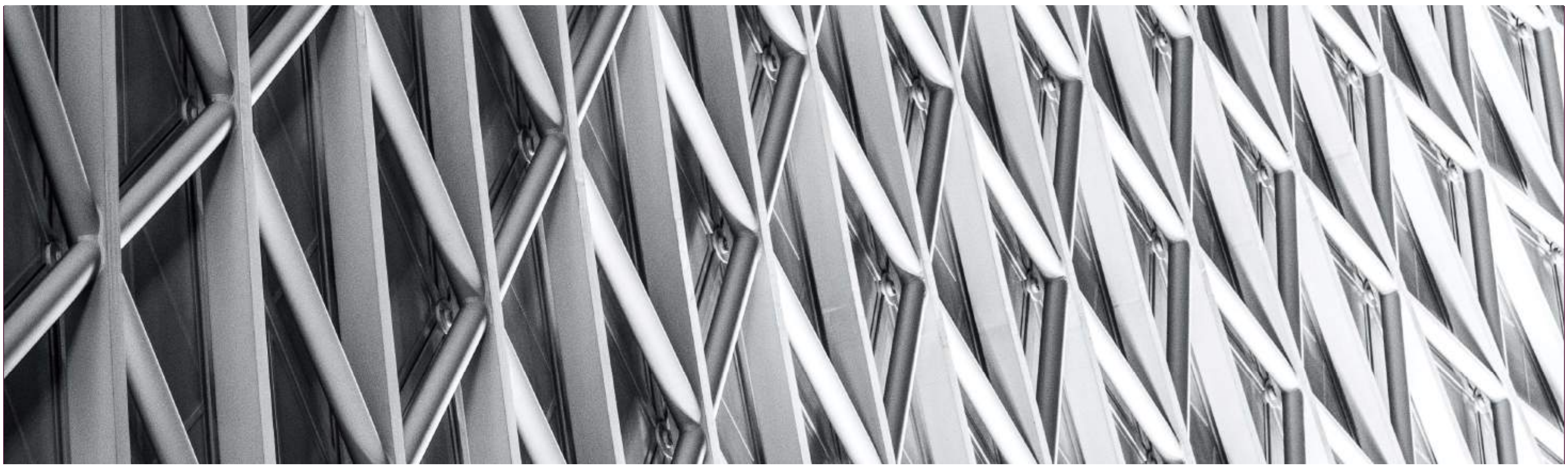
DISPOSAL OR TREATMENT: FUTURE CONSIDERATIONS FOR SOLID WASTE FROM THE CONSTRUCTION AND DEMOLITION INDUSTRY

UNITEC INSTITUTE OF TECHNOLOGY SYMPOSIUM 2020



SHANNON WALLIS – UNITEC INSTITUTE OF TECHNOLOGY

CONSTRUCTION & DEMOLITION WASTE

- Two billion tonnes of municipal solid waste (MSW) are produced annually [1].
- Construction sector – largest global user of raw material and energy resources [2].
- Construction, demolition and excavation (CD&E) waste contributes to a large share of the total MSW in developed countries [2].
- C&D wastes are defined by activity [3].

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CONSTRUCTION, DEMOLITION & EXCAVATION WASTE

- Average proportion of total waste reaching landfills is 30% [4] (derived from CD&E waste)
  - Proportion varies globally from 13% [5] to 60%+ [6,7].
- United Nations Environmental Programme (UNEP) [2] reported – the bulk of waste disposed via landfills was derived from CD&E waste in developing countries.

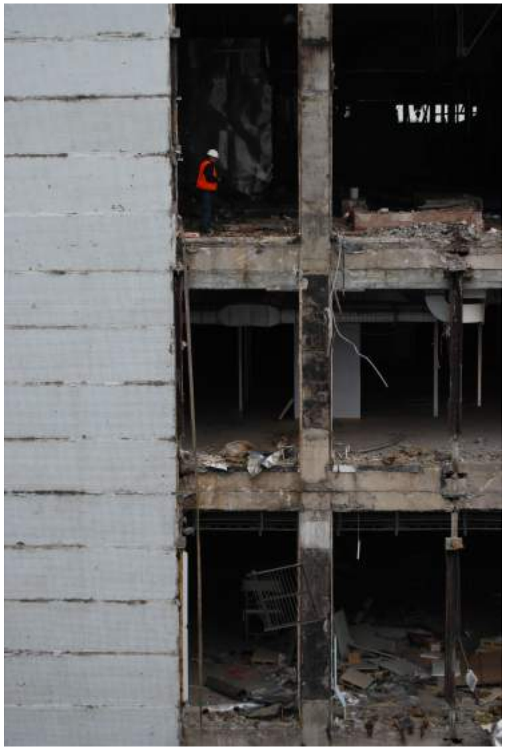
Waste generation and breakdown of waste in seven countries. *(Sources: [5-10]).*

