

INDUSTRIAL HAZARDOUS WASTE CHARACTERIZATION USING DUST CODE

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ABSTRACT

CAIMA (Industrial Assistance Center for the Environment) is a not-for-profit organization in the State of Minas Gerais, Brazil, and acts in the industrial residues management field, by providing the industry with advice on the implementation of Residues Management Programs that encompasses from residues characterization, reuse, recycling, and final disposal.

In order to help CAIMA in their decision process, calculations are performed to estimate the concentrations of hazardous wastes in soil resulting from the burial of industrial residues. The computer code DUST is used as the screening tool for analysis of the contaminant release processes from the landfills under different hydrogeological conditions.

The residues have several components including heavy metals, like Cr, Fe, and Pb, which can pose risks to human health.

The projected contaminant concentration information is used to improve decisions on what can be safely disposed as well as on the necessary waste form characteristics changes that could make the costs of municipal landfill disposal lower.

INTRODUCTION

Many tons of industrial residues are generated every month by the industrial activity in the region of Minas Gerais State, Brazil. According to the regulation standards a significant portion of this waste is considered class 1 which means this waste must be disposed of in a safe way in order not to pose risk to the human and environmental health.

CAIMA provides the following services to the industry:

1-Residues exchange- The industries can trade, search for methods of reusing, recycling or changing the waste composition so to make it less hazardous.

2- When other treatments are not possible, a disposal technology must be found for those residues considered hazardous. To accomplish this the Environmental Authorities are considering constructing a disposal facility for this type of waste within the state, and one of the most probable sites would be close to the industrial park of the city of Belo Horizonte, capital of Minas Gerais. For the immobilization, a number of different technologies could be chosen

depending on the geosphere conditions, including humidity, geology, hydrological characteristics etc.

Some points of interest in addressing disposal of hazardous wastes are: (1)

- 1- Waste treatment technology.
- 2- Waste form characterization.
- 3- Development of criteria for judging performance of waste forms.
- 4- Pursuing new materials for waste immobilization.
- 5- Cost/benefit analysis.

This paper represents a first step towards the achievement of the above items. By defining waste form performance criteria, expert judgement is used to determine a range of matrix materials for the waste immobilization that best match the criteria.

This set of calculation is based on the experience gained by LLW disposal units safety assessment, especially by using DUST code in other works (2).

The Disposal Unit Source Term (DUST) code is used in this work because of its capability to handle some important parameters as a screening tool. It is a one dimensional code that models the transport of contaminants from the waste containers to the boundary of the repository by applying either finite difference (FD) or multi-cell mixing cascade (MCMC) models.

FD is a numerical solution while MCMC is an analytical one. The FD model was used for our purposes.

DUST was used to analyze two different waste form release models, namely diffusion and dissolution, representing the two major possibilities of matrix for the waste immobilization. Diffusion is usually assumed to control the release of contaminant from the porous materials such as cement and polymers.

Dissolution is assumed as the release mechanism for non-porous media such as glasses and metals.

In this paper we analyze what would be the performance of two different material matrixes concerning their release mechanism.

THE RESIDUES

Every year many tons of wastes are generated as a consequence of industrial activity. Among the hazardous components of this waste a special attention is given to the heavy metals. A preliminary study shows that roughly the main hazardous contaminants are 11 weight % of Zn, 8 weight % of Cr and 3.5% weight of Pb.

We will focus our attention on the heavy metal constituents as a screening tool for prioritizing future work. As needed other contaminants and more sophisticated modeling can be performed. The main heavy metals present in the waste and used as the basis for our study are, Cr, Pb and Zn.

The drinking water standards are established by a regulatory department COPAM , Environmental Policy Commission, which establishes the limits for the concentrations of heavy metals in the drinking water.

The COPAM limits for the contaminants of interest are:

Pb: $2.5\text{E-}8 \text{ g/cm}^3$
Zn: $1.87\text{E-}7 \text{ g/cm}^3$
Cr: $5\text{E-}8 \text{ g/cm}^3$

WASTE FORM

A primary function of waste form is the retention of the contaminants. Also, structural stability is important in order to minimize the probability of waste form deterioration.

There are several different materials that are used for waste solidification. The choice of one or another depends on many factors like their physicochemical properties, costs, loading capacity, etc.(3)

Following are some examples of materials used as waste form matrix:(3)

1-Cement

Cement is one of the most used materials for waste solidification, mainly because of its relatively low cost and readily availability. Other advantages are: a) it can be processed at low temperatures and b) yield satisfactory waste forms when properly formulated.

Because of these advantages this material would be the first choice for further studies on hazardous waste immobilization, depending on its contaminant retention capacity.

Some disadvantages are that it depends on chemical reactions to solidify and chemical interactions between the waste and the cement may occur that will impede the solidification process.

