ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

TECHNICAL PAPER 21

Solid waste management and disposal systems at mills and refineries

By Philip Mulvey – Environmental & Earth Sciences

1.0 Introduction

Solid waste management at most mills and refineries is controlled by disposal costs. The focus of this paper will be waste management by disposal management.

2.0 Why manage waste?

2.1 EPA Licenses

In most Australian states there is a move to license all landfills according to environmental criteria and classify all wastes prior to disposal such that landfills can only receive wastes for which it is licensed (Hine P, 1999, NSW EPA, 1999 and NSW EPA, 1999). There are 300 licensed landfills in WA (Hine P, 1999) including those at mines. However there are more than 600 mines, mills and smelters in WA (W Carr pers. com, 2000), it is apparent that waste emplacement facilities are not licensed at mines, mills and refineries.

In discussions four years ago, a recently appointed environmental manager at a large refinery pointed out how surprised he was to find that the refinery management were proud of the effectiveness of their recycling policy. After five years they had successfully recycled kitchen scraps from the canteen and printer cartridges from the offices. In facilities where large raw materials, byproducts, waste products and offspec raw materials and products are generated waste management is often limited to tailing management and all other aspects are often ignored.

Currently in NSW, mills and refineries require operation licenses and consequentially are required to license their waste disposal. However, "mines where the only waste disposed is tailings, waste rock or inert waste generated at the mine" without disposal offsite of other wastes do not require to be licensed (NSW EPA, 1999). As nearly all mines dispose of waste on site they require waste licenses. Thus to comply with current legislation in NSW waste emplacement centres at mines, mills and refineries need to be licensed disposal facilities. Increasingly, unless the industry maintains a trackable waste management system, greater regulatory control by EPAs will occur.

2.2 Compliance with environmental management systems

To comply with environmental management (ISO 14001) and reporting, waste management systems are required.

3.0 Solid waste streams

Solid waste generated on a plant can include: medical waste, putrescible waste (canteen, mess), paper and cardboard (office), oily waste (filters, rags from workshop), biosolids, general refuse (tyres, plastics, cable etc), timber (pallets), green waste (garden clippings), demolition and construction wastes, contaminated soil as well as the production wastes (slags, filter cake, fume/baghouse dusts, muds, washery rejects, pickling liquor sludges, lime kiln refuse, ash, partly treated ore, offspec product or ore, etc)

Each of these has to be classified prior to disposal. Many of these wastes can be co-disposed for a better outcome or to generate a product.

4.0 Waste management overview

Waste management is based on the following simple rules **– GIVE WASTE A VALUE** by :

1. defining your footprint both of the plant and waste disposal and keep it to that; and
2. restricting waste disposal by charging the true disposal costs to the generator.

Clearly this is an end of pipe solution, but for existing plants this often the only solution and as will be explained in the paper through the realisation of major benefits the principles should be applied to new plants. To achieve these rules you have to:

1. define your receiving environment;
2. establish a leach protocol based on Australian Standard Leaching Protocol (ASLP) to simulate the extremes of the receiving environment;
3. establish the receiving water guideline and attenuation factor to define waste classes;
4. derive charges for wastes that comply with classes;
5. for wastes that fail the class, prepare and cost special procedures or immobilisation techniques to get the waste to comply;
6. plan and cost an environmental monitoring program; and
7. set up an internal interdepartmental system where the generator is charged for the true cost of waste disposal and is rewarded for waste reduction.

Information relating to these above-mentioned steps is provided in the following sections.

5.0 Planned footprint

The location of many plants is controlled by their location to transport and power and the presence of abundance space. One of Murphy's rules of economics is that you utilise as much space as is available. At the time of the initial planning of the site, the initial footprint should be decided. Every decade, or more frequently, a new plan is prepared for the plant. Areas for the setdown of raw materials, product, by product and waste product should be clearly delineated at this time. Exceedance by any department of these areas should be allowed but at substantial cost to that department. The cost should increase with time. The reason being to ensure off spec raw material or products are processed as quickly as possible and not left forgotten. Long term costly implications can arise from stored offspec raw material, product or waste products.

