

THE LOW-LOW-LEVEL MIXED WASTE REGULATORY GAP: A DISPOSAL AND RECYCLE IMPASSE

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ABSTRACT

Small steel mills in the United States receive and melt scrap steel in electric arc furnaces. The off-gas from these furnaces carries dust to the bag house where the dust is trapped and recovered. The EAF (Electric Arc Furnace) dust contains hazardous components lead, cadmium and chromium, causing it to be designated as U.S. EPA hazardous waste K061. The dust also carries about 20% zinc, a valuable byproduct for recovery. The EAF dust is normally either disposed of at a landfill licensed for hazardous wastes, or sent to a High Temperature Metal Recovery (HTMR) facility for recycle processing. During the past few years, there have been a number of incidents in which an industrial gauge source, containing the radioisotope Cs-137, has been inadvertently included in a load of scrap steel charged to an arc furnace. In each incident, the cesium and its encapsulation and holder melted, releasing the cesium into the off-gas system where it became distributed in hundreds of tons of EAF dust in the ducts and in the bag house. The contaminated dust, having both hazardous and radioactive components is a mixed waste. A regulatory gap exists that prevents disposition of this material, though it has only a low-low-level of radioactivity. A risk assessment was conducted for a midwest steel company that experienced a cesium meltdown incident. Most of the stored dust from this incident has an activity level less than the limit for the lowest category of LLW by a factor of 5,800, and some is only slightly above background. The significant pathways calculated include direct exposure to masses of the dust, ingestion of leachate and groundwater at a hazardous waste landfill, and potential releases to air and water during HTMR recycle processing. Results are presented that indicate that Cs-137 concentrations in EAF dust ranging from 4.4 Bq/g (120 pCi/g) to unlimited values, for the various pathways, would not cause workers in unrestricted areas or members of the public to receive doses exceeding limits in existing regulations. As a comparison, wood ash, which is unregulated and containing up to 0.78 Bq/g (21 pCi/g) Cs-137, is used in agricultural fertilizer. Regulatory relief, allowing Cs-137 contamination in mixed waste up to 3.7 Bq/g (100 pCi/g) is feasible and is needed, to break the impasse which prevents the economic and environmental benefits of disposal and recycling.

INTRODUCTION

Small steel mills in the United States receive and melt scrap steel in electric arc furnaces. Impurities in the scrap steel are removed during melting via slag and in the off-gas. The off-gas carries dust, containing a number of metals, to the bag house where the dust is trapped and recovered. Hazardous components: lead, cadmium, and chromium, cause the dust to be designated as U.S. EPA hazardous waste no. K061 (1). This dust also contains about 20% zinc, a valuable byproduct for recovery. The EAF (Electric Arc Furnace) dust is either disposed of at a landfill licensed for disposal of hazardous wastes, or sent to a High Temperature Metal Recovery (HTMR) facility for recycle processing (2,3). The processing recovers zinc and other metals of value and removes the hazardous constituents. The remaining iron rich material is released for unrestricted use.

Occasionally, an industrial gauge radiation source, containing the radioisotope Cs-137, inadvertently is included in a load of scrap steel charged to one of the arc furnaces. This source along with its encapsulation and holder are melted and the cesium released into the off-gas system where it became distributed in hundreds of tons of EAF dust collected in the ducts and in the bag house.

Unfortunately, a regulatory gap exists for disposition of the slightly radioactive contaminated EAF dust. The low activity does not justify the expense of handling as low-level waste, yet it is not of zero activity. The situation is complicated by the presence of hazardous constituents, making the waste a "mixed waste," not yet covered by regulations.

The study reported here was conducted for a midwest steel company that experienced one of the cesium meltdown

incidents. The study includes risk assessment of the significant environmental pathways as an aid in defining regulatory relief needed to permit disposal in a hazardous waste landfill and/or recycle-processing of the contaminated EAF dust.

CESIUM CONTAMINATION OF EAF DUST

As a chloride in industrial sources, CsCl melts at 646°C and sublimates at 1,290°C. After being subjected to temperatures as high as 1,700°C in an arc furnace, the form of cesium in EAF dust is likely one of the oxides. It is because of its volatility that the cesium in the melting incident leaves in the off-gas and ends up in the EAF dust; there is none detected in slag or in the steel product.