2-Polymers

There are a large number of polymeric materials that could be used for waste solidification. Here are presented two types:

- Epoxy: epoxies are thermosetting organic polymers that depend on chemical reaction to solidify. This is a drawback because likewise cements, the solidification process and consequently the properties of the final product or waste form can be altered by any subtle changes in the chemistry of the waste.
- Polyethylene: polyethylene is a thermoplastic material of the chemical formula (CH_2CH_2). A low-density polyethylene process has been developed for the encapsulation of radioactive and toxic wastes. Its compatibility with wastes over a wide range of conditions, material properties, solidification efficiency, ease of processability and economic feasibility makes it a viable candidate for waste solidification.
- More details on other materials can be found in reference 3.

3- Glasses

Glasses are typically amorphous structures with little long-range order. They are high melting point materials. Waste solids are generally incorporated into the glass structure as oxides produced during high temperature (1200 °C) processing conditions.

Some important disadvantages are the high temperature for the process of immobilization and high cost.

METHODOLOGY

A generic repository will be considered for the analysis with the primary objective being to determine the needs for engineered barriers and immobilization technology. The DUST (4), code (Disposal Unit Source Term) will be used as a screening tool. The DUST code is very convenient at this point because of the flexibility to rapidly simulate wide ranges of different contaminants and waste form release characteristics typical of the residues. The DUST code is a 1-Dimensional subsurface code. This code does not require a large amount of data and expert opinion can be used very easily. Projected concentrations in the drinking water will be used as a reference in order to compare the disposal facility's capability to meet the standard limits.

DUST helps to account for the most important processes that influence the release of contaminants to the environment. The lack of data on source term magnitude and characteristics will lead to large uncertainties and therefore further experiments and data collection will be needed in order to refine the current assessment.

Two materials are considered when modeling the repository: concrete for the engineered barriers and soil for backfill. The waste is considered uniformly distributed within the containers which are 55-gallon drums. Special attention is given to the release process and consequent concentration of contaminants at the groundwater level. This is because this screening calculation is focused on the ability of the facility to retain the contaminants and a study of the local geosphere will be considered later, e.g., concentration at a well 100 m down flow.

The finite difference method is chosen for the calculations because two different materials are being used for the contaminant migration path.

As there is no available site data, K_d values will be drawn from literature. In reference 2 there is a large database on heavy metals distribution coefficients. They are divided into four soil types: sand, silt, organic and clay. For each type there is a geometric average for K_d values. In order to be conservative we will take the lowest values, which correspond to sand, type soil. This can be considered conservative because the clay soil would be the choice for backfill material.

All the potential sites are located in a similar climate zone and the weather conditions are not expected to be substantially different. Therefore, for the first cut screening calculations average weather conditions will be assumed.

Typically leach tests are performed prior to other tests to demonstrate the ability of the waste form to retain the contaminant. This screening calculation is to help to determine the importance of contaminants inventory and the release mechanism on contaminants concentration at the bottom of a generic facility.

Other tests are related to the ability of the waste form to remain physically intact over a long period of time and are performed once the waste form is considered satisfactory as a barrier to the migration of the contaminants.

Certainly the cost will be a determinant on the decision of what technology to apply for the waste immobilization. As for each waste form there will be a characteristic release rate, expert judgement is used to decide which would be the most appropriate waste form according to the source term calculated by DUST.

This will act as a starting point for further research on new economical forms of immobilization of the waste.

ASSUMPTIONS

The assumptions for the screening calculations are:

- 1- The containers are considered to fail instantly.
- 2- The waste is evenly distributed within the waste form.
- 3- Waste form release will be modeled in separate simulations using the diffusion and dissolution release process models.
- 4- There is a concrete barrier at the bottom of the repository and another one as a cover.
- 5- The engineered barriers are supposed to last for 500 years.
- 6- Simulations with different dissolution release rates will be performed in order to determine which rates will be acceptable according to the target concentration limit.

Due to the lack of data, the most conservative values will be chosen according to the literature. All these values can be changed, as more site-specific data are available.

The parameter values are as follows:

Solubility: 10 mg/cm^3 , default in the DUST code. This value is high enough to ensure that solubility limits do not influence release.[4].

Diffusion coefficient: A conservative value of $10^{-6} \text{ cm}^2/\text{s}$. This value is equivalent to a Leach Index of 6, the minimum allowed by the waste form technical position. [4].

Dissolution rates: Two release rates are considered, $10^{-5}/\text{yr}$ and $10^{-2}/\text{yr}$. The reason for that is that $10^{-5}/\text{yr}$ is a maximum release rate for wastes containing long-lived radionuclides or highly toxic radionuclides as conservative and technologically feasible.

Expert opinion was used in order to establish the range limits for this parameter.

Other input data are:

Facility dimensions

As this is a one-dimensional calculation, it was considered 20 high and an unsaturated zone of 15m.

Infiltration

$1\text{e-}8 \text{ cm/sec}$ before barrier failure

$1\text{e-}6 \text{ cm/sec}$ after failure

Soil density = 1.6 gm/cm³

Concrete density = 2.0 gm/cm³

Moisture content (of backfill) = 0.36

Kd coefficients cm³/g (Geometric Averages). [2].

