible use in production of your mixes? yes __________ no __________ don't know __________

Would you be interested in attending a general meeting in Minneapolis in early July to learn more about the sludge ash feasibility study and to contribute your views on the subject? yes __________ no __________

SLUDGE ASH
DATA SHEET

1. Chemical Composition -

Silicon Oxide	27.0%
Aluminum Oxide	14.4%
Iron Oxide	8.2%
Sub Total	49.6%
Calcium Oxide	21.0%
Magnesium Oxide	3.2%
Phosphorus Pentoxide	20.2%
Total	94.0%

2. Specific Gravity 2.70 - 2.95
Bulk Dry Density 45-50 lbs/cu ft.

3. Particle Size and Distribution -

A. Without additional grinding
*70-85% passing #200
*65-80% silt (.06 - .002 mm)
*0-10% clay (< .002 mm)

B. With grinding
*100% passing #200

4. Not a Hazardous Waste

5. Shipping - Can be shipped wet (for open trucks or railroad cars) or dry (closed trucks or railroad cars)

6. Summary of Mn/DOT's test results

Mix Specification	Percent Sludge Ash	Average Percent Asphalt Content	Average Stability * (lbs)	Average Voids ** (%)	Average CWA *** (%)
2331	0	5.5	686	4.4	6.3
	2	5.5	1,109	4.0	4.8
	3	5.5	1,491	3.7	4.9
2361	0	6.1	1,770	7.0	4.5
	2	6.1	2,287	5.6	3.2
	3	6.1	2,527	5.0	3.9

* ASTM D 1559 Resistance to Plastic Flow of Bituminous Mixtures using Marshall Apparatus.
** ASTM D 2041 Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures
*** Mn/DOT's Cold Abrasion Test

ASPHALT PLANT
INTERVIEW FORM

Name of Firm: ______________________________

Address: ______________________________

Date of Plant Visit : ______________________________

Person(s) Interviewed : ______________________________

Interviewer : ______________________________

PLANT TYPE, CONDITION AND OUTLOOK

(1) Continuous: Pugmill__________ Drum Mix__________

(2) Batch__________

(3) Approx. Age of Plant and Equipment __________

(4) Future Outlook for Plant Operation

projected lifetime __________

phase out __________

expansion __________

PRODUCTION RATES AND CAPACITY

(5) Annual Plant Production : __________ tons/year (1981)

__________ tons/year (1982, est.)

(6) Approx. Length of Operating Season : __________ to __________

(7) Approx. Number of Operating Days/Year : __________

(8) Approx. Monthly Production Rates (tons or % of annual total)

April	______	Aug.	______
May	______	Sept.	______
June	______	Oct.	______
July	______	Nov.	______

(9) Variability of Production Rates (word description):

daily ______________________________

weekly ______________________________

monthly ______________________________

year-to-year ______________________________

(10) Maximum Daily Production Capacity : __________ tons/day

MATERIAL STOCKPILING PRACTICES

(11) How are aggregate and other materials now brought into plant?

____

(12) Inventory on Hand

BA-1 (Cost/ton) __________ BA-3 (Cost/ton) __________

BA-2 (Cost/ton) __________ 2361 Filler (Cost/ton) __________

(13) How many days of production capacity are typically being stockpiled?

____

INTERVIEW FORM (cont.)

POSSIBLE STORAGE AND FEEDING OF SLUDGE ASH

(14) Is mineral filler currently stored and used ? Yes _______ No _____

(15) Type of storage unit(s) used ____________________

(16) Storage capacity for mineral filler : ____________ tons

(17) Location of storage unit(s) ____________________

(18) Filler feed equipment ____________________

(19) Type of filler weighing or metering equipment ____________________

(20) Would existing storage units for mineral filler be suitable for sludge ash? Yes _________ No _________

(21) Would existing feed equipment be suitable for sludge ash? Yes _________ No ________

(22) Is there space available in the plant complex for erecting sludge ash storage units? Yes ______ No _______

(23) Is there space available in the storage yard for stockpiling long-term reserves of sludge ash? Yes _______ No ______

POLLUTION CONTROL EQUIPMENT

(24) Type of dust control equipment ____________________

(25) Location of equipment units in the production process ________

____

(26) Are fines recovered and returned to mix? Yes ______ No _____

(27) Could sludge ash be introduced into the production process without reducing pollution control effectiveness? Yes _____ No _____

If the answer is "No", describe what else would be needed? ______

____

OVERALL PLANT OPERATION

(28) Type of Operational Controls

automatic ______ semi-automatic ________ manual ________

(29) Could sludge ash be used without major adaptation of the control equipment and associated operational procedures?