The studied incident dispersed a small amount of radioactive cesium very finely throughout more than 600 tons of EAF dust. The estimated source activity was about 9.6 GBq (260 mCi), representing a sphere only 1.1 mm in diameter, dispersed throughout a volume of EAF dust equivalent to a 7 m cube! The first box of dust from the clean-out effort contains 3.3% of the total volume but approximately 78% of the cesium activity. The remaining volume of stored dust has an average contamination of only 3.7 Bq/g (100 pCi/g).

OPTIONS FOR HANDLING CONTAMINATED EAF DUST

The mixed waste consisting of EAF dust contaminated with Cs-137 is presently being stored on-site at this and other steel companies where source smelting incidents have occurred. The NRC has determined that concentrations up to 0.074 Bq/g (2 pCi/g) can be attributed to cesium fallout background and are not subject to regulation. Several Agreement

States concur with this determination. Virtually all EAF dust collected during and following a cesium incident exceeds this cutoff level. In the absence of regulatory relief, the only option available is to ship all of the contaminated material to Envirocare of Utah, the only LLW disposal site currently licensed to receive mixed waste. Envirocare is licensed to accept Cs-137 shipments having overall average concentrations up to 21 Bq/g (560 pCi/g). As some of the contaminated EAF dust is only slightly above the background level, and most of it averages only about 3.7 Bq/g (100 pCi/g), this is a very expensive option that would utilize LLW repository capacity better used for higher activity material.

Cost effective options that would permit disposal in local hazardous waste landfills or recycle processing depend upon establishing an allowable level or levels. Any established level would permit routing a portion of the stored material directly to a landfill or recycle, and would make it feasible to proceed with decontamination processing with the remaining material. If treatment of stored dust that exceeds the concentration limit is performed to remove cesium, it will only be done with the expectation that decontaminated material will result which has concentrations below whatever limit is established. Treatment to remove cesium from the EAF dust may be feasible, using a soil-washing process in which the cesium is dissolved into solution and sorbed in canisters of ion-exchange resin. All of the cesium cannot be removed by such a process, but the objective is to remove enough of the radioactive component to reduce concentrations to limits being sought in new regulations, to permit HTMR processing or disposal in a local hazardous waste landfill. Treatment may involve one or more than one pass to achieve the concentration levels required for the decontaminated material. The ion-exchange resins from treatment end up with concentrated Cs-137; this small volume would be disposed of in a low-level-waste repository. In the absence of closing the regulatory gap for this low-low-level mixed waste, an impasse continues.

STATUS OF REGULATIONS

The EAF dust, contaminated with Cs-137 is much lower in activity than the category designated as "Low-Level Waste" (LLW). The lowest concentration category of waste addressed in 10 CFR 61 (4) is Class A. This class applies for Cs-137 content up to 37 kBq/mL (10^6 pCi/mL, 1 Ci/m³), a factor of 5,800 times higher than the concentration in 96% of the stored contaminated EAF dust. As the EAF dust contains the hazardous components: lead, cadmium, and chromium, it is designated as U.S. EPA hazardous waste No. K061, and is regulated under RCRA (5). Waste containing both radioactive and hazardous components is "mixed waste." Regulations are not in place for low-low levels of radioactivity, and are not in place for mixed waste. Standards for LLW by the U.S. EPA are not expected for about two years. A brief summary of existing regulations follows.

Generalized radiation protection standards (6,7) limit radiation dose to the public to 1 mSv/y (100 mrem/y). Requirements for LLW and HLW repositories (4,8,9) tighten the limit for those applications "to any member of the public" to 0.25 mSv/y (25 mrem/y). The concentration limit for Cs-137 release in water to unrestricted areas is 0.74 Bq/mL (20 pCi/mL) (10). The NRC issued guidelines for release of land for unrestricted use limiting Cs-137 to 7.4 mBq/mL (0.2 pCi/mL) in groundwater and 0.56 Bq/g (15 pCi/g) in soil for unrestricted use (11), but has not extended the interpretation to material placed in a landfill (rigidly controlled). Drinking water standards (12)

limit Cs-137 further, to 4.1 mBq/mL (0.11 pCi/mL), corresponding to a dose rate of 40 μ Sv/y (4 mrem/y) for ingestion at the rate of 2 L/d. The limit for release of Cs-137 to air for unrestricted use is 74 mBq/L (2 pCi/L) (10). Regulations for packaging and shipping radioactive material (13,14) limit the dose rate at the package surface to 2 mSv/h (200 mrem/h), and 0.1 mSv/h (10 mrem/h) at a distance of 1 m.

