Managing organic-rich material and soil from decontamination actions

Ian McKinley & Susie Hardie

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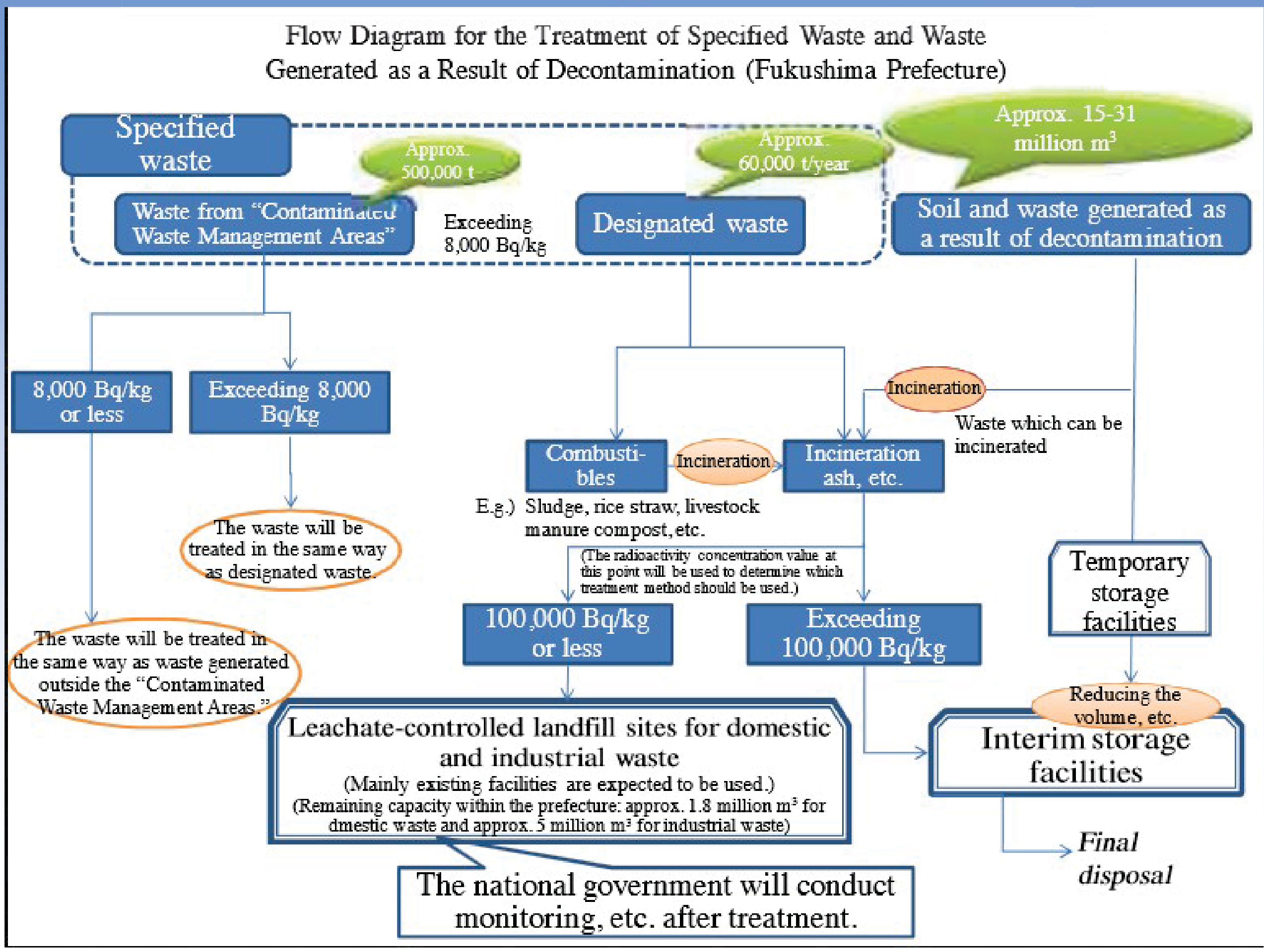
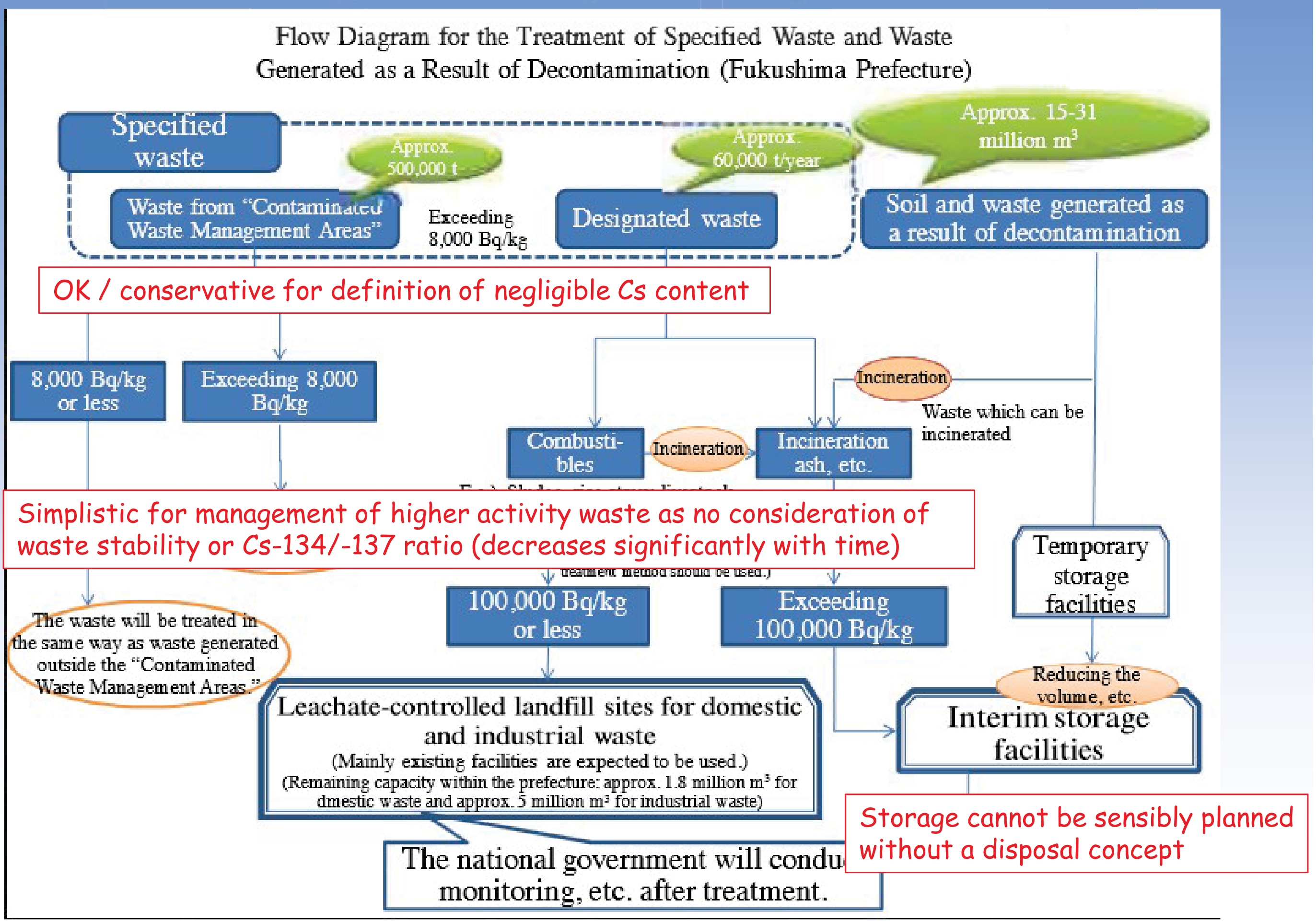
Introduction