Yes ________ No _________

If the answer is "No," describe the changes that would have to be made ____________________

____

(30) Overall, could the sludge ash be used at this plant without important impacts upon efficiency, productivity, investment and profitability? Yes ________ No ________

If the answer is "No," explain ____________________

____

APPENDIX C

(Shown in Volume II)

APPENDIX D

twin city testing
and engineering laboratory, inc.
662 CROMWELL AVENUE
ST. PAUL, MN 55114
PHONE 612/645-3601

REPORT OF: SLUDGE ASH CONCRETE TRIAL BATCHES

PROJECT: SLUDGE ASH CONCRETE

DATE: August 16, 1982

REPORTED TO: Enviroscience Inc
Attn: Richard M Anthony
2021 East Hennepin Ave
Minneapolis, MN 55413

FURNISHED BY:

COPIES TO: 1 - Metropolitan Council
Attn: James Frost
1 - Ladislav Cerny, U of Minn

LABORATORY No. 6-0474

INTRODUCTION:

This report presents the results of tests performed on concrete containing press cake sludge ash, as submitted to us by the Metropolitan Council, St Paul, Minnesota. The scope of our work was to batch and test concrete that had cement or fine aggregate partially replaced with the press cake sludge ash and compare these with a control without sludge ash. The materials used in batching the concrete were also tested. This work was requested and authorized by James Frost of the Metropolitan Council on July 12, 1982.

CONCLUSIONS:

Based on the test results, it is our opinion that the sludge ash could be used at a 5% replacement of the cement and at a 2% batch weight replacement of the fine aggregate without adverse effects to the compressive strength. The extended setting time should not be a problem as long as the concrete would be placed in areas such as footings or mass concrete placements or areas where rapid form removal is not required. The sludge ash did not meet the requirements of ASTM:C618 specifications and therefore in order for this material to be used in concrete, the ASTM:C618 specifications would have to be modified.

Additional tests will be required before this material can be used on a commercial basis. Tests must be conducted to determine the freeze-thaw durability, alkalie reactivity, dry shrinkage, abrasion resistance and the maximum allowable addition of the sludge ash to the concrete. Statistically, the data in this report can be looked upon only from a preliminary aspect as several batches of various proportions of cement to sludge ash content must be produced in order to determine the variability and best use of this material in concrete.

SUMMARY:

A summary of the test data is as follows:

1. The sludge ash did not meet ASTM:C618 specifications for the use of mineral admixtures in concrete.

2. The cement and aggregate met the ASTM:C150 and ASTM:C33 specifications, respectively.

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ST. PAUL, MN 55114
PHONE 612/645-3601

REPORT OF: SLUDGE ASH CONCRETE TRIAL BATCHES

DATE: August 16, 1982

LABORATORY No. 6-0474

TEST PROCEDURES:

The press cake sludge ash as received was ground to 95% passing the #200 sieve. The ground material was tested for physical requirements according to the specifications outlined in ASTM:C618 for testing of fly ash and raw or calcined natural pozzolan for use as a mineral admixture in portland cement concrete. The concrete aggregate was tested to meet ASTM:C33-81 specifications for concrete aggregates. The mill test report data for the cement used in the testing is attached in the Test Results portion of this report.

Four concrete trial batches were made using 1) a control batch without sludge ash; 2) a 5% cement replacement by weight with the sludge ash; 3) fine aggregate replaced using 2% of the total batch weight replaced by the sludge ash; and 4) fine aggregate replacement using 4% of the total batch weight replaced by the sludge ash.

The concrete was batched and tested in accordance with ASTM:C192 procedures. Nine 4" x 8" compression cylinders were cast per batch and were tested in sets of three at 3, 7 and 28 days.

TEST RESULTS:

The test results concerning the concrete batches and materials used are as follows:

Test of Sludge Ash (ASTM:C618) -

		ASTM:C618 SPECIFICATIONS	
Sample Identification:	Press cake sludge ash		
Date Received:	7-12-82	Class F	Class C
Percent Passing #200 Sieve:	95		
Fineness			
Retained on #325 Sieve, %	11.8	Max 34	Max 34
Specific Gravity, %	2.77		
Pozzolanic Activity Index			
With Portland Cement (%)			
Ratio to Control @ 28 Days	65.7	Min 75	Min 75
With Lime @ 7 Days (psi)	530	Min 800	Min 800
Water Requirement, % of Control	104	Max 105	Max 105
Soundness			
Autoclave Expansion (%)	0.02	Max 0.8	Max 0.8

*Huron Type I Portland Cement was used in all tests when applicable.