It should be noted that wood ash in several northeastern states contains Cs-137 concentrations above 0.48 Bq/g (13 pCi/g) and as high as 0.78 Bq/g (21 pCi/g) (15). Nearly 1.5 million tons of wood ash are produced annually in the U.S. and much of it is used in fertilizer as a source of potash. While use of wood ash as a fertilizer on food crops is not regulated, contaminated EAF dust having similar cesium content cannot yet be recycled or disposed of in a landfill.

RISK ANALYSIS

Risk analyses were conducted for: 1) disposal in a hazardous waste landfill, and 2) recycling with HTMR, using the existing regulations as a frame of reference. In all of the base cases, a cesium concentration of 0.74 Bq/g (20 pCi/g) is assumed as a normalized base. Under DISCUSSION, results are scaled up for each pathway to indicate cesium concentrations that could be permitted by regulations without exceeding allowable radiation exposure to workers or members of the general public. Radiation dose from direct exposure is examined first, as this pathway is associated with temporary storage, transport to other facilities, and handling at other facilities. The RESRAD code (16) was used for all of the calculations.

DIRECT EXPOSURE

The RESRAD computer code was first used to obtain the radiation dose at a distance of 1 m from the surface of a semi-infinite volume of EAF dust. Exposure is due to X-rays from the barium daughter of cesium. Because of self-shielding effects, the outer 0.5 m of material contributes almost all of the radiation dose, with the outer 0.25 m contributing 92% of the total. Figure 1 is a plot of the dose conversion factor (DCF) versus time, for a semi-infinite mass of dust. Initially, the DCF is 1.35 mSv/y per Bq/g (5 mrem/y per pCi/g), decreasing with time as the 30-year half-life radiodecay progresses. For a contamination concentration of 0.74 Bq/g (20 pCi/g), this initial base dose rate becomes 1 mSv/y (100 mrem/y). The base dose rate for semi-infinite extent must be multiplied by an area/shape factor to obtain the actual dose expected from a finite dimensioned source. Using RESRAD methods, the area/shape factor for typically-sized (7.3 X 2.1 X 1.1 m) dust storage boxes is approximately 0.1, leading to a dose rate of 0.1 mSv/y (10 mrem/y, 0.0011 mrem/h), for a person continuously standing 1 m from the center of a box containing 0.74 Bq/g (20 pCi/g) material. The corresponding dose rate for a worker continuously exposed for 2,000 hours per year would be only 23 μ Sv/y (2.3 mrem/y). Other values of the area/shape factor are applied for the configurations encountered for the various pathways. The 0.74 Bq/g (20 pCi/g) base case concentration could be scaled up by a factor of 8,600 before exceeding shipping regulations.

DISPOSAL IN HAZARDOUS WASTE LANDFILL

Some of the EAF dust is normally disposed of in hazardous waste landfills after immobilization treatment. However, existing regulations and operational practice do not accommodate waste having radioactive contamination (mixed

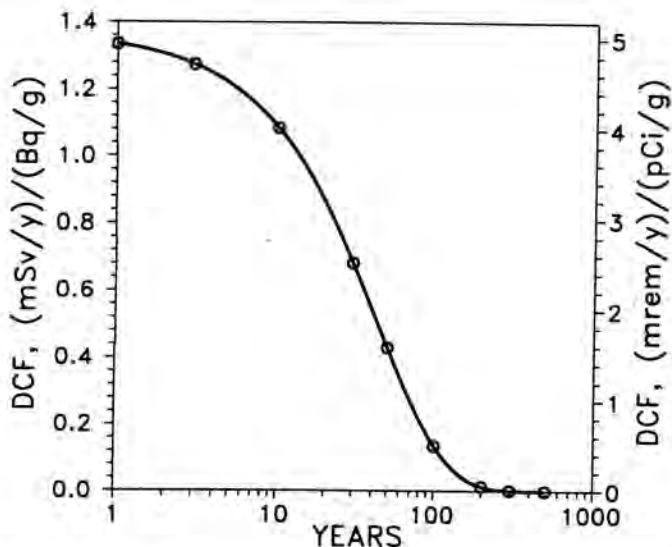


Fig. 1. Dose conversion factor versus time for semi-infinite mass of EAF dust.

waste). Regulatory relief is sought that will establish a level of Cs-137 contamination acceptable for disposal in a landfill.