Country	Year	Total Mass	Waste Generation per Capita (2015)	CD&E	Household	C&I**	Others
UK [6]	2016	222.9	1.8	61%	12%	19%	8%
Australia [8]	2016	66.8	2.2	31%	21%	31%	18%
Germany [7]	2015	351.2	2.1	60%	15%	17%	9%
Japan [10]	2011	380	-	20%	11%*	63%	6%
South Africa [5]	2017	42.7	2	13%	20%	7%	60%
Hungary [9]	2016	16	-	23%	18%	34%	25%
Romania [9]	2016	178	-	0%	2%	95%	3%

Notes: Total and waste generation per capita as million tonnes. *Food, paper products and communication devices only.
**C&I include commercial and industrial, as well as agricultural and energy generation sectors.

WASTE DISPOSAL OPTIONS

- Established waste disposal and treatment processes – composting, incineration, landfill and recycling
  - CD&E waste – research indicates a high potential for recovery [5-8].
- In NZ, it is possible to recycle and/or reuse most streams of C&D waste.
- Other barriers preventing effective recycling or reuse include:
  - Lack of training and education to encourage on-site waste separation,
  - Space limitations on site for adequate materials storage,
  - Lack of incentives to reduce waste.
- Hazardous CD&E derived wastes – recycling or re-using waste is rarely a viable option.



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HAZARDOUS WASTE

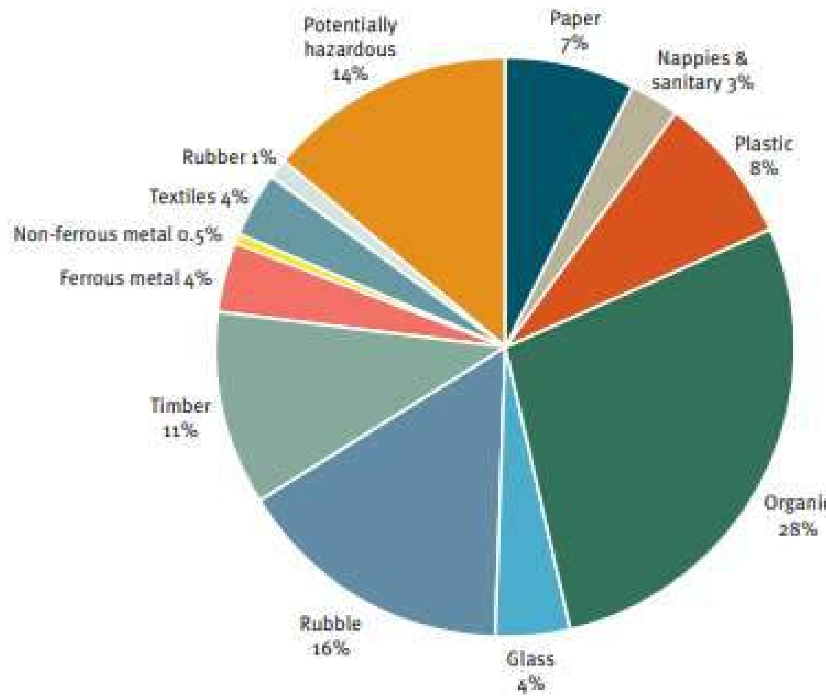
- "Contains hazardous substances at sufficient concentrations to exceed the minimum degrees of hazard specified by Hazardous Substances Regulations 2000" [11].
- Globally, we produce 400 million tonnes of hazardous waste each year [14].
- Hazardous Products (HP), Hazardous Waste (HW), Hazardous By-Products (HBP).
- Contaminated soil waste and asbestos waste contributes a significant portion of low concentration, high volume waste to landfill.
  - Previous study quantifying C&D waste materials in all states across Australia (2008-2009) – 1,055,797 tonnes of contaminated soil waste and 728,477 tonnes of asbestos waste [15].
- Are there other options for the disposal of CD&E waste? And, do these options include more sustainable waste treatment?

