# Ash Recycling - The Coming of Age!

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## INTRODUCTION

A major concern of the Waste-To-Energy (WTE) industry is ash disposal and the uncertainty of controlled long term ash management. Ash management costs have risen steadily over the last ten years making it the fastest rising cost segment of the WTE industry. The challenge of how to curb the rising cost while maintaining the protection of human health and the environment has been accomplished by responsibly recycling the ash on a commercial basis.

American Ash Recycling Corp. (AAR), utilizing the Duos Engineering (USA), Inc. patent pending ash recycling technology, has promoted ash recycling on a commercial basis in the United States. An important product of the processing and recycling of non-hazardous municipal waste combustor (MWC) ash is Treated Ash Aggregate (TAA). Additionally, ferrous and non-ferrous metals are recovered and unburned materials removed and returned to the WTE facility for re-combustion. The TAA is sized and then treated by the WES-PHix® immobilization process in order to reduce the potential solubility and environmental availability of the metal constituents of the MWC ash. The TAA is available for commercial use in such applications as an aggregate substitute in roadway materials, asphalt and concrete applications, as structural fill, and as landfill cover.

Commercial and technical considerations that must be addressed before ash can be beneficially recycled are: permitting requirements, physical and chemical characteristics, potential end uses, environmental concerns (product safety), product market development, and economic viability. True recycling only occurs if all of these considerations can be addressed.

This paper presents the details of AAR's most recent experience in the development of an ash recycling facility in the State of Maine and the associated beneficial use of the TAA product. Each of the considerations listed above are discussed with a special focus on the permitting process. A major component of the permitting process involved the development of a comprehensive life-cycle human health and environmental risk assessment to evaluate the potential long term effects which may arise from the beneficial use of AAR's TAA product. The extensive analytical data required in both the development of the risk assessment and the physical and chemical characteristics of the TAA will be reviewed. AAR's process and the permitted beneficial uses of the TAA product are explored as well as the methodology and overall approach utilized in the development of the project.

## PROCESS DESCRIPTION

The process description outlined below is based on Duos Engineering (USA), Inc., an AAR affiliated company, patent pending design.

Incoming MWC ash will be received at the designated material input staging area of AAR's ash recycling facility. From there, the ash is conveyed to initial screening, which separates it into two size gradations consisting of less than and greater than 3", for further processing.

The larger size gradation is conveyed to a slow speed, high torque shredder for size reduction. After being reduced to a proper size, it is combined with the smaller of the two size gradations. The combined material stream next passes magnetic separation which extracts the ferrous metals. The ferrous metals are directed to the ferrous cleaning unit where any ash adhering to the metal is removed. The removed ash is reintroduced into the process for further processing.

After magnetic separation, the remaining material is screened into the two sizes: less than 3/8" and greater than 3/8". The smaller fraction is treated using the patented WES-PHix® chemical immobilization process and subsequently conveyed to the TAA storage area. The larger fraction is directed to the Windzifter®, which uses proprietary air separation technology to remove unburned combustibles such as paper, plastic, and wood from the ash stream.

The unburned combustibles are then discharged through air locks and conveyed to a controlled storage area. The unburned stream is then returned to the MWC for recombustion. After the unburned combustibles are removed, the material flows to the eddy-current separator for non-ferrous metal removal. The remaining material (after non-ferrous metal removal) is conveyed to a crusher where it is reduced to 3/8" or less. This material is reintroduced to the process at a point prior to magnetic separation for further processing and ferrous and non-ferrous recovery. The non-ferrous material is conveyed to the MartinTag non-ferrous cleaner which uses a proprietary metals cleaning technology to remove any residual ash. The cleaned non-ferrous metals are then separated into their individual components, i.e., brass, copper, coins, and aluminum.

The process is designed to keep the material in a continuous loop until substantially all metals and unburned combustibles have been removed and the remaining ash has reached a uniform size gradation. The ash is then treated with the WES-PHix® chemical immobilization process in order to produce the final product, TAA, which is suited for beneficial use.