- Decontamination activities will produce vast quantities (in the order of 30 M m^3) of waste / contaminated material that needs to be managed safely
- Particular challenges are associated with
  - soil
  - organic material or material with a significant organic content
- Original plan for short term (3 y) temporary storage of such waste constrained by increasing delay in implementation of interim storage / centralised treatment

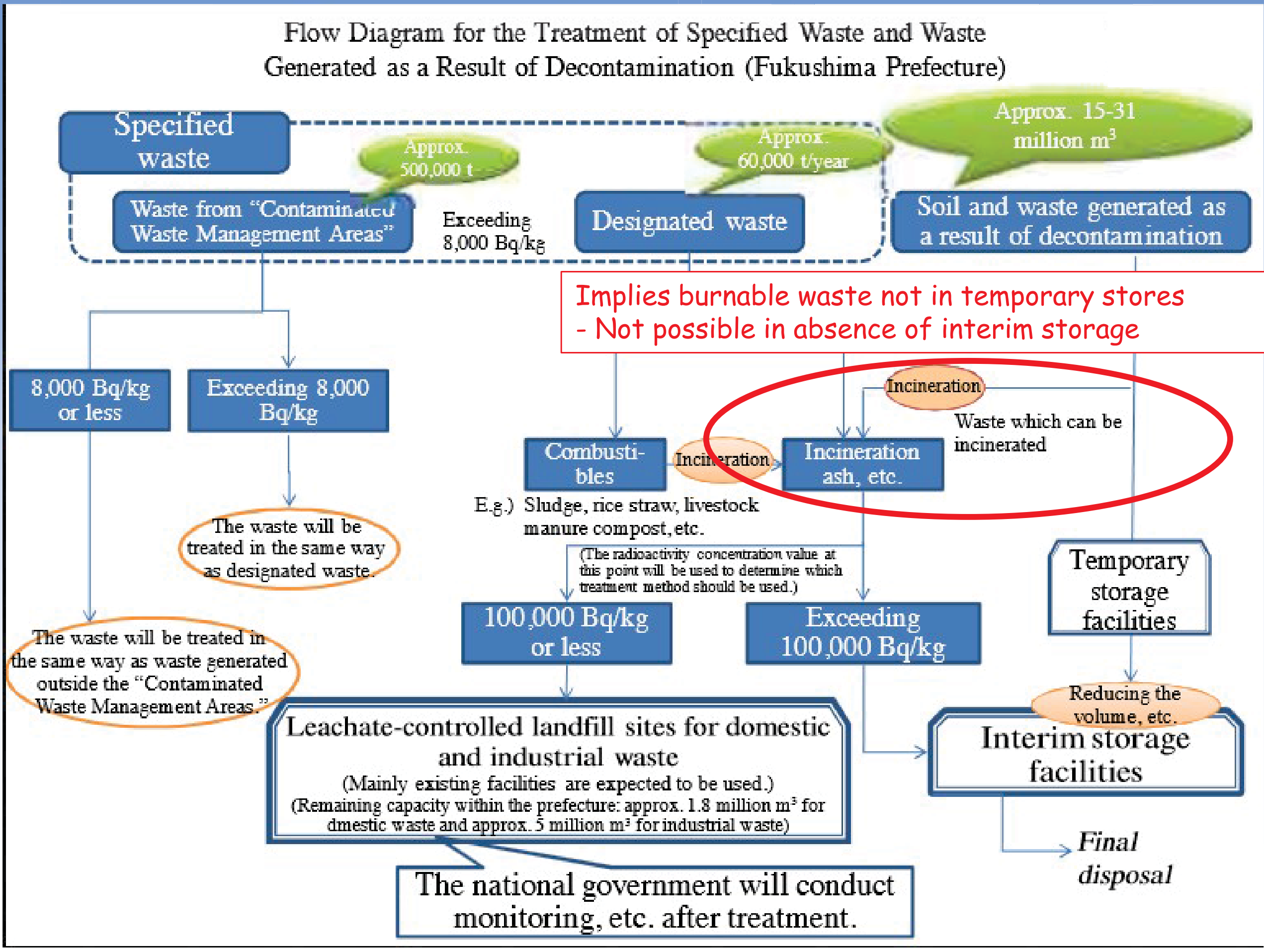
Overall management plan



Management plan - problems



Management plan - problems