Description of Landfill

The landfill facility used for the risk analysis is located in the Midwest. It was designed with a double liner and leachate collection system as required for RCRA compliance. The bottom preparation has a 1 m thick low-permeability recompacted soil, covered by a High Density Polyethylene (HDPE) Flexible Membrane Layer (FML). A drain net layer (molded HDPE grill-like material) is placed above the lower FML, followed by a second FML layer, another drain net, and a filter fabric to inhibit waste material from clogging the drain net. Above this is 0.3 m of sand as leachate drainage/bedding material, covered by coarser filter material. The leachate collection system in the bedding material includes transport pipes leading to sump pits. A 1.2 m (4 ft) diameter lined manhole provides leachate detection and pumping access to the sump pits. After waste is emplaced (thickness 7-15 m), it is covered with a sequence of layers more than 2.9 m thick. The surface is contoured and grassed to promote runoff of precipitation and minimize erosion.

The geologic setting of the landfill consists of three major geologic units. The surface formation is Illinoian Drift, which is predominantly silty clay till with interbedded sand, gravel, and silt. Below this is Shelbyville Outwash, predominantly sand with some gravel and silty sand. Below this is Pennsylvanian Bedrock, predominantly gray shale with coal, limestone, and sandstone. The water table is within the Shelbyville Outwash.

Waste received at the facility is treated to obtain a waste form meeting RCRA immobilization requirements, including meeting the TCLP (Toxicity Characteristic Leaching Procedure) requirements (1).

Potential Release Pathways

After eliminating non-applicable pathways, the remaining pathways evaluated are:

- **Direct radiation exposure:** 1) during waste receipt and treatment, 2) to emplaced waste prior to covering, and 3) after waste is covered.

- **Direct leachate drinking scenario:** The leachate collection system remains intact and drinking water is withdrawn via the manhole from the leachate sumps or via a well into the leachate drainage/bedding material.
- **Aquifer drinking water scenario:** The leachate collection system degrades, leachate moves down to the aquifer and drinking water is withdrawn via a well into the aquifer at the down-flow edge of the disposal trench.

Results obtained for these scenarios show that there is no risk beyond the site boundaries. Hence, no scenarios for transport to off-site locations need be considered.

Pathway Modeling and Results

A representative model for the sequence of layers for use in RESRAD code calculations of leaching and downward movement of water was prepared using the geologic and hydrologic descriptions and data in the RCRA Permit Application. The layering model is summarized in Table I. The vertical distance from the bottom of the waste to the water table, as modeled, is 32.5 m.

TABLE I
Layering Model for Groundwater Scenarios

Layer	Designation in RESRAD	Thickness, m
Disposal trench:		
Cover Layers	Cover	2.9
Waste	Contaminated Zone	8.1
Drain Layer	Unsaturated Zone 1	0.4
Drain Nets/FMLs	----	----
Clay	Unsaturated Zone 2	0.9
Underlying geology:		
Illinoian Drift	Unsaturated Zone 3	16.0
Shelbyville Outwash	Unsaturated Zone 4	15.2
Shelbyville Outwash	Saturated Zone	12.2
Penn. Bedrock	----	----

Leaching of emplaced waste and downward transport occurs by infiltrating water. The most important parameter in leaching of Cs-137 from the waste and in movement in groundwater is the distribution coefficient, K_d . The higher the value of K_d , the more the species tends to be sorbed onto solid material and have movement retarded relative to the water movement. For cesium, values of K_d are typically greater than $100 \text{ cm}^3/\text{g}$, ranging as high as 18,000 in tuff (16,17). A conservative value for sand, $K_d = 80$, is used in this study for the base cases. The RESRAD code uses a sorption-desorption, ion-exchange leaching model.