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ST PAUL, MN 55114
PHONE 612-645-3601

REPORT OF: SLUDGE ASH CONCRETE TRIAL BATCHES

DATE: August 16, 1982

LABORATORY No. 6-0474

TEST RESULTS: (cont)

Test of Cement (ASTM:C150) - As taken from the cement lot mill test report as presented by the National Gypsum Company

		ASTM:C150, TYPE I SPECIFICATIONS
Physical Analysis -		
Time of Set (Gillmore)		
Initial Set	3 hrs 35 min	Min 1 hr
Final Set	5 hrs 40 min	Max 10 hrs
Air Content	10.23%	Max 12%
Soundness	0.036%	Max 0.80%
Specific Surface (Blaine)	4483 sq cm/g	Min 2800 sq cm/g
Compressive Strength		
3 days	3243 psi	Min 1800 psi
7 days	4351 psi	Min 2800 psi
Chemical Analysis -		
Alkalies ($Na_2O + 0.658K_2O$)	0.65	Max 0.60**

**These optional limits apply only when specifically requested.

Test of Aggregate (ASTM:C33) -

Type of Aggregate	Shiely concrete sand	ASTM:C33 SPECIFICATIONS
Mechanical Analysis (ASTM:C136)		
Passing 3/8"	100%	100%
#4	98	95-100
8	93	80-100
16	76	50-85
30	45	25-60
50	15	10-30
100	3.3	2-10
Fineness Modulus	2.7	2.3-3.1 (Max Var. ±0.20)
Deleterious Substances:		
Clay Lumps & Friable Particles (ASTM:C142)	0.6	Maximum 3.0%
Material Finer than #200 (ASTM:C117)	1.3	Max 5.0% (3.0% for concrete subject to abrasion)

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and engineering laboratory, inc.
662 CROMWELL AVENUE
ST PAUL MN 55114
PHONE 612 645-3601

REPORT OF: SLUDGE ASH CONCRETE TRIAL BATCHES

DATE: August 16, 1982

LABORATORY No. 6-0474

TEST RESULTS: (cont)

Test of Aggregate (ASTM:C33) - (cont)		ASTM:C33 SPECIFICATIONS
Lightweight Particles (Specific Gravity under 2.00, ASTM:C123)		
Coal and Lignite	None	Max 1.0% (0.5% appearance of concrete is important)
Shale	0.3	
Total	0.3	
Organic Impurities (ASTM:C40)	Lighter than Plate #1	Plate 3 or Lighter
Specific Gravity (B.O.D., ASTM:C128)	2.64	
Absorption (%, ASTM:C128)	1.0	

Test of Coarse Aggregate (ASTM:C33) -		ASTM:C33 SPECIFICATIONS
Type of Aggregate	3/4" gravel	
Mechanical Analysis (ASTM:C136)		
Sample Number	1	3/4"-#4
Sample Size	3/4"-#4	
Passing 1"	100%	100%
3/4	95	90-100
1/2	64	-
3/8	42	20-55
#4	5.6	0-10
8	1.2	0-5
Fineness Modulus	6.56	
Deleterious Substances:		CLASS DESIGNATION MAXIMUM ALLOWABLE (%) 4S
1. Clay Lumps & Friable Particles (ASTM:C142)	0.1	3.0%
2. Soft Particles (ASTM:C235)	0.5%	
3. Chert (Specific Gravity under 2.40)	0.1%	5.0%
4. Sum of 1 & 3 above	0.2%	5.0%
5. Material Finer than #200 (ASTM:C117)	0.3	1.0%
6. Lightweight Particles (Sp. Gr. under 2.0, ASTM:C123)		
6A. Coal and Lignite	None	0.5%
6B. Shale	Trace	
6C. Total	Trace	
7. Iron Oxide	0.3%	

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REPORT OF: SLUDGE ASH CONCRETE TRIAL BATCHES

DATE: August 16, 1982

LABORATORY No. 6-0474

TEST RESULTS: (cont)

Test of Coarse Aggregate (ASTM:C33) - (cont)

Specific Gravity (B.O.D., ASTM:C127)	2.66
Absorption (%, ASTM:C127)	1.0

Concrete Trial Batches -

Specifications:

Mix Number	1 (Control)	2	3	4
Ash Replacement	No sludge ash	5% cement replacement	Fine aggregate replacement by 2% batch weight	Fine aggregate replacement by 4% batch weight
Size of Coarse Aggregate	3/4"-#4	3/4"-#4	3/4"-#4	3/4"-#4
Slump	3"-4"	3"-4"	3"-4"	3"-4"

Materials:

Cementitious Materials	A. Huron Type I Bulk Portland Cement furnished by National Gypsum Company (ASTM:C150) B. Press cake sludge ash furnished by Metropolitan Council
Fine Aggregate	Sand furn by J L Shiely Co, Nelson Plant (ASTM:C33)
Coarse Aggregate	Gravel furn by J L Shiely Co, Nelson Plant (ASTM:C33)

Batch Weight (oven dry basis):

Cementitious Materials				
A. Type I Portland	517#	491#	517#	517#
B. Sludge Ash	0#	26#	80#	160#
Total	517#	517#	597#	677#
Fine Aggregate	1415#	1423#	1345#	1265#
Coarse Aggregate (3/4"-#4)	1750#	1750#	1750#	1750#
Water, Net (% of control)	287#(100)	280#(98)	305#(106)	323#(113)
W/C Ratio (W/A+B)	0.56	0.54	0.51	0.48
Slump	4"	3 1/2"	3"	3 1/2"
Air Content	2.4%	1.6%	1.6%	1.3%
Temperature	68°F	73°F	73°F	73°F
Unit Weight	148.78 pcf	148.78 pcf	149.19 pcf	148.40 pcf
Yield	26.9 ft^3	25.9 ft^3	27.0 ft^3	27.2 ft^3

twin city testing
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662 CROMWELL AVENUE
ST PAUL, MN 55114
PHONE 612 645-3601

REPORT OF: SLUDGE ASH CONCRETE TRIAL BATCHES

DATE: August 16, 1982

LABORATORY No. 6-0474

PAGE: 6

TEST RESULTS: (cont)

Concrete Trial Batches - (cont)

Time of Set (ASTM:C403) -

Mix Number	1	2	3	4
Initial Set (hrs)	4.2	6.5	9.9	11.6
Final Set (hrs)	5.6	8.6	12.2	13.8

Compressive Strength - (4" x 8" cylinders, ASTM:C39) (% of control)

Mix Number	1	2	3	4
3 Day Test	100.0	98.0	96.2	83.3
7 Day Test	100.0	98.5	99.6	65.2
28 Day Test	100.0	98.9	100.0	72.8

REMARKS:

If you have any questions concerning this report, or if we may be of further assistance to you, please contact us.

TWIN CITY TESTING AND
ENGINEERING LABORATORY INC

Steve H Kosmatka, Civil Engineer
Construction Materials Department

Brian J Pashina, P.E.
Manager, Construction Materials Dept

SHK:BJP:ma

APPENDIX E

Enviroscience, Inc.

CONSULTING ENGINEERS

HENNEPIN SQUARE BUILDING
2021 EAST HENNEPIN AVENUE
MINNEAPOLIS, MN 55413

(612) 379-7242

June 29, 1982

Gentlemen:

Our firm, Enviroscience, Inc., was recently hired by the Metropolitan Council to study the feasibility of using sludge ash from the Metro Plant at St. Paul as a fertilizer or as an additive to fertilizer mixes. Our firm specializes in consulting studies which involve the fields of environmental and civil engineering.

An important part of the Metropolitan Council study is to contact fertilizer producers and blenders in the metropolitan area to determine their potential interest in using the sludge ash material (60-90 tons/day) as a fertilizer or fertilizer additive.

The ash as produced by the incineration of sludge at the Metro Plant is a fine (primarily the size of fine sand and silt), granular material having a specific gravity of about 2.8.

The attached chemical analysis sheet gives a breakdown of the major constituents in the sludge ash. The extractable phosphorus, potassium, calcium, magnesium, manganese and sodium are also shown in the table along with the equivalent calcium carbonate. In general, although the total phosphorus pentoxide is high, the available (or extractable) phosphorus is relatively low.

We would appreciate your answering the few brief questions in the enclosed form and returning it to us the self-addressed stamped envelope. We would greatly appreciate your prompt response so that we can evaluate whether this material would have a use in fertilizer. Your response to the questions on the enclosed form in no way obligates your company to use sludge ash.

If you would like additional information at this time regarding the study, please call myself or Isaac Yomtovian at (612) 379-7242. Thank you in advance for your assistance.