	Sand	Silt	Organic	Clay
Cr	70	30	270	1500
Zn	200	1300	1600	2400
Pb	270	16000	22000	550

RESULTS

Figures 1 to 3 show the results of release from the disposal unit through different mechanisms. Figures 1 and 2 are release by dissolution and Figure 3 is release by diffusion. As said before, porous media typical release mechanism is through diffusion. And dissolution is assumed for non-porous materials. All the figures show peak concentrations bellow the standard limits and close to 10,000 years for Cr while for Zn and Pb the peak concentrations will occur after that time.

This result can be explained in terms of contaminant Kd's and initial inventory. Chromium (Cr) with a Kd of 100 cm³/g was lower than for Lead (Pb) and Zinc (Zn) which was 200 cm³/g. As for Zn and Pb, the initial inventory for Pb was 3.5 weight % in comparison to 11 weight % for Zn.

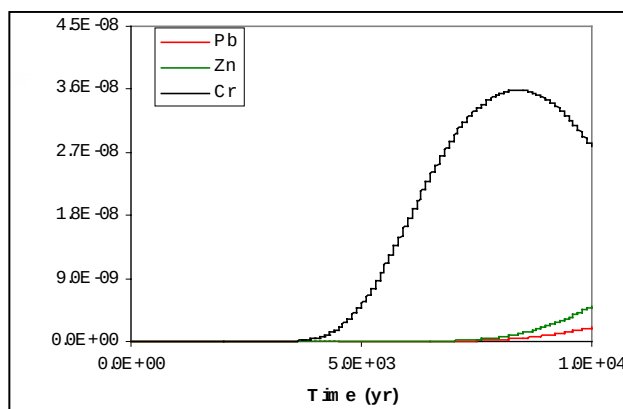


Fig. 1: Release by dissolution with a dissolution rate of 1E-2/yr

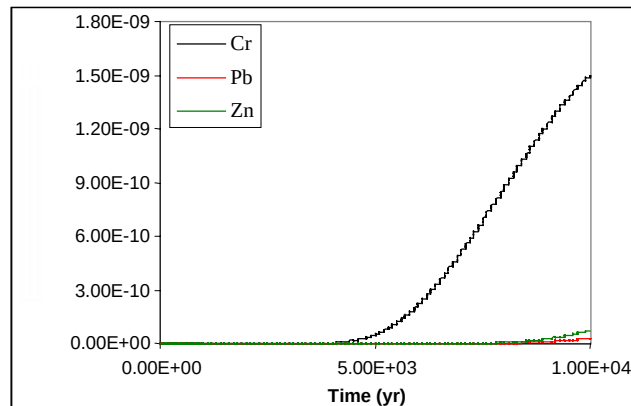


Fig. 2: Release by dissolution with a dissolution rate of $1\text{E-}5/\text{yr}$

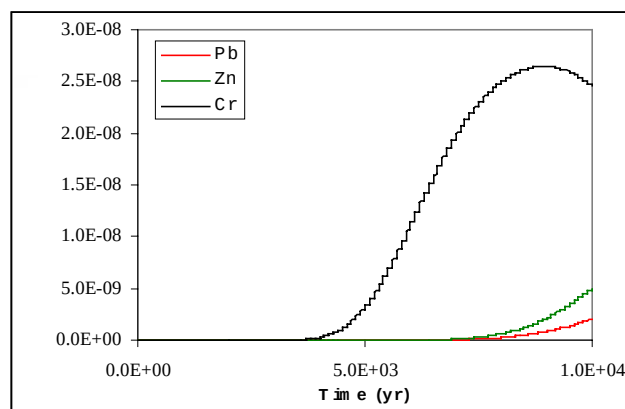


Fig. 3: Release by Diffusion

CONCLUSIONS

Two types of release mechanisms were simulated, diffusion and dissolution, representing two different waste form matrixes: a) porous materials such as cement and polymers, and b) non-porous materials such as glass.

The results show that, for the inventories and other conditions here simulated, the concentrations at the ground water level are reasonably comfortable as far as the standard limits are concerned.

There are still other factors to be considered in future works. For example uncertainty analysis. These results are based on parameter values with considerable ranges of variation. However such values were chosen as conservative and as so they can be used as a reasonable basis for the decision of pursuing further research on cement as a waste form matrix for the hazardous waste.

A next step in this research will be

- a) A sensitive analysis to show how different parameter values will affect the results.
- b) Uncertainty analysis by considering ranges for the most important parameters.
- c) Analysis of load capacity for cement and compare it to other matrix materials. This will be part of a cost/benefit analysis.
- d) Analyze the effects of chemical reactions on the contaminant mobility in the soil.

Some other points to be considered are building a trench instead of a repository, which could considerably lower the costs.

This shows the importance of further investigations on other materials like polymers that even though are more expensive have some advantages like higher loading capacity, weight, and ease of molding.

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