THE INFLUENCE OF WASTE TREATMENT, CONDITIONING AND PACKAGING ON DESIGN FOR DISPOSAL

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ABSTRACT

The design of a repository for low and intermediate level waste will always have a number of targets; safety, capacity, cost and ease of operation being prominent. Achieving the targets requires a total design of the waste management system, which ranges from treatment of the raw waste form at the source of arising to design for post-closure performance of the repository. In working on repository designs and their safety assessments, the authors have found that different waste forms have significant influences on the repository and this paper is concerned with those influences.

INTRODUCTION

The design of a repository for LLW and/or ILW will always have a number of targets: safety, capacity, cost and ease of operation, being prominent. Achieving the targets requires a total design of the waste management system, which has to include the conditioned waste and its packaging. In working on repository designs, the authors have found that different waste forms have significantly different influences on the repository.

As the starting point, volume reduction at source will lead not only to reductions in repository volume but also to reductions in the requirements for transport and on-site handling. The installations will be designed to a throughput and the designer has to be interested in both the baseline estimate of arisings and in the potential variations as consignors update their plants or circumstances change. At a more detailed level, the equipment for handling and stacking waste packages depends not only on their weight but also on the accuracy with which the stack needs to be constructed. With monolithic packages the demands for placement accuracy are minimal; with skeletal or thin-walled packages a stack needs to be carefully structured to carry its own weight. In shallow disposal, the waste stack will normally be required to support the weight of capping material and the design of the cap system may depend on the support available from the waste stack.

Similar considerations will apply to measures that can be taken at the repository, and to the choice of package for transport and disposal.

Paradoxically, long term behaviour is an area where little interaction has been found between waste conditioning and repository design. Partly this is because no balance has been struck between containment features of the conditioned waste and those of the repository construction; both are considered valuable in a multiple barrier system. However, the principal reason is that safety in the very long term is believed to be dominated by the characteristics of the conditioned waste and of the far field. The former characteristics are clearly also influenced by measures taken at source or at the repository.

THE EFFECT OF MEASURES TAKEN AT SOURCE

Five aspects of conditioning measures at source will have an influence on the repository design. These are:

- waste sentencing and classification measures,
- treatment of the waste form,
- encapsulation of the waste,
- package type,
- self-shielding.

Waste sentencing and classification

Appropriate waste sentencing procedures can allow the separation of wastes for example into combustible and non-combustible forms, or into compactable and non-compactable forms. These will have a bearing on conditioning measures down-stream and therefore on the repository design as explained below.

Furthermore, sentencing can be used to reduce the amounts of radioactive waste for disposal. At some facilities, all waste originating within the radiologically controlled area are deemed to be radioactive and sent for disposal; this can involve for example large amounts of soil at a site where construction is being carried out to extend plant. In that specific case, the sentencing of very low level soil for conventional disposal will reduce the amount of disposal and hence the size of the repository and the cost to the consignor. This can also modify the engineered design of the repository as the mechanical characteristics of waste containing mostly soil may dictate a simple trench-type vault whereas a smaller waste stream containing non-compactable metallic components may be better disposed of in an engineered vault.

Segregation of closely related streams can reduce the amounts of waste requiring deep disposal. For example, LWR fuel end pieces in a reprocessing plant can be routed separately from the fuel and cladding (which are fed to the dissolver). This will reduce the amount of high beta-gamma, alpha waste which requires the most onerous precautions; the segregated end pieces will be high beta-gamma and short lived, and could be disposed of in a different (less costly) facility to wastes of medium to high alpha content.

Waste treatment

Volume reduction by compaction, or by incineration may considerably reduce certain waste volumes and hence affect the size and cost of the repository.

For example, operational low level waste would have the following typical composition:

Compactable	68%
Non-Compactable	32%
or	
Incinerable	69%
Non-incinerable	31%

If the operational low level waste is simply collected in drums and overpacked and grouted, the typical yearly arisings in Great Britain of 30 000 m^3 of low level waste would occupy a disposal volume of 36,000 m^3 (assuming a degree of in-drum compaction).