Consider first the direct radiation exposure during receipt and treatment operations at the landfill. As stated earlier, the dose rate for a worker continuously exposed (2,000 hours per year) to 0.74 Bq/g (20 pCi/g) EAF dust in a configuration having an area/shape factor of 0.1 would be $23 \mu\text{Sv/y}$

(2.3 mrem/y). This corresponds to transportation and receipt at the landfill facility. For area/shape factors ranging up to 0.18 for treatment operations, a worker dose up to 40 $\mu\text{Sv/y}$ (4 mrem/y) is calculated. Treatment dilutes the assumed base concentration to 0.59 Bq/g (16 pCi/g), and also reduces the density. The initial value of the DCF for the base case semi-infinite volume of treated waste, by the RESRAD Code, is found to increase slightly to 1.4 mSv/y per Bq/g (5.2 mrem/y per pCi/g). However, at the reduced concentration, this leads to 0.84 mSv/y (84 mrem/y) full-time continuous exposure to a semi-infinite volume of treated waste, somewhat less than for the untreated EAF dust. Emplacement of treated waste in a disposal trench is done in bands less than one meter wide. If contaminated waste occupies one emplacement band, an area/shape factor of 0.12 applies, yielding a worker dose rate up to 23 $\mu\text{Sv/y}$ (2.3 mrem/y). The shielding provided by the 2.9 m thickness of cover layers, added after waste is emplaced, reduces the initial direct exposure rate for a large contaminated area by more than fourteen orders of magnitude to the negligible level of 1.6 aSv/y (1.6×10^{-13} mrem/y)! This very low dose rate also decreases continuously with time. By the time only 0.4 m of cover is applied, the initial dose rate becomes less than 10 $\mu\text{Sv/y}$ (1 mrem/y).

The direct leachate drinking scenario assumes that the well is not continued down to the aquifer in the Shelbyville Outwash, and instead only seeks to make use of infiltrating water from precipitation by drawing from the leachate drainage/bedding material. As an extreme condition, it is assumed that the entire disposal trench is filled with the Cs-137 contaminated waste material. The base case for this scenario assumes a conservative value of 80 for K_d . The annual dose rate for an individual drinking two liters per day is plotted versus time in Fig. 2. The dose rate at time zero is 73 $\mu\text{Sv/y}$ (7.3 mrem/y), but if emplacement is at the time of landfill closure, the dose rate after the 30 year post-closure assured monitoring period drops to 36 $\mu\text{Sv/y}$ (3.6 mrem/y). The corresponding initial concentration of Cs-137 in the leachate is 7.4 mBq/mL (0.20 pCi/mL), decreasing to 3.7 mBq/mL (0.10 pCi/mL), which is within drinking water standards (12), after the 30 year monitoring period. If it is conservatively assumed that the trench is as much as 10% filled with cesium contaminated waste, the dose rate at the end of the control period becomes 3.6 $\mu\text{Sv/y}$ (0.36 mrem/y) and the water would be at 0.1 times the drinking water standards. The aquifer drinking water scenario results show that with reasonable values of K_d , such as 80 cm^3/g , the Cs-137 decays to negligible levels long before the time when contaminated leachate reaches the water table. The breakthrough time is 7,300 y; the cesium simply does not reach the aquifer and basically zero dose results from this scenario, regardless of initial concentration in the waste material.

RECYCLING USING HIGH TEMPERATURE METAL RECOVERY

Description of Processing

Dust from electric arc furnaces (EAF dust) is processed by High Temperature Metal Recovery (HTMR) at Horsehead Resource Development Co., Inc. (2,3) to remove lead, zinc, copper, and cadmium. In addition to removing hazardous components, processing recovers valuable metals such as zinc. A residual material called "IRM" (Iron Rich Material) has had hazardous materials removed, and is released for unrestricted use in the construction industry.