Asbestos Sheeting (Ian Murgatroyd)

Asbestos Removal – Canberra, Australia (Authors Own)

LANDFILL DISPOSAL

- Modern landfills – designed to minimise the impact of MSW on the environment and human health
  - Provide storage but require land-use restrictions and continuing maintenance [16].
- Landfills – most common method of waste disposal (in NZ)
  - Estimated 3.2 million tonnes of waste to MSW landfills in 2006 [17,18].
- NZ has seven different types of landfills:
  - Five non-hazardous landfills (MSW, managed, C&D, cleanfill, industrial) [20],
  - Two hazardous landfills (Class A, Class B) [21].



Waste Composition [19]

LANDFILL DISPOSAL

- Number of landfills in NZ – reduced from 327 to 60 between 1995 to 2007
  - 54% utilised engineered liners for leachate containment [18].
- Amount of waste to landfill in NZ – increasing to just over 1 tonne/capita/yr [22]
  - Approximately 5 million tonnes of waste per annum.
- Estimated 26% of waste to landfill – derived from C&D waste.
  - Value does not include waste sent to cleanfill sites – estimated between 2.7 and 3.7 million tonnes (2007) [23].

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FUTURE OF LANDFILL TECHNOLOGY

- 1995 – Seminar in the United States called to examine "an alternative approach to landfill operation that greatly minimizes long-term risks associated with potential landfill containment system failure." [24].
  - Alternative approach = bioreactor landfilling – stated that "this method represents the future of waste disposal because it transforms waste disposal practice from a passive system to an active process." [24].
- 2000 – NZ revised their Centre for Advanced Engineering Landfill Engineering Guidelines (1992) to Landfill Guidelines (2000) [25].
  - Guidelines stated "bioreactor and aerobic landfills have not been designed or operated in New Zealand to date."
  - Overseas research and trials monitored for their applicability to NZ (e.g. bioreactor landfills) [25].
  - Superseded in 2016 to Technical Guidelines for Disposal to Land (August 2018), with no reference to bioreactor landfills [26].
- Current landfill designs and management issues, including –
  - Poor level of degradation of waste, issues associated with leachate toxicity (increased chemical use) [27], and large land requirement.
- Trend towards increasing disposal costs for hazardous waste disposal – encouraging illegal dumping of waste [28-29]

LANDFILL FAILURES

- Late 1980's – community of Oakland County Waterford Township (US) – groundwater contamination [30].
  - Unclear on cause of failure – leachate collection and removal, or liner fault [30]
- Failures of historic, recently closed, and active landfills – trend that could become more frequent.
  - Landfills exposed to extreme weather events combined with poor siting and lack of adequate regulation.

Worldwide landfill failures. (Sources: [31-38]).

Location	Date	Cause	Fatalities
Payatas, Manila, Phillipines [31]	Jul. 2000	Heavy rain triggering landslides	More than 200
Leuwigajah, Java, Indonesia [32]	Feb. 2005	Explosion due to sudden biogas release, 3 days of high rainfall	Approx. 143
Morro do Bumba, Niteroi, Brazil [33]	Apr. 2010	Heavy rain triggering floods & landslides	Approx. 200 (across the region)
Baguio, Phillipines [34]	Aug. 2011	Typhoon – collapse of retaining wall	5
Guatemala City, Guatemala [35]	Apr. 2016	Heavy rain	Approx. 30
Koshe, Ethiopia [36]	Mar. 2017	Conflicting reasons	Approx. 120
Meethotamulla Garbage Mountain, Sri Lanka [37]	Apr. 2017	Instability – approx. 48.5m high pre-collapse	Approx. 40
Verter Recycling Landfill, Basque Region, Spain [38]	Feb. 2020	Instability – with asbestos waste release	2