Sincerely,

Richard M. Anthony, P.E.
Vice President

RMA/njk

Enclosures

RESPONSE FORM

(Please fill out and return to Enviroscience, Inc., in the self-addressed return envelope)

Name of Firm: ______________________________

Person Filling out Form: ______________________________
(name)

____
(title)

Type of Plant: Fertilizer Producer ______________________

Storage and Distributor ____________________

Other ______________________________

Approximate number of tons of fertilizer produced:

____________________ tons per ______________________
(day, week, month or year)

Would you like to receive more detailed technical information? yes ____________ no ______________

Would you like to receive a sample of the sludge ash material? yes ____________ no ________________

Do you think that the sludge ash would have a possible use in your fertilizer mixes? yes ________ no ___________ don't know ______________

Would you consent to a plant visit by a member of our staff to discuss the use of sludge ash in your fertilizer mixes?
yes ______________ no __________________

RESULTS OF CHEMIÇAL ANALYSIS

CHEMICAL COMPOSITION: (%)

Silicon Oxide (SiO_2)	27.03
Aluminum Oxide (Al_2O_3)	14.36
Iron Oxide (Fe_2O_3)	8.22
Total	49.61
Sulfur Trioxide (SO_3)	0.84
Calcium Oxide (CaO)	20.97
Magnesium Oxide (MgO)*	3.21
Moisture Content	0.086
Loss on Ignition	0.20
Available Alkalies as Na_2O*	0.516
Available Sodium Oxide as Na_2)	0.305
Available Potassium Oxide as K_2O	0.320
Total Alkalies as Na_2O	0.882
Total Sodium Oxide (Na_2O)	0.467
Total Potassium Oxide (K_2O)	0.631
Barium Oxide (BaO)	0.297
Strontium Oxide (SrO)	0.018
Phosphorus Pentoxide (P_2O_5)	20.20
Titanium Dioxide (TiO_2)	2.85
Total Chemical Composition	99.29

Extractable Potassium	183 PPM (Parts Per Million)
Extractable Calcium	2,757 PPM
Extractable Magnesium	432 PPM
Extractable Sodium	70 PPM
Extractable Manganese	14 PPM

Calcium Carbonate Equivalent 8.51%

Brady's #1 Phosphate 6,740 PPM (As Phosphorus)

APPENDIX F

A. P. GREEN REFRACTORIES CO.

MEXICO MISSOURI 65265 U.S.A. PHONE: 314 47

April 23, 1982

Metropolitan Council
300 Metro Square Building
Saint Paul, MN 55101

Attention: Mr. Carl J. Michaud
Environmental Planner

Gentlemen:

We have studied your letter of April 19, 1982 and have concluded that we would not have any interest in this material. There are too many so-called impurities in it for our use.

Some of our people have commented that a possible potential might be as a fertilizer.

Thanks, however, for contacting us.

Yours very truly,

George E. Brinkerhoff
Manager - Technical Services

GEB/gjb

APPENDIX G

United States Department of the Interior

BUREAU OF MINES

TWIN CITIES RESEARCH CENTER
5629 MINNEHAHA AVENUE SOUTH
MINNEAPOLIS, MINNESOTA 55417

June 8, 1982

Mr. James L. Frost, P.E.
Metropolitan Waste Control Commission
300 Metro Square Building
St. Paul, Minnesota 55101

Dear Mr. Frost:

Enclosed are the test results of some preliminary work done on the lime-conditioned sludge ash. For the sake of comparison, similar tests were done on a western coal fly ash. As we discussed on May 24, 1982, the Zimpro process sludge ash unfortunately was not effective in removing heavy metals. However, the lime-conditioned sludge ash performed well enough to merit further consideration. Hopefully we can get back to you with further developments later this summer.

Thank you again for your help in sending the ash samples and the accompanying data.

Sincerely yours,

Daniel N. Tallman

DANIEL N. TALLMAN, Research Chemist
Mine Hydrology
Mine Wastes and Leaching Processes
Twin Cities Research Center

Enclosure

REMOVAL OF HEAVY METALS BY PRECIPITATION WITH ALKALINE MATERIALS

	Dosage, g/l	Metal concentrations, mg/l		
		Cu	Mn	Zn
Lime conditioned fly ash	1.21	<0.10	5.7	<0.10
	2.05	<0.10	0.39	<0.10
	4.15	<0.10	.06	<0.10
	0.62	0.13	12.0	3.6
Coal incineration fly ash	0.625	<0.10	0.46	<0.10
	1.27	<0.10	.06	<0.10
	0.27	0.22	13.9	6.9
Untreated head sample	-	10.8	15.1	12