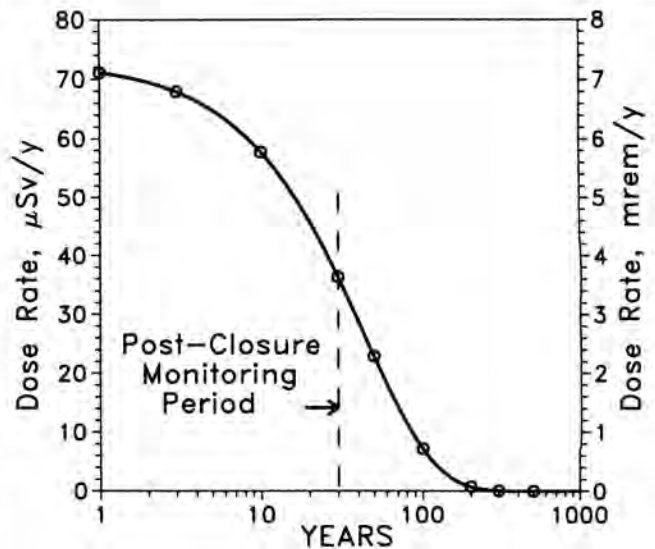


Fig. 2. Dose rate from direct drinking of landfill leachate.

The processing sequence is shown in the flow chart in Fig. 3. The top box: "Subject EAF Dust," refers to a load being tracked such as material contaminated with a radioisotope, assuming regulatory relief is obtained for low-level mixed waste. An incoming load of Subject EAF dust at the Waelzing Plant at Chicago, Illinois is blended at typically 10:1 with material from other uncontaminated sources. In Waelzing rotary kilns, operated at temperatures up to 1,300°C, Zn, Pb, and Cd volatilize and with suspended dust in the off gas go to the bag room. The material collected in the bag room is called "Crude ZnO." Solid material discharged from the kiln is the IRM, and air discharged from the bag room is released through a stack.

The Crude ZnO is shipped by rail to the Palmerton Plant at Palmerton, Pennsylvania for upgrading. An incoming load is blended at typically 5:1 with material from other shipments. In rotary calcining kilns, operated at temperatures up to 1,100°C, Pb and Cd volatilize along with 5-10% of the zinc, under oxidizing conditions, and go to the bag room where the collected material is called "lead chloride concentrate." The lead chloride concentrate is shipped to a plant in Oklahoma for wet processing to recover PbSO_4 , ZnCO_3 , Cu sponge, and Cd sponge. The remaining solution after removal of metals goes to a waste water tank at the plant waste water treatment facility. The likely fate of the cesium during processing at Horsehead is to 1) volatilize in the Waelzing kiln and be collected in the Crude ZnO, 2) revolatilize in the calcining kiln and be collected in the lead chloride concentrate, and 3) dissolve into wet processing solutions and end up in the waste water tank. The pathways that are examined consider variations from this likely sequence in which all of the cesium somehow becomes released to the atmosphere at either of two facilities.

Pathways Considered and Results

For the pathway analysis, the base case level of Cs-137 contamination in EAF dust is assumed to be 0.74 Bq/g (20 pCi/g). The pathways considered are:

- Direct exposure to contaminated EAF dust.
- Direct exposure to materials during processing.
- Release to atmosphere at Waelzing kiln.
- Release to atmosphere at calcining kiln.
- Release to waste water at wet processing facility.

Material quantities in process, air flows, and water quantities, were examined for each step of the processing sequence in Fig. 3. Results indicate that radiation dose from direct exposure is the greatest for the incoming contaminated EAF dust. Considering a reasonable geometry, the dose to a worker continuously (2,000 hours per year) standing next to a large shipping trailer or pile of dumped EAF dust (area/shape factor 0.18) assuming 0.74 Bq/g (20 pCi/g), was obtained by the RESRAD code to be 40 μ Sv/y (4 mrem/y, 0.002 mrem/h). After blending, the average concentration is reduced to 0.074 Bq/g (2 pCi/g), but the larger pile increases the area/shape factor to about 0.4. The net dose rate to a worker continuously stationed 1 m from this blended pile becomes 9 μ Sv/y (0.9 mrem/y). Similarly, the net effect of dilution and concentration at each stage through the multi-plant processing is that the direct exposure dose to a semi-infinite mass of material ranges from 0.05 to 0.40 times that of the incoming contaminated EAF dust. Then, at each stage, various values of the shape/area factor (less than 1.0) apply to reduce the dose rate for the finite sources. Therefore, the direct exposure dose rate throughout the processing sequence is at all times less than that from the initial incoming contaminated EAF dust. In addition, expected work patterns of intermittent instead of continuous presence and greater than one meter average distance reduces the expected dose rate from the conservatively calculated values.