TREATMENT OPTIONS – CHEMICAL & PHYSICAL

- Chemical transformation processes – potential to reduce toxicity prior to further treatment or disposal.
  - Often expensive and could produce hazardous by-products.
- Chemical methods include – complexation, neutralisation and oxidation [44].
- Physical processes include – complete thermal destruction (incineration), and removal of substances from aqueous solution (e.g. carbon adsorption).
- Hazardous substances include – pre-treatment or pre-disposal stages.
  - Often involve high energy costs.
- Disadvantages of these processes include:
  - Waste production (often toxic), high energy usage, and lack of adaption to wastes of highly variable quality.
  - Incineration – high energy costs, may not be sustainable long-term (low carbon economy), responsible for production of air pollutants such as dioxins (unless well-maintained) and highly toxic by-products (such as incinerator ash).

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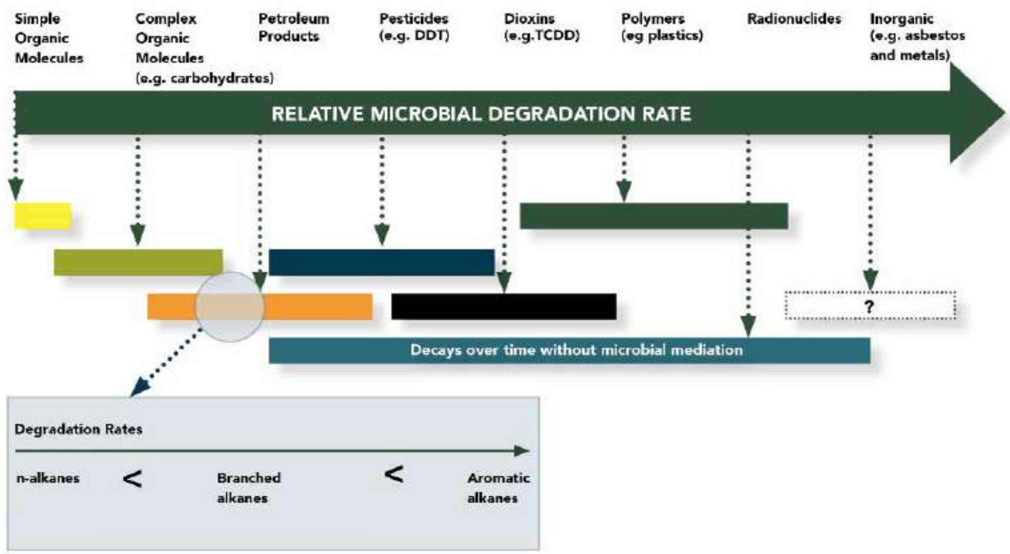
TREATMENT OPTIONS – BIOLOGICAL

- Biological processes have been slow to adopt – limitations on substances resistant to biodegradation.
- Readily biodegradable substances can be treated via biological processes – substances which are either hazardous or inorganic are generally considered to be untreatable.
- Treatment of solid wastes remains problematic – bioremediation (biological process) is capable of treating both solid and liquid wastes.
- Bioremediation can be either in-situ, (bioventing and bioaugmentation); or ex-situ (landfarming and bioreactors (slurry reactors)) [46].
  - In-situ treatment – more desirable – lower cost and provide less disturbance (treating in place),
  - Ex-situ bioremediation – excavation of contaminated soils and transferred to a separate location for treatment [46].



Continuum of relative microbial degradation rate, where length of bar indicates relative degradation timeframe. (Degradation rates of petroleum products [47])

TREATMENT OPTIONS – BIOLOGICAL – BIOREACTOR

- Bioreactor (or activated) landfill, defined where "liquid or air is injected in a controlled fashion to the waste mass in order to accelerate or enhance biostabilisation of the waste." [44].
- Primarily for organic wastes – designed and operated under conditions to enhance biodegradation and biogas production.
- Addition of moisture serves two purposes:
  - Creation of conditions favourable for transport and proliferation of the microbial community,
  - Provides a pathway for mixing organic substrates, nutrients and waste products and the dilution of high concentrations of microbial inhibitors [48].
- Least promising option for many wastes – based on estimates of biogas production (anaerobic digestion of organic waste) [49].
- Currently do not deliver promise of accelerated treatment – still produce undesirable toxic products (e.g. landfill leachate) and rank poorly in environmental impact.
- Use of bio-landfilling has not served to improve the actual degradation of solid wastes substantially in full-scale applications [48],[50].