## PERMIT REQUIREMENTS

In order to utilize the TAA, beneficial use permits are typically required. Several states have developed beneficial use regulations of MWC ash while many others are in the process. The main concern of any environmental agency is: What is the effect on human health and the environment when beneficially using this product? A myriad of other issues must be addressed during the permitting process but the main question of the safety of the product must be answered in a scientifically defensible way.

This paper focuses on AAR's most recent experience in the State of Maine for obtaining environmental permits. The three permits required for AAR to operate and beneficially use their product within the State were: 1) Solid Waste Processing Facility Permit, 2) Minor Source Air Permit, and 3) Special Waste Utilization License (Beneficial Use).

The Processing Facility permit application was typical for processing facilities as was the Air Permit. The Air Permit was required because of AAR's use of the Windzifter®, which removes the unburned material from the ash. The Windzifter® utilizes a baghouse to control any discharge of particulates to the air but since it has a potential to emit, a minor source air permit was required. The Beneficial Use permit is product specific and unique, therefore, it will be discussed in detail.

The following requirements must be met in order to obtain a Beneficial Use Permit:

- The beneficially used waste-derived-product must perform equivalently to the material it is replacing;

- The beneficial use shall produce a product which meets or exceeds the generally accepted product specifications and standards for the same product produced using a raw material; and
- The beneficial use will not pollute any waters of the state, contaminant the ambient air, constitute a hazard to health or welfare or create a nuisance during and after the active life of the project.

The Maine Department of Environmental Protection (DEP) requires the following material be included as part of the Beneficial Use of a Special Waste Permit application:

1) General description of the waste-derived-product and its proposed use;
2) Specific information regarding the physical, chemical or biological characteristics of the waste-derived-product;
3) The quantities, by weight and/or volume of the solid waste and waste-derived-product;
4) Waste characterization plan - analytical data demonstrating that the solid waste is non-hazardous;
5) Demonstrated Product Markets. The following information may be submitted in support of this requirement: a) Contract to purchase proposed product; b) Description of how the proposed product will be used; c) Demonstration that the proposed product complies with industry standards and specifications for that product; d) Other documentation that a market for the proposed product or use exists;
6) Demonstration that the nature of the proposed use of the waste-derived-product constitutes a beneficial use rather than disposal;
7) Description of the operation of the facility which is proposing to use the solid waste and the product produced or the manner in which the waste shall be used. The complexity and degree of detail of the description will vary depending on the magnitude and complexity of the process;
8) A description of how the solid waste and the waste derived product will be stored;
9) A technical comparison of the waste derived product and the virgin material it is replacing. An evaluation shall demonstrate that the physical and chemical properties of the materials are comparable and that the waste derived product will serve as an effective substitute for the analogous raw material. This demonstration may include a discussion of the risks and drawbacks and an assessment of similar application of the proposed beneficial use; and,
10) Records and Annual Reporting.

AAR submitted the permit applications to the Maine DEP after detailed discussions which outlined the specific information that would be acceptable in order to meet all of the requirements. The most difficult question to answer in a scientifically defensible way was: Is this material safe to human health and the environment when beneficially used in the requested applications? AAR approached this question, in agreement with the DEP, by performing a chemical characterization of the TAA and a comprehensive human health and environmental risk assessment (HRA) based upon the chemical constituents found in the characterization report. The HRA evaluated the potential long-term environmental effects which may arise from the beneficial use of TAA.

## CHEMICAL CHARACTERISTICS OF TAA

In order to obtain specific information regarding the physical and chemical characteristics of both the ash and TAA, MWC ash from an operational waste-to-energy facility in Maine was transported to the AAR Nashville facility for processing in October 1995. Composite samples of the MWC ash were collected prior to processing and multiple composite samples of TAA were collected as well. TAA samples were collected after 10, 20 and 30 tons of the aggregate were produced. All of the composite samples were forwarded to the State University of New York (SUNY) for both physical and chemical characterization. A characterization report titled "Chemical and Physical Characteristics of AAR's Processed Ash Aggregate Produced from Maine Energy Recovery Company's MWC Combined Ash[1]" was prepared by the University (Roethel, 1995) which detailed the analytical results, analytical methods, and the appropriate quality control/quality assurance data.