Extreme scenarios for total releases to the atmosphere, involving no bag room trapping at the Waelzing or calcining

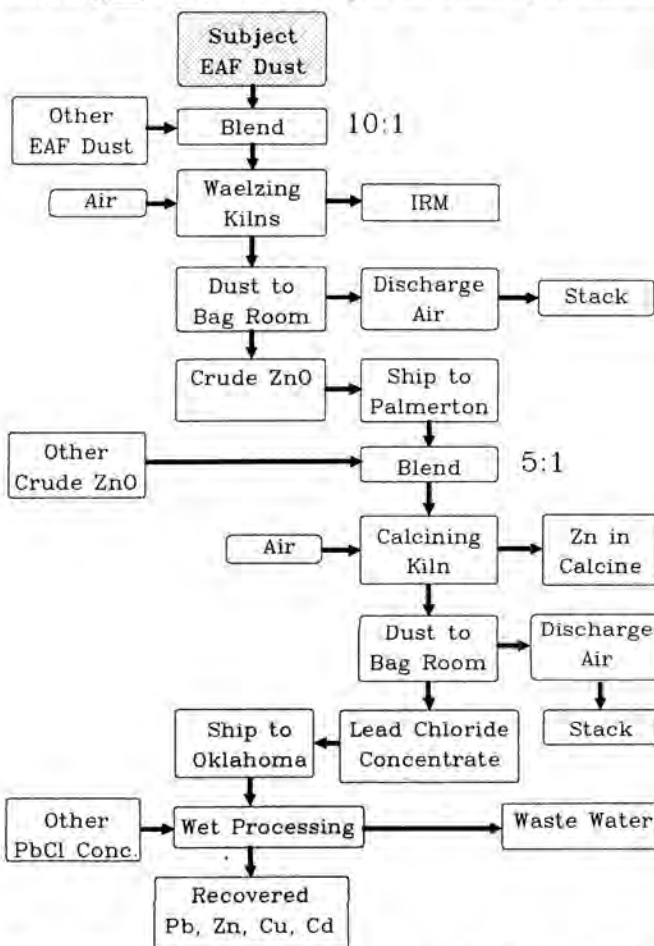


Fig. 3. Flow chart for high temperature metal recovery processing at Horsehead Resource Development Co.

kilns, result in air concentrations less than the limit for unrestricted release by factors of 16 and 29, respectively. This means that these total release to atmosphere scenarios would not exceed the air concentration limit unless there is more than 11.8 or 21.5 Bq/g (320 or 580 pCi/g) of Cs-137 in the original EAF dust. Even higher contamination values would be "allowable" for partial releases to the atmosphere.

If all of the cesium passes through to wet processing waste water, the Cs-137 concentration in the waste water tank is less than the limit for unrestricted release by a factor of 23. This implies that the waste water would be within the limit for EAF dust concentrations up to $23 \times 0.74 = 17$ Bq/g (460 pCi/g).

DISCUSSION

The EAF dust is designated as hazardous waste No. K061, and with Cs-137 contamination is "mixed waste." Regulations are not in place for very low levels of radioactivity, and are not in place for mixed waste. The lowest class of Low-Level Waste (Class A) permits up to 37 kBq/mL (1 Ci/m³) of Cs-137. This is over 60 times as great as the maximum concentration in the most contaminated container of stored dust for the incident studied, and is 5,800 times as great as the average concentration in the balance of stored dust from the clean-out operations. Handling the contaminated EAF dust as LLW is "overkill", involving unnecessary expense and use of repository space better used for higher activity material.

All of the calculations, using the RESRAD code, were made with the Cs-137 concentration in EAF dust normalized to 0.74 Bq/g (20 pCi/g). Any of the numbers in the results scale linearly for other initial EAF dust concentrations. Table II summarizes scaled up concentrations that would be limiting values for meeting various regulations and guidelines.

The EAF dust while in storage and before treatment at either the landfill or Horsehead, represents the greatest potential dose from direct exposure. The most limiting pathway condition obtained would permit up to 4.4 Bq/g (120 pCi/g) without exceeding regulatory dose limits. Potential annual exposure time for a member of the public during shipment of contaminated loads is much less than for a full-time worker. The transportation packaging exposure limit permits concentrations greatly exceeding that of any of the EAF dust. After waste is emplaced at a landfill and covered, the shielding provided by the cover would permit an unlimited Cs-137 concentration.