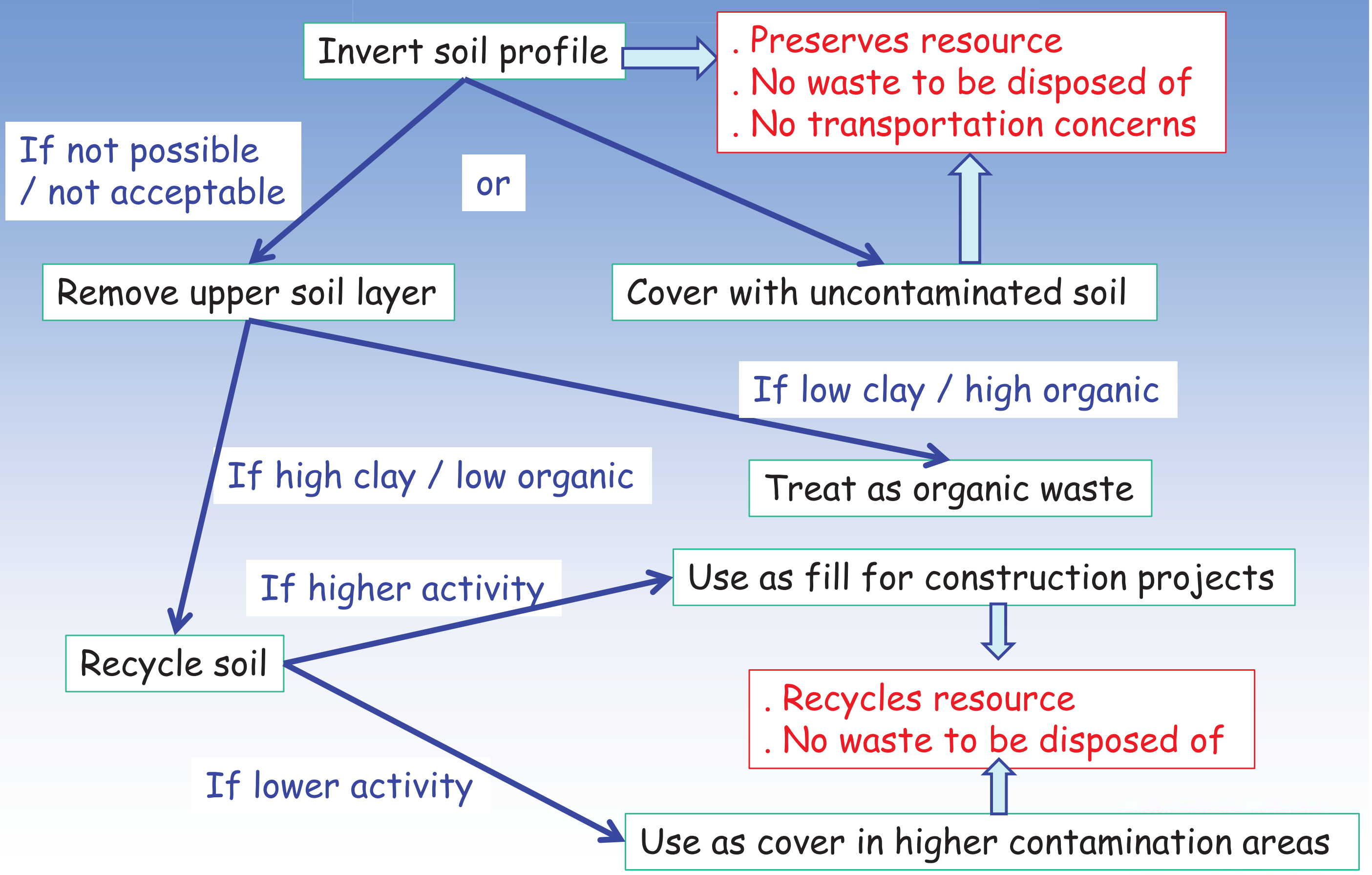
Organic waste / soil management

- For future waste arisings, it would be advantageous to reduce volumes of organics and stabilise it in a way that biodegradation during storage would be reduced
- Because the volumes are so high, cost-effectiveness is an important consideration
- Practical constraints must be considered (e.g. limits on transportation of contaminated material between sites) – but it may be useful to identify how changes in regulations may allow more effective management of such material