Figure 1 outlines the analyses which were performed on TAA and leachates reported in the study. A broad spectrum of analytical analysis was performed on the TAA in order to demonstrate to the Maine DEP the complete TAA characterization. The chemicals of concern, as determined in Roethel, 1995, that were used in the risk assessment include metals and dioxins/furans analysis. The metals considered in the HRA were: arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver and zinc. Metal leachate data was obtained in accordance with the US EPA Monofilled Waste Extraction Procedure, more commonly known as EPA Method SW-924. This multiple extraction leaching test is significantly more predictive of how TAA will behave in the environment than the TCLP test.

Dioxin/furan data were obtained from samples of TAA. This data was used in exposure scenarios which evaluated direct contact with TAA and served as the basis of the modeled airborne particulate concentrations and deposition rates. Actual dioxin leachate data was obtained from the US EPA's <u>Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, Co-disposal Sites</u>[2], September 1987. The dioxin leachate data did not represent AAR's TAA but were provided as a worst-case approximation of leaching from landfills when municipal solid waste and MWC ash are deposited together.

In establishing the inorganic composition of the ash and TAA, samples were digested using hydrofluoric and boric acids ($HF/H_3BO_3$) which is a departure from the standard EPA total metal digestion protocol incorporating nitric acid ($HNO_3$). This modification was undertaken to permit an analysis of metals bound within a siliceous matrix which would not be digested if nitric acid were utilized. Typically, the concentrations measured using the more aggressive $HF/H_3BO_3$ digestion technique are higher, increasing between 10%-30% above those determined using $HNO_3$. This was done to determine the true total metals concentrations.

Dioxin and furan concentrations were determined for duplicate samples of TAA. Toxicity Equivalent Factors (TEF's) were used to express the concentration of the different isomers and homologs of dioxin/furans as an equivalent amount of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

The physical characterization showed that the AAR process yields a uniform product, consistently achieving a particle size distribution appropriate for a diverse array of applications. The data indicated the aggregate is well graded, consisting of about 30 percent gravel, 65 percent sand size particles, and 8 percent fines (smaller than 200 mesh). The particle size distribution and percent volatile matter are both very similar to existing TAA data produced at AAR's Facility in Nashville, TN. The data in this investigation, the previous data gathered by AAR and the completed HRA all suggest the use of TAA is an environmentally acceptable beneficial use strategy.

## HUMAN HEALTH AND ENVIRONMENTAL RISK ASSESSMENT

In order to demonstrate to the Maine DEP that the TAA would not pollute any waters of the state, contaminate the ambient air, constitute a hazard to health or welfare or create a nuisance, Radian International (Radian) performed a comprehensive HRA to evaluate the potential long-term environmental effects which may arise from the beneficial use of TAA.

The HRA, titled "Assessment of Potential Human Health and Environmental Effects from the Beneficial Use of American Ash Recycling Corporation's Treated Ash Aggregate[3]" (Roffman, 1995), was a major component in the permitting process. The data utilized in the HRA came from the Roethel, 1995, Characterization Report.

The HRA was conducted in accordance with applicable US EPA and Maine DEP risk assessment guidelines. The risk assessment evaluates the human health and environmental risk associated with the TAA from the time of creation to its beneficial use in roadways, landfills and other potential uses including its final reuse or disposal. The HRA included life cycle analyses which examined stages in the processing and proposed usage of the TAA during which releases may occur. For each stage, a human health risk assessment and an environmental risk assessment were performed for potentially affected receptors. To ensure that potential secondary effects were not overlooked, not only direct contact of receptors with TAA, but also potential impacts on local air and water quality were evaluated in the risk assessments.

The risk assessment presents estimated human health and environmental risks resulting from exposure to chemical constituents in AAR's TAA for the following stages in the potential uses of TAA:

- Loading and unloading of TAA
- Storage of TAA;
- Transportation of TAA;
- Production of asphalt paving material containing TAA;
- Use of TAA as a protected subbase in a roadway;
- Use of TAA as a commercial protected structural fill;
- Use of TAA as daily cover and final cover for landfills;
- Use of TAA as an aggregate substitute in asphalt or concrete materials; and
- Final use or disposal of paving materials containing TAA.