A large smelter being decommissioned and sold found that the second worst contaminated area on site, arose from dumped fume that had been left onsite for some time as treatment costs were expensive. Consequently cost of remediation of contaminated groundwater exceeded initial cost to treat this material substantially. In another case a long establish plant with plenty of available land had an expanding foot print as offspec raw material was stockpiled awaiting blending. Several decades later some of these stockpiles remain as the process has changed or the manager who placed the piles has moved on and the reason for placement is forgotten.

Plan your footprint and stick to it. Ensure that non-compliance is costly.

6.0 Classification of wastes

6.1 Basis behind leach protocols adopted in Australia

In NSW, Vic, Tas and Qld the acetic acid leach is used following the toxic characterisation leaching procedure (TCLP) based on USAEPA Method 1310a. WA uses a better derivation for Australia known as the Australian standard leaching protocol (ASLP) according to Australian Standards AS 4439-1997. Prior to designing a leach protocol it is necessary for a mine to evaluate the basis behind those used by the state governments.

In the USA it is often reported that there is a trend away from landfills because of the problems associated with them. Vast areas of the USA, particularly in the north and the east, have:

- a precipitation excess;
- are mountainous or close to mountains such that erosion dominates over weathering;
- have been affected by glaciation.

This means that the soil is quite permeable, allowing water to infiltrate readily, creating large tracts of potable groundwater. Leachate from landfills built in this environment rapidly degrade water supplies. Southern and Central California are not like this and in these areas landfills are seen as the current and future prime method for disposal of wastes.

Australia is different from California and radically different from the rest of northern USA, as most of Australia has a precipitation excess, has only a slight gradient and weathering dominates over erosion. Soils are derived *insitu* and are usually stratified, containing clays which physically retard water and chemically attenuate leachate.

Due to evaporation effects layers of sesquioxides also develop in the soil and these also assist in chemical attenuation of leachate. Water usually takes a long time to reach the water table, which is often of poor quality, and barely useful for stock water.

The impact of landfill in this environment is far less than that of northern and eastern USA. Thus landfills are currently, and will be viewed in the future, as the best method of disposal of waste for most of Australia.

6.2 Current guidelines for leachability

To ensure that toxic substances are not placed at a sufficient rate to cause harm to the environment, guidelines for construction and guidelines for evaluating substances fit for disposal have been derived. The most recent guidelines released in Australia have been in NSW. WA is about to release landfill guidelines pursuant to 63 – 65 Schedule Part 1 of the Environment Protection Regulations, within the next few weeks. These guidelines follow a similar approach to NSW.

Unlike the rest of Australia the Perth and the west coast lie on the Swan Basin, which has extensive sand deposits with groundwater being of potable quality. Thus for this area of WA conditions are not dissimilar to those typically found in the USA.

In Tasmania, NSW and Victoria, the EPA's have released guidelines for assessing the leachability of industrial waste for landfills. These guidelines recommend the use of the Toxic Characterisation Leachate Procedure (TCLP) which essentially uses 0.1 N acetic acid mixed on a basis of 1 part soil to 20 parts water. The results are compared against a value and depending on the result the waste is classified into different categories and can only go to landfills that are licensed to receive that category. The comparison values are derived from multiplying the drinking water guidelines by an attenuation factor. For the NSW guidelines, generally the attenuation factor, for inert waste is approximately 10 times drinking water standards, solid waste is 100 times and industrial waste is 400 times. No justification of these attenuation factors have ever been undertaken for Australian conditions.

If the water down gradient is not used for drinking these are inappropriate guidelines. Where aquatic or marine waters are within a kilometre, criteria for discharge into these waters may be more appropriate. These levels have not been as well studied as drinking water guidelines, however, the NHMRC released Australian Water Quality Guidelines for Fresh and Marine Waters in November 1992. These guidelines are currently under review and a new set of criteria is expected to be released shortly.

Nevertheless, for a majority of sites, the criteria based on 10 or 100 or 400 times drinking water guidelines may be inappropriate, however, deriving site specific guidelines may be too expensive.