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TREATMENT OPTIONS – BIOLOGICAL – BIOREMEDIATION

- Utilises living organisms (e.g. plants, microbes and their enzymatic products) to reduce toxicity in xenobiotic compounds [51].
- Microorganisms – versatile and capable of rapid adjustment during environmental changes – can protect their ecosystems from deterioration.
- Process, either:
  - Naturally occurring metabolic activity – utilised during bioremediation for the degradation, transformation or accumulation of many substances [52].
  - Microbial augmentation – non-native species [51].
- Benefits – cost effective, sustainable and in-situ application is easily implemented.
- Despite perceived low potential for biological degradation of inorganic species, successful steps towards bioremediation have been identified recently.
  - E.g. bacterial bioremediation of metal-contaminated waste [51], successful use of bioremediation strategies for radionuclides [53-54].

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TREATMENT OPTIONS – BIOLOGICAL – BIOREMEDIATION

- Phytoremediation (acidic mining drainage in mine tailings) – plants facilitating the immobilization of heavy metals (e.g. lead, cadmium, zinc, iron and nickel) [55].
  - Phytocapping (growth of plants over mine tailings) – addition of amendment layer on the mine tailings to enable plants to adapt to biotoxins and the acidic pH [55].
- Potential bioremediation of inorganic hazardous materials (e.g. asbestos) [56]
  - Factors to address – (in particular) lack of organic material and nutrients for growth.
- Landfarming (ex-situ bioremediation technology) – contained, controlled degradation of contaminants in varied soil conditions to optimize the rate of degradation [57].
  - Contaminated waste mixed with soil amendments (e.g. soil bulking agents and/or nutrients), adjusted for parameters (e.g. moisture, pH and aeration (by periodic tilling)) [57-58] – allows contaminants to interact with the soil and climate of the site to degrade, immobilize and transform contamination constituents [57].

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TREATMENT OPTIONS – BIOLOGICAL – BIOREMEDIATION

- Disadvantages include:
  - Issues associated with – accurate scale-up and lack of standardised methods for measuring biodegradation rates – resulting in scarce data sets,
  - Use of lab scale experiments to predict field scale results appears risky for determining treatment rates,
  - Bacterial or plant-based processes may produce large volumes of pollutant-loaded biomass – can result in further waste disposal issues.
- Use of fungi for bioremediation processes may present greater opportunities, especially for hazardous substances.
  - E.g. Asbestos – removal of iron from asbestos materials has been indicated using lichens and fungi [56],[59-60].

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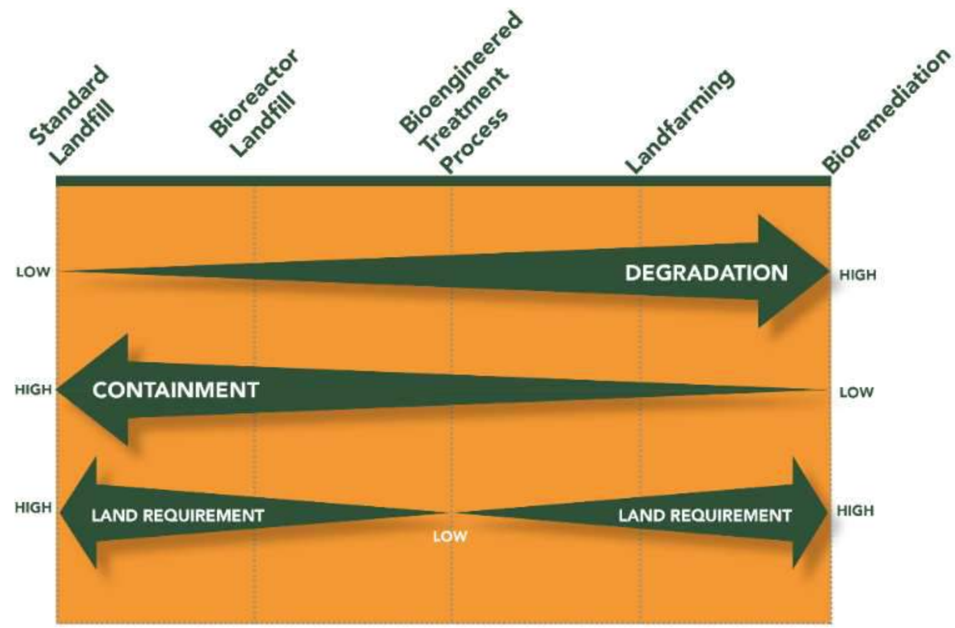
ADVANCED TREATMENT POTENTIAL