Potential health risks to workers and potentially affected residential receptors were evaluated for each of these stages, when applicable. The exposure pathways considered for this risk analysis are as follows:

- Worker exposure to constituents of TAA by accidental ingestion and inhalation;
- Worker exposure to TAA constituents dissolved in rainwater runoff;
- Inhalation of airborne particulates emitted from a TAA processing facility by residents living near the facility;
- Residential exposure to soils potentially impacted by deposition of particulates of TAA emitted from storage piles, processing plants and the erosion of roadways; Residential exposure of soils potentially impacted by overland transport of TAA constituents via runoff from 100 percent TAA storage piles, and storage piles containing mixtures of 40 percent TAA encapsulated with asphalt or cement;
- Residential exposure to TAA constituents which have been leached from storage piles, roadway

subbase, and landfills utilizing TAA as a daily or final cover. This scenario assumes that the constituents enter a groundwater system which is used for typical residential purposes, including drinking and bathing;

- Exposure to TAA constituents in a surface water body potentially impacted by overland transport from 100 percent and 40 percent TAA storage piles;
- Exposure through the food chain. This scenario assumes food is grown in soils impacted by releases from a TAA processing facility, from storage piles, and from roadway deterioration.

These potential risks were quantified by applicable US EPA risk assessment equations. They used predictive computer models which utilized the physical and chemical data developed in Roethel, 1995.

Throughout the HRA conservative assumptions were employed so that the US EPA concept of a "Reasonable Maximum Exposure (RME)" was maintained. RME's are defined as "the highest exposure that is reasonably expected to occur" for a given exposure pathway. The HRA, therefore, uses exposure factors which are likely to overestimate potential risks, so that the health of the public is safeguarded.

**Exposure Assessment**

The purpose of the exposure assessment is to estimate the type and magnitude of potential exposures to constituents detected in the TAA. Results of the exposure assessment are combined with chemical-specific toxicity information to characterize the potential human health risks. Table 1 presents the appropriate exposure factors employed in the risk assessment calculations. The exposure assessment consists of the following steps:

- Identification of potentially exposed populations and exposure pathways as described above;
- Determination of exposure concentrations which are estimates of the chemical concentrations to which persons (receptors) may be exposed. In this HRA, exposure point concentrations consist of the following:

    1) Determination of soil exposure point concentrations from both deposition and runoff, and
    2) Determination of groundwater exposure point concentrations employing ground water modeling using specific input parameters, groundwater fate and transport data and mass input.

- Air emission exposure point concentrations and deposition derivations were determined using the following:

    1) Emission rate derivations which include:
       Truck loading and unloading of TAA;
       Transport of TAA;
       Material handling at a production facility;
       Storage of TAA;
       Particulate emissions from a mixing plant;
       Emissions associated with roadbed decomposition.

    2) Deposition rate derivations which describe the rate at which particulate matter settle out of the atmosphere onto the ground. This requires knowledge of the average particle size,

the particle density, the viscosity of the air, and the gravitational constant.

3) Particulate concentration modeling using the US EPA Industrial Source Complex-Short Term (ISCST2)$^4$ model to estimate potential maximum ground-level concentrations of TSP
and PM10. The dispersion modeling requires specification of the following parameters:

Source data;
Receptor Data;
Meteorological data;
Model options;
Exposure point concentrations.
Determination of surface water exposure point concentrations; and
Potential food chain exposure.

**Risk Effects**

The potential risks assessed in the HRA include both noncarcinogenic (non-cancer) and carcinogenic (cancer) health effects. Each risk is shown as a numeric value which is subsequently compared to US EPA acceptable criteria.