6.3 Leaching medium

The TCLP was designed to characterise waste for disposal in well drained unsaturated landfills that generate organic acids such as domestic waste landfills. The NSW SPCC document WD-3 (SPCC 1988) the predecessor to the 1999 regulations (NSW EPA, 1999) states:

"The leaching medium to be used in the test depends on the presence or absence of acidic or acid generating wastes at the proposed landfill site. If the industrial waste is to be disposed of in a landfill with putrescibles wastes (eg domestic waste), a buffered acetic acid leaching medium is used. However, if the waste is to be put in a landfill on its own, then a distilled water leaching medium is generally satisfactory. "

This approached was beginning to address the variations in leaching medium within which the waste is placed, but the penultimate draft published in December 1991, does not make this distinction, nor the guidelines that were released in 1999 (NSW EPA, 1999b). Nevertheless, the non-volatile TCLP do test was designed principally to simulate the disposal of wastes into a putrescible landfill, that is an aerated organic acid extractant. This is a totally inadequate simulation for many bulk limited waste type landfills, eg waste disposal of coal washery rejects or fly ash disposed with seawater into a saline reducing environment, and any waste that contains sulfides.

In many Australian landfills perched water tables develop due to the low permeability of the underlying sediments or in the emplaced material. Under saturating conditions, anaerobic or reducing conditions develop and the pH rises to between 7 and 8, though, in the short term putrescible landfills produce mildly acidic reducing leachate ranging in pH from 5 to 7. Thus, in most landfills, the TCLP becomes meaningless as some metals are more mobile and more toxic under reducing conditions. Other leach tests may more appropriate if based on local conditions.

6.4 The dilution attenuation factor

The 1988 NSW draft guidelines stated that "this 100 times factor has been adopted from the US EPA requirements."

"The TCLP is designed to address the mobility of both organic and inorganic compounds and to apply compound specific dilution/attenuation factors generated by groundwater transport models."

"The dilution/attenuation factor has been selected on the grounds that a reduction in concentration would occur during constituent migration from the bottom of a disposal unit through an unsaturated zone and through a groundwater source (ie the saturated zone) to a drinking source (eg a drinking water well). Many other factors such as potential dispersion in all directions, one dimensional and uniform advective flow, adsorption and chemical degradation from hydrolysis are also considered."

It is apparent from these two statements that the dilution/attenuation factor is supposed to be species specific, but this is quite simply not the case. The 10 times 100 times and 400 times value are totally arbitrary.

For most Australian conditions the silty clay causes solution dispersion to be greater (due to increased tortuosity), and attenuation is immensely greater. As a generalisation the chemistry and physics of transport is completely different, with once again Swan Basin being one of the major exceptions.

7.0 Criteria for disposal of a industrial waste to a non-putrescible limited landfill

Though the leach test may be inappropriate for disposal of a small amount of industrial waste to a putrescible landfill (ie containing degradable organic matter) in Australia, the criteria and the dilution/attenuation factors are sufficiently conservative to safeguard the environment. In instances where discharge to surface water does not occur and the local groundwater is not used a more appropriate dilution/ attenuation factor may be derived (Mulvey, 1999). This is particularly the case for limited waste streams applies essentially to non-putrescible landfills.

For example, in 1985 Tomago Smelter set up a waste emplacement facility to receive cyanide and fluoride waste at Wallaroo a site specific retardation factor was derived for both cyanide and fluoride resulting in the site becoming licensed to receive fluoride wastes well above concentrations allowable by the standard TCLP.

7.1 Deriving leachate

Many industrial landfills are operated by the generator and are dominated by one or two bulk wastes with a number of waste streams being minor inputs. They may be deposited subaqueous in dams, (eg, coal washery rejects), or deposited as a wet slurry, (eg, filter cake or neutralised spent pickled liquor), or dry (eg. fly ash and flue dust). For most of these wastes the TCLP is completely inappropriate.