If the compactable fraction were super-compacted and the resulting pucks overpacked, the total disposal volume would reduce to 24,000 m^3.

If on the other hand the incinerable fraction were incinerated, mixed with grout and overpacked, the total disposal volume would reduce to 18,000 m^3.

This means that treatment by supercompaction would reduce the disposal volume two thirds and by incineration to one half.

A further important aspect of waste treatment is the reduction of the organic content of the waste by incineration or wet oxidation. As highlighted in (1), the presence of organic substances which degrade is liable to lead to considerable increases in the solubility limit of actinides (by several orders of magnitude), and affect their sorption in the surrounding rock. This may require deeper repositories, hence more expensive ones. An additional aspect of reducing the organic content of the waste is that this will reduce the evolution of gases which may escape from the repository,which provide an additional pathway for exposure of man and the environment.

In addition, the degradation of organics substances will affect the strength of the conditioned waste product through void formation, which for shallow repositories can lead to cap collapse unless structural integrity is provided by other (often expensive) means.

Choice of encapsulation matrix

The application of conditioning by encapsulation, and the choice of a conditioning matrix will help reduce the rate of release of radioactive material, following an accidental drop of the package. This in turn can influence the design and hence costs of filtration systems in the waste receipt buildings and in the vaults.

A stable matrix with a low voidage will provide the basis for the structural stability of the waste stack. Lack of structural stability in the long term may cause considerable problems particularly for shallow repositories; where a stack is protected from ingress of water by capping, failure of the stack to support the cap will initiate a destructive cycle of water ingress - deterioration, stack failure, and cap failure. Remedial measures are not only expensive but unlikely ever to restore the desired protection.

A strong, low permeability matrix reduces the water flow through the waste mass hence the migration of radionuclides and the exposure of man to the radioactivity.

The nature of the conditioning matrix will influence the post-closure performance of the repository. For example a cementitious conditioning matrix will provide an increased pH over long time periods, which reduces the solubility limit of actinides. This can in turn affect the depth required and hence cost. Furthermore, a high pH environment will on balance inhibit the type of microbial activity which can lead to the generation of gas.

Package Type

Waste packages not transported in containers will be qualified for the IAEA Transport Regulations which include the requirement for them to be stackable 6 high. It is in fact rare for transport packages intended for disposal, to be stacked 6 high and a careful alignment of one or the other would be needed if they ever were so stacked.

In disposal, the stack height may be determined by overall repository design economics to be more than 6 packages (e.g. in a cavern or silo deep underground) or less in a shallow trench. Where they are stacked with inspection corridors between them, seismic stability may dictate a height of perhaps 3 packages.

However if the stacked packages are required to support the cap over a shallow disposal vault, the weight of the cap may be equivalent to several packages and therefore, in order to build the cap safely, packages designed to the 6 high criterion will perhaps only be acceptable 2 high. The design of the foundation to the stack will also be affected by the structural arrangement of the package in this case.

In the longer term, if it is the package structure which supports the cap in shallow disposal, it is the life of the package and its contents which determines the life of the cap. Once packages fail, it may be important - in consideration of medium and long term safety - to predict whether they and the contents together will produce an even settlement pattern or localised "catastrophic" collapse.

An important feature is evident: as far as the repository is concerned the package structure is a combination of the package itself and the conditioned waste inside it. A package designed for transport alone limits the options for the repository substantially more than does a grouted monolith.

A factor of some interest is the voidage in the package and how voidage is manifested. If there is void at the top of the waste in the package, then this will be reflected in a lack of structural strength of the roof of the package. The grouting techniques (and the method of placing the waste in the packages) should be such to promote as effective void filling as possible.