Noncarcinogenic health effects are characterized by a value known as the Hazard Quotient. According to the US EPA guidelines, if the Hazard Quotient is greater than unity (>1), "there may be concern for potential health effects", and when the Hazard Quotient is less than one (<1), "it is unlikely for even sensitive populations to experience adverse health effects". It is, therefore, desirable that:

$$\text{Hazard Quotient} < 1$$

The ratio of the Intake to Reference Dose is termed a Hazard Quotient and is a measure of the potential health effect of a given exposure. Therefore,

$$\text{Hazard Quotient} = \text{Intake} / \text{Reference Dose}$$

Carcinogenic risks are expressed as a probability of contracting cancer. This probability is defined as an "incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen". Incremental refers to the fact that the cancer risk is in excess of the individual's normal risk without this exposure. The means by which intake is converted to a probability of carcinogenic risk is the Carcinogenic Slope Factor (CSF). To compute the probability of contracting cancer, the intakes are multiplied by the chemical-specific CSF's. Therefore,

$$\text{Carcinogenic Risk} = \text{Dose} \times \text{CSF}$$

The US. EPA states that its carcinogenic risk goal is $1 \times 10^{-6}$ to $1 \times 10^{-4}$ where a carcinogenic risk of $1 \times 10^{-6}$ is equivalent to one excess incidence of cancer in 1,000,000 persons and a $1 \times 10^{-4}$ risk indicates a risk of one in 10,000 individuals.

### Risk Assessment Results

The potential health risks associated with the production and utilization of TAA were in every instance less than the US EPA acceptable criteria for both carcinogenic and noncarcinogenic risks.

The data indicate the potential noncarcinogenic health risks or Hazard Quotient incurred if individuals are exposed to the chemical constituents of 100% TAA storage piles and in environmental media affected by migration of these constituents from the pile, are less than the US EPA acceptable criteria.

The maximum carcinogenic risks to workers and nearby residential adults and children in the considered exposure scenarios were within the US EPA acceptable range.

### Results of the LEAD 5 Model

Potential risk to children exposed to lead in residential soils were evaluated by the US EPA's LEAD 5 model. This exposure situation assumed that TAA is blown from storage piles, roadways, and an asphalt mixing plant and that the particulates are then deposited on soils near these sources. It is further assumed that young children play in this soil outdoors, and that soil dusts infiltrate their homes so that they are exposed both outdoors and indoors for a period of six years. US EPA default values were assumed for other media the child may be exposed to, such as contributions from food, waters, and air. It should be noted that the US EPA default values for water and air concentrations in the LEAD 5 model are greater than lead concentrations estimated in the HRA for these media.

Table 2 shows the results of the LEAD 5 model which indicate that the total lead blood level is below the current US EPA acceptable level of 10 μg/dl.

### HRA Summary

Human health and environmental risks resulting from exposure to chemical constituents for the following stages in the life of the TAA were assessed in this study: the storage and handling of the TAA, the production of a TAA/asphalt mixture, the use of TAA as a roadway subbase, use as commercial structural fill, and the final disposition of TAA/asphalt or cement paving materials.

Results of this study indicate that both potential noncarcinogenic and carcinogenic risks are well within US EPA recommended goals for all exposure situations evaluated in this HRA. Review of the specific risks shows that much of the estimated risk arises from direct worker contact with 100 percent TAA. The worker exposure scenarios assume that a worker's hands and the full length of both arms are completely covered with TAA every workday for 25 years, i.e., the worker wears no gloves, long-sleeved shirts, or other protective equipment. These risks can easily be reduced by proper administrative and engineering controls.

The HRA confirms the potential carcinogenic and non-carcinogenic risks to residents resulting from air emissions, rainwater runoff, structural fill, and leaching from piles, and roadways are well below US EPA criteria.

Despite the conservative assumptions made throughout the HRA the potential human health risks as well as the potential ecological impacts resulting from the utilization of TAA in storage piles, processing plants, structural fill, roadways and landfills, are within acceptable ranges. Risks are overestimated following conservative US EPA guidance in order to assure that if error occurs, the error is on the side of safety. The findings of the HRA indicate the potential risks associated with the use of TAA as a product are well within or below US EPA guidelines.

## POTENTIAL END USES

The potential end uses for any new product must be determined prior to submitting the permit application. Based upon extensive study and years of commercial operation AAR has determined that TAA is suitable for use as:

- Base and sub-base under roads and other paved surfaces,
- Aggregate for asphalt manufacturing,
- Structural fill material,
- Substitute aggregate in concrete; and,
- Daily landfill cover and closure materials.