As the waste may be subject to different influences a series of leachate simulations may be required. In order to define an appropriate leachate test or tests the following factors need to be considered.

1. Transportation medium: for wastes deposited subaqueous or as a slurry, the transport medium should be used as a leachant. This may be local dam water, groundwater or seawater.

2. Groundwater or leachate from other wastes: if the groundwater varies seasonally and may rise to within the landfill, particularly when a hole or valley has been filled, local groundwater should also be used as a leachant. When a waste is placed down gradient of another waste, the leachate from the upgradient waste will pass through the down gradient waste. In this instance leachate or groundwater from the perched watertable within the up gradient waste should be used as the leachant.

3. Extreme environmental conditions: most sites could be subject to an extreme environmental condition, ie 1 in 1000 year storm or flood, king tide or tsunami. A leachant should be prepared to simulate these conditions.

7.2 Deriving dilution/attenuation factor

A site specific attenuation factor can be derived in the laboratory that can be used instead of the conservative default value of 100 times appropriate water quality criteria.

The attenuation factor at any site is variable depending on the ion. The attenuation factor for a particular ion for certain site soil conditions is known as the retardation factor, and is the ration of the contaminant velocity compared to that of groundwater.

How to derive the retardation factor is addressed in Mulvey 1999.

If site specific dilution/attenuation factors are derived, a factor has to be derived for each of the relevant contaminants in the leachate.

7.3 Monitoring

Monitoring is undertaken not just to comply with regulatory guidelines but also to confirm the landfill is leaking according to the rate predicted by the conceptual model (see Mulvey, 1998).

8.0 Case study

BHP Steel operates a large landfill of approximately 300 hectares on Kooragang Island, an island in the Hunter River delta, near Newcastle. The landfill had been receiving a variety of wastes since 1970. Up until the late 1980s tipping at the landfill was largely uncontrolled. In the early 1990s, due to the proximity to a wetland and increasing environment awareness, it was decided to managing the wastes entering the landfill. The wastes disposed at that time from the steel works are shown in Table 4.

TABLE 1 WASTE FROM THE STEEL WORKS DISPATCHED TO KOORAGANG ISLAND

Waste	Tonnes/annum
Coal washery rejects	60 000 to 100 000
Fly ash	50 000
Basic oxygen steel making primary fume	30 000
Effluent treatment plant sludges	7 500
BOS secondary fume	3 000
Blume castor dust	100
Castor demolition baghouse dust	>100

During the audit it was found that a range of wastes from affiliated companies was also being disposed at this landfill.

The wastes arrived on the island by pipeline or truck. Essentially the piped wastes are mixed and pumped across to the island using seawater. Many millions of litres of seawater are pumped across per year. This seawater creates a perched water table that, with time, becomes anaerobic. A groundwater survey found that, as a result of previous disposal of lime kiln slurries, groundwater can have a pH as high as 12.2, whilst remaining saline. These environmental conditions were assessed and a leach protocol was derived as follows:

1. Seawater buffered to pH 7.6;
2. Seawater buffered to pH 12.2;
3. Anaerobic water buffered to pH 7.6.

This leach protocol was approved by the EPA as a replacement of the TCLP. The acceptance criteria currently used were 100 times ANZECC Marine water quality guidelines (ANZECC 1992) or the drinking water guidelines at the time.

A whole range of trucked wastes from a variety of sources was found to fail the disposal criteria. They were banned from the island unless it could be approved that they were absorbed onto the bulk waste. Often the chemical binding capabilities of the bulk waste is ignored or not realised. Coal mining and coal burning create wastes that have absorption properties that can be used to stabilize other wastes. Fine coal washery rejects and fly ash have a large surface area and can have a significant absorption capacity for metals and some hydrocarbons. Lead and zinc dusts and fumes from the baghouses of refineries, steel mills and associated companies, oil wastes and other organic wastes were mixed in varying ratios with coal washery refuse, flyash and a combination of both and subjected to site specific leach tests as well as the TCLP. The fly ash was found to have better retention properties as the coal washery had less surface area for adsorption.