Self-Shielding

The provision of self-shielded packages will reduce the requirements for shielding structures at the waste repository (waste receipt building, transfer containers, transport routes). Handling will on balance be easier and hence cheaper. On the other hand, more space will be required inside the repository either for the transport route and unloading area (if re-usable, shielding overpacks are used) or as disposal volume (if disposal self-shielding packages are used).

Consider for example the case of operational ILW in 500 litre drums, arriving at the Repository Surface Facilities of a deep repository in Reusable Shielded Transport Containers (RSTC's), with the drums being in stillages inside the RSTC.

A number of options are open to place this waste stream into the vault:-

a) Waste supplied in disposable self-shielded boxes, taken to the vault,

b) Transfer the waste packages (in a stillage) to the vault unshielded.

c) Transfer the drums from the RSTC into a disposable overpack - different shielding thicknesses may be considered to balance economics (which favour light packages) and operational facility (which favours heavy shielding).

d) Transfer the waste into the vault still in the RSTC.

e) Transfer the waste into a re-usable overpack (the Vault Shield Box - VSB).

In the design study during which the authors analysed this point, the VSB option was chosen because:

a) We did not want to transport the items unshielded - even in a non-man access area, because of the difficulty of recovery from an accident or a breakdown.

b) The cost of disposable shielding is high, particularly in vault space and therefore excavation costs. For example:

Raw waste volume - 1 m^3

Packaged waste volume (in drums) - 1.2 m^3

Emplacement volume - no overpacking - 2 m^3

Volumes in steel overpack (< 10mSv) - 4 m^3

Volumes in concrete overpack (< 10mSv) - 5.5 m^3

Volumes in concrete overpack (< 10mSv) - 8.8 m^3

The impact of overpacking in large units can be enormous for tunnel vaults where the packing fraction is very sensitive to package dimensions of the order of the tunnel diameter.

It can be seen that, although handling operations would be generally easier if the waste were to be contained in a disposable overpack (either supplied by the consignor or at the repository), but the cost in additional vault space is very high (several hundred million pounds in a case recently considered by the authors).

EFFECT OF MEASURES TAKEN AT THE REPOSITORY

Timing of conditioning measures

The processes discussed in the chapter above for conditioning the wastes could in principle be applied at the repository. A decision to carry out conditioning at the repository will clearly have an effect on the size and hence cost of the surface facilities.

Overpacking

Overpacking is one of the measures described in the previous chapter under self- shielding but it is particularly important for repository design and as such is being examined separately. It would have made handling much easier but would have increased the costs by a considerable margin (see above example).

On the other hand, overpacking might also reduce the dose rates to the extent that the position of waste packages in the repository becomes largely irrelevant in the operational phase. If this is not carried out it might become necessary to take special precautions with higher dose rate packages as is the case at the La Manche repository in France where high dose rate packages have to be placed at the centre of a waste stack and separately grouted in.

So overpacking can assist in handling operations, as well as providing shielding. It can also provide the waste with additional structural integrity - see above - and in some repository designs this may be important (e.g. a shallow repository where the waste supports the cap).

A further consideration concerns retrievability. Emplacing the waste in overpacks can clearly improve the chance of retrieving the waste packages in future if necessary. Waste stacked in concrete overpacks may not need to be grouted in place at all, as the structural strength and chemical buffering are provided by the overpack. Again the way that conditioning may influence the repository design will vary depending on the fundamental repository design or parameters. In some cases, retrieval may not be an issue at all, in others, it may be paramount.

<u>Volume reduction and encapsulation</u>

Commercially, it may be attractive or even inevitable, that the repository be equipped to treat the waste, consigned as appropriate for the site of origin and then treated as appropriate for disposal.

This allows the repository operator to assure [the quality of] the waste as it is sent for disposal. It also allows the operator to take on the technical aspects of changes to the waste treatment that may be implied by changes in rates of arisings, characteristics of raw waste, or long term safety.