## PRODUCT MARKETABILITY

AAR has developed a Marketing Plan which is based upon its experience in successfully marketing the TAA and ferrous and non-ferrous metals produced at its Nashville, Tennessee ash recycling facility. AAR has sold, to a variety of end users, more than 260,000 tons of TAA produced to date. TAA is readily accepted by industry based upon its proven similarity in engineering and structural characteristics to natural aggregate. Based upon geographic location, the cost of TAA is typically lower than natural aggregate. In addition, the concept of recycling a material versus using a non-renewable natural resource is an attractive bonus to using TAA.

For the Maine project, AAR was able to demonstrate to the DEP the marketability of the TAA by contracting with a Scarborough, Maine paving company to purchase all of AAR's production. The company has over fifty years experience in the paving and construction industry and upon evaluating the TAA determined it met their strict standards of acceptability as a replacement for natural aggregate.

In addition to the TAA produced by AAR's process, metals are also recycled and sold. The process separates, cleans, and sizes both ferrous and non-ferrous metals which ensures the highest value is received. Again, AAR's experience over the last three and a half years of commercial operation has enabled it to develop a marketing plan for its recycled products that has been proven to be successful.

## CONCLUSIONS

The Beneficial Use Permit, the Solid Waste Processing Facility Permit, and the Minor Source Air Permit for the production and beneficial use of TAA in the State of Maine were issued in July 1996. The permitting process is a lengthy and detailed procedure which requires critical reviews of all data, detailed studies, marketability, financial stability, as well as economic feasibility of the overall project. AAR was able to demonstrate the environmental safety of their product and the project's economic feasibility to the satisfaction of the Maine DEP.

New technologies are constantly faced with challenges starting with the initial concept all the way through to commercial operations. This is especially true for complex issues like MWC ash recycling. Environmental rules and regulations are often conservative to ensure the protection of human health and the environment, yet even with the strict requirements, AAR was able to successfully demonstrate the safety of utilizing their TAA. With the permit approvals for a new facility in the State of Maine, the beneficial use of ash is broadening and can be held up as a model for future projects.

In the hierarchy of integrated waste management, recycling is the major preference over landfilling. AAR's ability to recycle virtually 100% of the incoming MWC ash helps to meet the nations goals of reduction and recycling. AAR has met the challenge of curbing the high cost of ash management while maintaining the protection of human health and the environment with its proven commercial ash recycling technology. AAR's technology and experience on a commercial basis has demonstrated that ash recycling has finally come of age!

## REFERENCES AND BIBLIOGRAPHY

[1] Roethel, F. J., 1995. Chemical and Physical Characteristics of AAR's Processed Ash Aggregate Produced from Maine Energy Recovery Company's MWC Combined Ash, December.

[2] US Environmental Protection Agency, 1987a. Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, and Co-Disposal Sites. Office of Solid Waste and Emergency Response, EPA/530-SW-87-02A, October.

[3] Roffman, H. K., 1995. Assessment of Potential Human Health and Environmental Effects from the Beneficial Use of American Ash Recycling Corporation's Treated Ash Aggregate, December.

[4] Bowers, J. F., et al., 1979. Industrial Source Complex (ISC) Dispersion Model User's Guide. US EPA Office of Air Quality Planning and Standards, EPA 450/4-79-030, Research Triangle Park, North Carolina.

# TABLE 1

## Exposure Factors Employed in Risk Assessment Calculations.

| Dermal Contact with Soils / TAA | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Skin Surface Area (sq. cm./event) | 3910 | 3120 | 3120 |
| Soil to Skin Adherence Factor (mg/sq. cm.) | 1.0 | 1.0 | 1.0 |
| Absorption Factor (unitless) | Chemical dependent | Chemical dependent | Chemical dependent |
| Exposure Frequency (days/year) | 350 | 350 | 250 |
| Exposure Duration (years) | 6 | 24 | 25 |
| Body Weight (kg) | 15 | 70 | 70 |

| Ingestion of Soils | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Ingestion Rate (mg/soil/day) | 200 | 100 | NA |
| Absorption Factor | 1.0 | 1.0 | NA |
| Exposure Frequency (days/year) | 350 | 350 | NA |
| Exposure Duration (years) | 6 | 24 | NA |
| Body Weight (kg) | 15 | 70 | NA |