Landfill Groundwater Ingestion Pathways

Because of retardation of movement even with the conservatively low value for K_d , cesium does not reach the water table and there is therefore no upper limit for cesium contamination for the aquifer drinking scenario. Concerning the direct leachate drinking scenario, assuming as much as 10% of the trench contains contaminated waste material, the Cs-137 content of the EAF dust could be a factor of 10 greater than the base case concentration, or 7.4 Bq/g (200 pCi/g), before the average leachate would exceed drinking water standards after the 30-year post-operations control period. For expected higher values of K_d , or lower contaminated fill fractions, correspondingly greater concentrations would be allowable.

Pathways to Air and Water During HTMR Processing

The likely fate of cesium during HTMR processing is to 1) volatilize in the Waelzing kiln and be collected in the Crude ZnO, 2) revolatilize in the calcining kiln and be collected in the lead chloride concentrate, and 3) dissolve into wet

TABLE II
Summary of Risk-Based Cs-137 Concentration Limits for
Electric Arc Furnace (EAF) Dust

Pathway	Concentration Limit Bq/g (pCi/g)	Notes
Direct exposure:		
Storage and transport	8.1 (220)	1
Transportation Packaging	6,300 (1.7 x 10 ⁵)	2
Landfill direct exposure:		
Transport and receipt	4.4 (120)	1
Treatment and emplacement	8.1 (220)	1
After covering	unlimited	1
Landfill leachate drinking	51 (1,380)	1,3
	7.4 (200)	3,4
Landfill aquifer drinking	unlimited	
HTMR recycling:		
Direct exposure	4.4 (120)	1
Release to air at Waelzing kiln	11.8 (320)	5
Release to air at calcining kiln	21.5 (580)	5
Release to waste water	17 (460)	6
Notes:		
1 0.25 mSv/y (25 mrem/y) limit, 10 CFR 60, 10 CFR 61		
2 0.1 mSv/h (10 mrem/h) limit at 1 m, 10 CFR 71, 49 CFR 173		
3 10 % of trench filled with contaminated waste		
4 drinking water regulations, 40 CFR 141		
5 atmospheric release regulations, 10 CFR 20		
6 water release regulations, 10 CFR 20		

processing solutions and end up in the waste water tank. The three air and water pathways considered assume that all of the cesium does end up in the waste water or that alternatively it all somehow escapes into the stack and atmosphere at one or the other kilns. Results indicate that EAF dust Cs-137 contamination could be 11.8 Bq/g (320 pCi/g) and greater before exceeding allowable concentrations for release to unrestricted areas for these air and water pathways.

CONCLUSIONS

It is important for economic and environmental reasons that regulatory relief be obtained to close the regulatory gap concerning low-level mixed waste to eliminate the present disposal and recycle impasse. This would permit doing something with EAF dust contaminated with Cs-137, instead of continuing to store the material. Similar problems involving other radionuclides and other industries likely exist but were not a part of this study. An adequate regulatory level for Cs-137 in mixed waste would permit recycle processing or disposal in local hazardous waste landfills. An adequate regulatory level would permit cost-effective decontamination processing to be applied to facilitate recycle processing or disposal. The results for risk analysis of the various applicable pathways indicate that Cs-137 concentrations in EAF dust ranging from 4.4 Bq/g (120 pCi/g) to unlimited values would not cause workers in unrestricted areas or members of the public to receive doses exceeding limits in existing regulations.

Obtaining regulatory relief is complicated by the interactions required among NRC, EPA, agreement states, regional LLW compacts, and individual state nuclear and environmen-

tal protection agencies. The risk assessment performed in this study indicates that a Cs-137 contamination level of up to 3.7 Bq/g (100 pCi/g) is not unreasonable as an allowable limit for disposal in a landfill or for HTMR recycling. An interim level, such as 0.74 Bq/g (20 pCi/g), might be necessary while higher levels are under consideration among the various agencies. This level would be comparable to that in some unregulated wood ash used in agricultural fertilizer, and to the 0.56 Bq/g (15 pCi/g) level in NRC guidelines for soil in reclamation work.

REFERENCES

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