Soil

- Soil is a valuable resource and, wherever possible, removal should be avoided (e.g. deep ploughing, burial in-situ below root zone)
  - This is especially the case for high clay content soils, as Cs uptake is effectively irreversible and will not pass into crops
  - Can be combined with temporary modified land use – e.g. non-food agriculture
- For organic rich soils or those with a shallow hard pan, removal may, however, be selected as the decontamination option
  - Alternative may be in-situ decontamination (e.g. phytoremediation, mycoremediation)
- Removed soils / bioremediation wastes are vulnerable to biodegradation, the risk / consequences of which will increase with organic content

Soil management

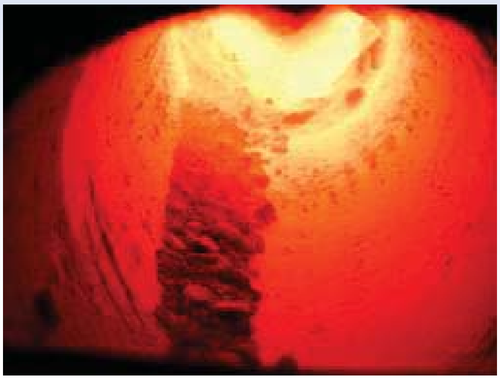


Organic waste volume reduction

- Most of such waste has a high water content: reducing this will decrease volume / mass and also reduce vulnerability to biodegradation
- Dehydrated organic material in a low humidity environment has a low degradation rate: demonstrated by laboratory and modelling studies, supported by natural analogues
- For high cellulose waste (massive wood), more extensive heat treatment (pyrolysis) produces charcoal: this is relatively stable under even wet conditions (e.g. biochar disposal considered as CCS option)

Incineration

- The most common organic voltreatment approach is incineration, which gives a very large degree of volume reduction: as long as temperatures are not excessive, 100% of Cs retained in ash, which – under dry conditions – is chemically stable
- Specific constraints associated with incineration include:
  - Cost / requirement for dedicated facilities with capture of fly ash
  - Environmental impact, production of CO_2
  - Need to package / immobilise ash to avoid contact with water (potentially particularly tricky if high pH / high K)
  - Contamination of plant and eventual decommissioning wastes (can be reduced by appropriate design)



Ash management

- Ash from incineration of organic material is water-soluble and, as it usually contains a significant quantity of K, Cs in leachate may be relatively mobile. This would especially be the case if leachate is hyperalkaline
- Storage in water-tight containers: steel drums possible, but robust plastic containers used for chemicals may be a cheaper / more robust option
- To assure containment for centuries, maybe conditioning for disposal (e.g. bitumen or resin – not cement-based mortar)
- Alternative option: leach waste and extract Cs into stable specific ion-exchanger (e.g. KCFC)

Bio-technology

- The organic component of contaminated material can be utilised if the products can be assured to contain no / negligible radio-Cs. A number of options exist, e.g.
  - Biogas from anaerobic degradation
  - Biofuel from fermentation
  - …
- The benefit of this approach is use of resources to produce a commercial product. Concerns include:
  - Cost / requirement for dedicated facilities
  - Need to package / immobilise waste
  - Contamination of plant and eventual decommissioning wastes
- Options for extension of existing technology (e.g. wood pulp) or modern variants (e.g. biopolymers)

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Problems with temporary stores

- The temporary storage facilities in remediated areas were designed only for a 3 y lifetime. Even then it was recognised that assuring containment over such a period would be very difficult due to the nature of the waste and its basic packaging
- Due to delays in implementation of the interim storage facility (also unsurprising), a lifetime of about a decade is now required. Based on both national and international experience, this should be regarded as a minimum value
- It is thus required to:
  - Characterise the condition of existing temporary stores
  - Where required, remediate / enhance them for a >10 y lifetime
  - Revise designs for future stores

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Sources of instability problems