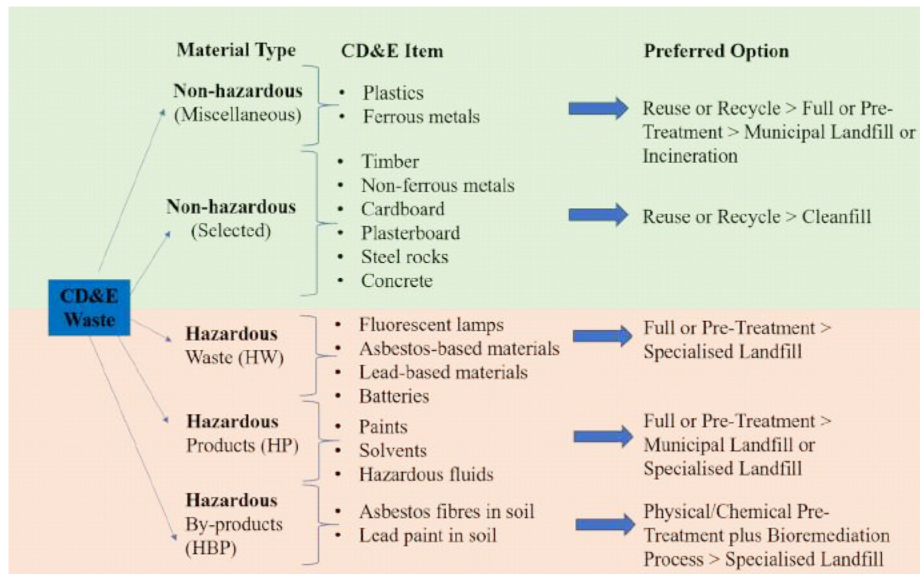
- Bioremediation provides large-scale, long-term option for relatively slow microbial degradation of a wide variety of compounds requiring low energy and low-level maintenance.
- Landfarming also shows promise but will require further adaptation to ensure public safety due to the tilling process to provide aeration.
- Disadvantages of bioremediation and landfarming – potential migration of very stable hazardous substances (e.g. asbestos), therefore containment to provide degradation is needed.



Disposal vs treatment in terms of microbial degradation, containment, land requirements.

BIOENGINEERED TREATMENT PROCESS

- Potential to create an engineered treatment process - using aspects of current landfill design with optimised bioremediation (Bioengineered Treatment Process).
- Sustainable approach – requires identification and separation of the waste types.
- Process may require pre-treatment and followed by well-managed waste processes rather than singular landfilling.
- Advantages of process train may include:
  - Creation of less toxic environments due to separation of hazardous substances.
  - Reduction in creation of highly toxic hazardous mixtures.
  - Potential for reuse or recycling of hazardous substances (after processing).



Defining and treating hazardous and non-hazardous CD&E waste.

CONCLUSIONS

- Water and wastewater industry – well-established biological treatment processes
  - Including – suspended and fixed growth microbial systems.
- Similar investments and advancements for solid waste treatment processes have not been forthcoming.
- May be due to:
  - High land space requirements, lack of incentives and perceived lack of feasibility.
  - However – landfill processes are simple and low cost (by comparison) despite shortcomings in terms of sustainability.
- Proposed bioengineered treatment process aims to:
  - Expand and adapt methods for organic waste bioreactor (or activated) landfills,
  - Incorporating treatment processes utilized by bioremediation,
  - Landfill design suitable for the treatment of hazardous CD&E waste (to minimise risk to public but maximise treatment).
- Long-term – Development of multiple biotechnological processes (according to waste type) may provide a better and more sustainable solution to combined waste disposal in landfills.

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- Some further information can be found in the following published research article:
  - WIT Transactions on Ecology and the Environment, Volume 247, 2020
    - *"Disposal or Treatment: Future Considerations for Solid Waste from the Construction and Demolition Industry"*

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