| Dermal Contact with Groundwater / Runoff | Child Resident | Adult Resident | Adult Resident |
|---|---|---|---|
| Skin Surface Area (sq. cm./event) | NA | 19400 | 4240 |
| Exposure Frequency (days/year) | NA | 350 | 150 |
| Exposure Duration (years) | NA | 30 | 25 |
| Exposure Time | NA | 0.5 | 0.5 |
| Body Weight (kg) | NA | 70 | 70 |

| Ingestion of Groundwater | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Ingestion Rate (l/day) | NA | 2 | NA |
| Exposure Frequency (days/year) | NA | 350 | NA |
| Exposure Duration (years) | NA | 30 | NA |
| Body Weight (kg) | NA | 70 | NA |

| Inhalation of Particulates | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Inhalation Rate (cu.m./hr) | NA | 0.83 | 0.83 |
| Exposure Time (hours/day) | NA | 24 | 8 |
| Exposure Frequency (days/year) | NA | 350 | 250 |
| Exposure Duration (years) | NA | 30 | 25 |
| Body Weight (kg) | NA | 70 | 70 |
| | | | |

# TABLE 1

## Exposure Factors Employed in Risk Assessment Calculations.

| Ingestion of Surface Water | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Contact Rate (L/hour) | 0.05 | 0.05 | NA |
| Exposure Time (hrs/day) | 2.6 | 2.6 | NA |
| Exposure Frequency (days/year) | 350 | 350 | NA |
| Exposure Duration (years) | 6 | 24 | NA |
| Body Weight (kg) | 15 | 70 | NA |

| Dermal Contact with Surface Water | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Skin Surface Area (sq. cm./event) | 9310 | 19400 | NA |
| Exposure Time (hrs/day) | 2.6 | 2.6 | NA |
| Exposure Frequency (days/year) | 350 | 350 | NA |
| Exposure Duration (years) | 6 | 24 | NA |
| Body Weight (kg) | 15 | 70 | NA |

| Food Chain Exposure | Child Resident | Adult Resident | Adult Worker |
|---|---|---|---|
| Ingestion Rate (mg/day) | NA | Chemical Specific | NA |
| Exposure Frequency (days/yr) | NA | 350 | NA |
| Exposure Duration (years) | NA | 30 | NA |
| Body Weight (kg) | NA | 70 | NA |