In another study similar metal rich waste was mixed with waste from the fertiliser industry to created insoluble metal salts.

If it could be shown that mixing these wastes complied with the classification criteria, the waste generator had to pay for the infrastructure costs associated with the mixing. A large number of wastes failed the criteria, even after co-disposal trials and consequently these wastes were banned from the repository.

At a less sensitive site the procedure would be the generator then has the option of paying for the disposal at a special designed monocell for these hazardous wastes, including the increased monitoring costs, together with chemical stabilisation, or to re-engineer the plant, so less or different waste, is generated.

For example when waste generators were not allowed to dispose at Kooragang Island the alternatives were to use a commercial hazardous waste disposal process at a cost of over $500/tonne or find ways of not producing that waste. As a result of the introduction of these measures, arisings of nonbulk wastes at the steel works and associated industries were reduced substantially by changes introduced by staff who were forced to think of more efficient manufacturing systems. Instead of a few personnel in the environment department looking at recycling, the creative energies of the whole work force was focussed on waste reduction for the waste stream that mattered the most, the hazardous waste stream.

Reportedly this resulted in substantial savings in operational costs, over and above the costs to manage the waste management plan and the increased environmental monitoring.

Such a processes ensures ownership of the waste and responsible disposal rests with the generator.

9.0 Disposal verses storage

It is interesting to note that there is an increasing trend at the moment to use artificial liners in landfills and aim for zero leachate discharge. In addition, particularly for putrescible landfills, the waste is segmented into cells, heavily compacted and sealed by well compacted cover to minimise infiltration. Natural decay is delayed. This effectively stores rather than disposes of the waste. The disposal problem is deferred to another generation.

This philosophy of waste management has potential serious long term implications and has come about through poor management of the disposal philosophy, resulting in a release of contaminants at a rate faster than the environment can absorb.

The philosophy of disposal purposely encourages interaction with the environment at a rate at which the environment can handle the contaminants. Such an approach requires a detailed definition of the waste, the medium through which it travels (soil, rock and groundwater) and an understanding of the interaction of the two. It also results in active decay/attenuation/degradation occurring whilst active site management is in place.

For a stored waste landfill design as the landfill is usually perceived as not leaking, monitoring and maintenance of leachate collection system reduces or ceases with time yet the potential for the breakdown of the liner or cover increases with time. When the breakdown occurs, the time capsule freezing degradation is broken and contaminated leachate pulses into the environment, in all probability, after active management has ceased.

Waste disposal requires monitoring to confirm that the conceptual model of leachate migration is correct.

10.0 Conclusions

Waste management is a function of reducing the footprint of all unwanted material and ensuring the true cost of monitored safe disposal is passed onto the generator. This requires ensuring the landfill has a liner and a monitoring system and if hazardous waste is disposed, a leachate collection system is implemented. The waste has to comply with the disposal criteria or be modified so that it does meet the disposal criteria. Compliance costs including increased monitoring are meet by the internal client.

Such a system usually results in significant waste reduction as the generator has to meet the cost of disposal.

11.0 References

1. ANZECC. (1992). *Australian Water Quality guidelines for Fresh and Marine Waters.*
2. Hine, P. (1999). *Industrial waste and contaminated soil classification for disposal in WA in Soil Technology – Contaminated Land*. Centre for Land Rehabilitation: UWA.
3. Mulvey, P. (1999). *Theory behind proactive assessment of contaminated land In WA in Soil Technology – Contaminated Land.* Centre for Land Rehabilitation: UWA.
4. Mulvey, P. (1998). Groundwater Monitoring. *Mining Environmental* Management, 6(4), 13-20.
5. NSW Environment Protection Authority. (1991). *Draft Environmental Guidelines for Landfill Disposal of Industrial Waste.* New South Wales Environment Protection Authority (NSW EPA.
6. NSW Environment Protection Authority. (1999). *Environmental guidelines: assessment, classification & management of liquid & non-liquid wastes.*
7. NSW Environment Protection Authority. (1999). *Guide to licensing under the Protection of the Environment Operations Act 1999*