The implication is that the operator must recover the waste from the container in which the consignor sends it; this in turn means that the consignor will be required to pack containers in a way that is amenable to their being emptied. Alternatively, where supercompaction is used, the consignor will have to use a package type e.g. drum or box amenable to supercompaction by the repository plant. The repository operator will in turn have to take measures to deal with damage in transit and with deficiencies in packing not corrected at the consignor's site.

Grouting at the repository site may, by co-ordination of package design, not call for the package to be emptied but the disposal design will have made assumptions about the pattern of grout distribution in each package. The operator will therefore be concerned not just to define how the waste is to be put into a transit/grouting/disposal package, but also to confirm that it is acceptable as it enters the grouting plant.

Grouting, at the repository site, of packages filled elsewhere may in outline be an attractive balance of consignor, transport, and repository activities. It is, however, the repository operator who will take responsibility for the disposal package and allowance must be made for his being able to check the package "quality" as he does so.

The volume reduction option ought to be amenable to cost optimisation, taking account of:

- capital and operating costs of centralised (at the repository) volume reduction plant as against distributed (at the consignor's) plant;
- on-costs for plant, such as licensing, management etc;
- transport costs for the same mass of waste reduced to higher density forms as against bulkier forms;
- treatment costs for mass reduction, eg incineration, to consign the same radioactive inventory in reduced volume and mass.

This aspect involves commercial projections and negotiations as ultimately each consignor will have to carry out his own optimisation.

CHOICE OF PACKAGE

The best transport package may not be the best disposal package as the criteria are different.

If the package is changed, the transport package must be robust, easily decontaminable (in case of accident) and compatible with good radiological practice at the repository - where workers may be more constantly handling them than at consignors' sites.

It the transport package is reusable, unit cost is less significant than if they are once-through. Economics of design for transport become separate from economics of design for disposal.

The disposal package must fit the disposal condition and the "construction" technique for the waste stack. This could imply concrete packages (heavy, which is a disadvantage in transport) or megaliths (eg. for steam generators, which it is unreasonable to send on road or rail but acceptable to build on site).

Unless the megalith is attractive, ie unless the operator wants to dispose in units bigger than

- 65 ton (UK rail transport)
- 25 ton (most road transport)
- 2.5 m sq cross-section (most land transport)
- 10 m long (most land transport)

The transport package can be the disposal package if the waste inside it is in the disposal waste form. If the disposal package is the transport package, 3 parties have to agree ie the repository operator, the transporter, and the consignor. But only the repository operator can make the safety case. He must therefore define at least one package that is acceptable to receive and dispose of unless he agrees to retreat and repackage all waste.

CONCLUSION

The chain of waste management from origin to disposal involves several parties. The totality of the management system will include contractual interfaces based on specification - the repository operator putting requirements on the consignors and commercially all parties reaching their cost-optimised strategy within the technical constraints.

The repository operator will clearly have a central role as he has to make the operational and long term safety cases, both of which rest on the characteristics of the packaged waste.

The repository operator, who needs the industry's views on what treatment, conditioning and packaging are convenient, can identify a range of incoming packages consistent with the authorised disposal conditions, recognising the possibilities of:

- incoming packages being to the disposal acceptance criteria
- incoming wastes being extensively treated on site

It then becomes a matter of negotiation and design to reject unsatisfactory waste forms and agree the range of acceptable forms. Like any design, this will be an interactive process as preferences emerge. The disposal condition will be different from one repository to another, as far field conditions differ and radionuclide inventories differ.

The accepted waste forms and packages will therefore also differ, reflecting such consignors preferences as conform to the particular repository's specifications.

In an ideal world, the entire design of waste conditioning, packaging, transport, site treatment and disposal would be a single multi-disciplinary operation. In reality a process of design, cost/charge estimates, negotiation, and redesign will take place. Being repository designers the authors consider the process should be led by disposal conditions and long term safety. Waste treatment, clearly dominates consignors' and repository operators' priorities.

With increasing public attention to long term safety, the authors believe that repository design criteria will have an increasing application to waste conditioning, and this is amply illustrated in this paper.

REFERENCES

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