- The wastes stored – especially organic materials and soils – are inherently unstable and will degrade with time. Even worse, some of the degradation processes are autocatalytic and can lead to "runaway" reactions (e.g. biodegradation can produce heat and acidic leachates which, in turn, increase degradation rates to the point that spontaneous combustion may occur). This is well known from both conventional and old nuclear near-surface disposal.
- The containment barriers (clay, thin plastic sheeting) are inherently vulnerable to both the effects of waste degradation and also external perturbations from biological activity (plants & animals) and extreme weather conditions (typhoons, hot-cold temperature cycles)

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Possible consequences of instability

- Leaching of radio-Cs containing fluids, possibly with Cs in a form that is little retarded (e.g. associated with high pH fluids, organic macromolecules, colloids or suspended particles)
  - As surface water flow
  - As flow of deeper groundwaters
- Uptake of Cs into biota, which may be mobile and/or enter the food chain:
  - Microbes
  - Plants & fungi
  - Insects
  - Micro-fauna
  - Macro-fauna

Characterisation of existing sites

- Best approach probably involves initial external scanning (e.g. with boom-mounted equipment). This could include:
  - Collimated gamma scans (probably best large volume NaI)
  - Thermal scans (ideally under cool/cold conditions)
  - Geometry scans (e.g. laser) to detect physical deformations
- Scanned data integrated within 3D (or 4D) GIS to check for any anomalies (could be part of a regular monitoring programme for sites – e.g. every 1-2 years)
- In case of anomalies, tailored programme of sampling and analysis would be initiated

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Remediation of perturbed sites

- If integrity of barriers completely lost, there may be no alternative to removal, repackaging and storage in a new facility

- Otherwise, remediation could focus on reinforcing the existing barriers. A possible option here would involve spraying asphalt on degraded covers and, if needed, emplacing asphalt walls in trenches around the site

- Unlike clay, asphalt has well-proven abilities to resist plant, animal and physical degradation on a multi-decade timescale). Technology is also well established (and cheap) for applying this material in an quality assured fashion

Redesign of temporary stores (1)

- In order to assure containment of the wastes involved for periods of at least 10 y either:

- *Waste must be processed before emplacement (incineration / sterilisation)*

or

- *Sites must be selected / designed for more robust containment*

NB remediation of a failed site could be an order of magnitude (or more) costlier than doing it right in the first place – this will be seen over the coming years in Fukushima

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Redesign of temporary stores (2)

- Maybe best centralised, utilising existing infrastructure wherever possible (e.g. quarries, industrial wasteland)
- Focus on outer asphalt barrier to maintain integrity of any inner clay layer
- If organic waste not incinerated, aim to reduce rate / impact of biodegradation (drying, high P compaction, mix with ash?)
- Establish rigorous initial dimensions to allow changes to be monitored (swelling, slumping)
- Consider emplacing thermocouples around organic waste

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Interim storage

- The timescale considered – in the order of 30 years - is tricky as this will cause little decrease in the toxicity of Cs-137, but is a long period when considering the stability of wastes and packages
- It is assumed that all organic waste is incinerated before storage: main concern is thus storage of ash
- Under expected evolution, no leaching of waste should occur: special concern thus for perturbation scenarios
- Important focus on overall resilience of concept (i.e. including robustness / ease to recover) in case of unexpected perturbation

Disposal

- The removal of waste after 30 years of storage is likely to be very expensive and have potentially negative impacts in terms of environmental impact, sustainability etc.
- Even if not socio-politically possible at present, the option of a future decision to retain the waste at the interim storage facility should be assessed
- For disposal at a distant site, the logistics of transport (favouring a coastal location) and cost-effectiveness for this low hazard material should be considered
  - E.g. possible use of existing excavations such as disused quarries or mines

Conclusions

- Management of waste resulting from decontamination is one of the costliest and most politically sensitive aspects of remediation
- To the extent possible, waste production should be minimised:
  - Avoid soil removal
  - Recycle contaminated soil for other purposes
- Storage of organic waste should be minimised due to known problems from biodegradation:
  - In case of incineration, very carefully consider ash conditioning for storage / disposal
  - Consider biotechnology to gain benefits from organic materials
- Remediation / storage / disposal should be assessed in an integrated manner to improve cost / benefit

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