# TABLE 2

## Summary of Human Health Risks Results of US EPA Lead5 Model Runs.

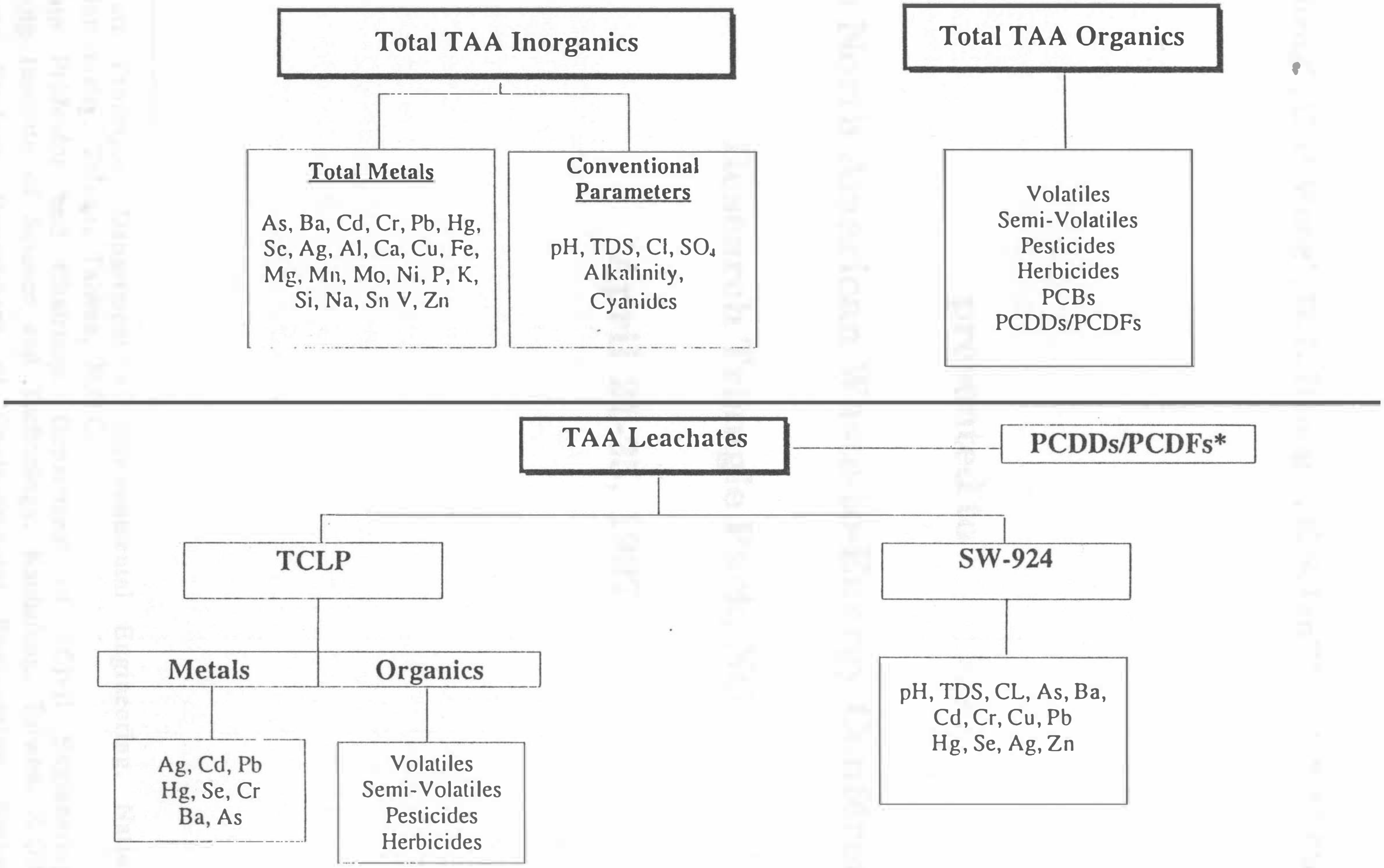
| AGE | CHILD BLOOD LEAD LEVELS (ug/dl) | | |
|---|---|---|---|
| | Deposition from 100% TAA Storage Pile Soil Lead = 12.0 mg/kg | Deposition from Roadway Soil Lead = 0.112 mg/kg | Deposition from Asphalt Mixing Plant Soil Lead = 4.9 mg/kg |
| 0.5-1 | 1.68 | 1.57 | 1.62 |
| 1-2 | 1.35 | 1.24 | 1.29 |
| 2-3 | 1.36 | 1.26 | 1.30 |
| 3-4 | 1.40 | 1.30 | 1.34 |
| 4-5 | 1.44 | 1.33 | 1.38 |
| 5-6 | 1.47 | 1.36 | 1.41 |
| 6-7 | 1.53 | 1.42 | 1.47 |

| AGE | CHILD BLOOD LEAD LEVELS (ug/dl) | |
|---|---|---|
| | Overland Transport 100% Ash Storage Pile Soil Lead = 7.0 mg/kg | Deposition from 40% TAA Storage Pile Soil Lead = 4.8 mg/kg |
| 0.5-1 | 1.63 | 1.61 |
| 1-2 | 1.30 | 1.28 |
| 2-3 | 1.32 | 1.30 |
| 3-4 | 1.36 | 1.34 |
| 4-5 | 1.39 | 1.37 |
| 5-6 | 1.42 | 1.40 |
| 6-7 | 1.49 | 1.47 |

Current US EPA Blood Lead Level Crtierion is 10 ug/dl.

# FIGURE 1

## TOTAL AND LEACHATE ANALYSES PERFORMED ON TAA



* PCDDs/PCDFs in leachates for the daily municipal landfill cover scenario originate from actual leachate samples collected from municipal landfills which also accepted municipal waste combustor ash, as reported in the U.S.EPA Report: Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills and Co-Disposal Sites, EPA 530-SW-87-028, Oct. 1987.