



## LEADER

# Safe disposal and effective destruction of clinical wastes

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In this edition of the *Journal of Hospital Infection*, Kanemitsu *et al.*<sup>1</sup> report their findings from laboratory studies intended to evaluate the efficacy of incineration as a method for sterilization of clinical wastes. High-temperature incineration is regarded as a wholly effective 'gold standard' method for the sterilization of wastes, although few attempts have been made to obtain 'proof of process' and formal evidence for this has been lacking. Kanemitsu *et al.*<sup>1</sup> seek to address this issue and, in so doing, raise wider questions regarding the relative merits of the available waste-disposal technologies.

It is almost impossible to reproduce the complex physical and thermodynamic conditions of the incinerator under laboratory conditions. In a modern incinerator, wastes entering the combustion chamber quickly reach temperatures approaching 1000 °C. Supplementary fuel may be introduced to support minimum operating temperatures, with careful and fully automated management of the complex gaseous environment to ensure even and complete destruction of wastes. The fixed temperatures selected by Kanemitsu *et al.*<sup>1</sup> to simulate the temperatures found in clinical waste incinerators in a static furnace cannot fully reflect the complex dynamics of the incineration process and the interplay between heat source, combustible and non-combustible solids, and the gaseous phase

of the incineration chamber. Despite evidence that temperatures of 300 °C for 15 min up to 1100 °C for 3 min were sufficient to sterilize test pieces and provide a sterility assurance level of  $10^{-6}$ , data from the direct study of incinerator effluents are inconclusive.<sup>2-4</sup> That uncertainty, which may reflect methodological difficulties rather than deficiencies in the incineration process, necessitates a wide margin of safety engineered into incinerator design. This should include operating temperatures no less than 1100 °C and residence times for gases and solids sufficient to allow for the often wide variation in load rate, and in the composition and calorific value of feedstocks. Many older incinerators operating at lower temperatures, and those without effective monitoring and integrated feedback control systems, will not provide the necessary assurance for satisfactory performance and must be withdrawn from service.

Incineration of clinical wastes must be controlled and validated. How should this be achieved? Continuous monitoring of operating parameters includes physicochemical profiling throughout the combustion zones, and measurement of pollutant concentrations in effluent gases. Feedback systems provide adjustment of operating conditions to ensure satisfactory performance. Is there also a place for additional biological monitoring? Placing test pieces in the load for later recovery is not practicable since sample carriers may be difficult or impossible to recover. Difficulties in sampling hot exhaust gases and the problems of securing

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meaningful data that accurately reflect the complexities of the incineration process make routine biological monitoring of the incineration process impracticable, if not impossible. Although microbiological sampling systems for incinerators have been devised and evaluated,<sup>5,6</sup> biological monitoring is not normally required as part of the statutory monitoring of commercial waste incineration plants.

In contrast, the 'alternate disposal technologies' of microwave,<sup>7</sup> hot oil augur<sup>8</sup> and autoclave treatment are subject to routine biological monitoring, most commonly by the introduction of test pieces incorporating *Bacillus stearothermophilus* or *Bacillus subtilis* spore preparations into the load. These conventional microbiological studies may require modification to accommodate easy retrieval of test pieces from treatment residues, and usefully supplement physical monitoring of time and temperature profile to support process control and performance monitoring based on engineering alone. Using biological indicators, it is possible to define minimum sterilization assurance levels for each of the alternate disposal technologies and ensure that these are maintained in regular use. The US State and Territorial Association on Alternate Treatment Technologies (STAATT), on behalf of the US Environmental Protection Agency, proposed four sterility assurance levels to define the levels of microbial inactivation applicable to the disposal of clinical wastes. Level III inactivation is the minimum standard of performance required for all clinical waste treatment processes (Table I). Biological monitoring is thus appropriate for all alternate disposal technologies intended for the treatment of clinical waste, although this will apply only on commissioning and periodically thereafter. Biological test systems are not used for routine in-process control.

One further and fundamental question remains—is it necessary to ensure sterilization of clinical wastes? Clinical wastes invariably contain significant amounts of packaging materials and more general refuse items, and only a tiny proportion

may comprise items that present a risk of infection.<sup>9</sup> The microbial load of clinical waste is markedly less than for domestic refuse, yet clinical wastes, which comprise less than 40% of the total solid wastes from hospitals, are responsible for more than 60% of the costs of disposal. This provides strong support for a move away from costly destruction of clinical wastes by incineration, through waste minimization and additional segregation of wastes at source to reduce to a minimum that component of clinical wastes that carries a clear and unquestionable infection risk. Such initiatives can vastly reduce the volumes of clinical wastes sent for disposal; significant cost savings may accrue. However, although waste minimization and advances in product packaging are to be applauded, further segregation of wastes at source may be of doubtful benefit. The need for accurate segregation of wastes into 'infective' and 'non-infective' components would be prone to error. Incorrect classification and improper segregation of waste may increase associated risks to ancillary staff and contractors.

Schemes for the additional segregation of wastes at source, predicated on expectation of infection risk, must also address the chemical and physical composition of wastes including the environmental impact of their subsequent treatment residues. Processing of wastes must additionally address a need to ensure effective destruction and prevention of illicit re-use of sharps etc., to render safe all pharmaceutical wastes that may be present and ensure minimal environmental impact from their treatment residues, and to address concerns regarding aesthetic issues that dictate total destruction of tissue wastes etc. It has been a mainstay throughout decades of improvement in the standard of clinical waste disposal that segregation at source is prone to error and best avoided. To propose, primarily on the basis of cost, that waste will be subdivided into several categories, each with its own container, identification and preferred route for disposal, invites errors in segregation and the risks associated with it.

**Table I** STAATT sterility assurance levels for waste disposal technologies

Level I	Inactivation of vegetative bacteria, fungi and lipophilic viruses at $\geq 10^6$ reduction
Level II	Inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria at $\geq 10^6$ reduction
Level III	Inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites and mycobacteria at $\geq 10^6$ reduction, and inactivation of <i>Bacillus stearothermophilus</i> or <i>B. subtilis</i> spores at $\geq 10^4$ reduction
Level IV	Inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites, mycobacteria and <i>B. stearothermophilus</i> spores at $\geq 10^6$ reduction

Together with the simple practicalities that limit, often critically, the space available to accommodate additional waste containers in cramped clinical areas, proposals for further segregation of clinical wastes may be largely unworkable. In contrast, a case can be made based on economics and environmental impact, risk reduction and simple practicalities for co-disposal of all health-care wastes using incineration as an effective, non-polluting and all-embracing technology.

Although attempts at waste minimization are to be applauded, more fundamental changes to clinical waste management must be considered. Economic arguments supporting the lower capital and operating costs of alternative treatment technologies generally fail to address the environmental impact, transport costs and cost of landfill disposal for treatment residues that are markedly less for high-temperature incineration. While there remains a place for alternative technologies in the management of clinical wastes, fully destructive processing by incineration provides the most effective solution to the management of these complex wastes. Importantly, incineration affords minimum environmental impact without the need for more extensive segregation of wastes at source.<sup>10,11</sup> Further advances are possible. Plasma technologies achieve even higher temperatures than conventional high-temperature incineration. High-temperature plasma arcs create a heat source of enormous power and versatility; temperatures within the plasma column typically exceed 10 000 °C, giving average bulk temperatures within the plasma reactor in the range of 1300–1500 °C. Together with the intense ultraviolet light emitted from the plasma arc, these temperatures ensure the rapid destruction of all organics present in the feedstock, reducing emission levels and creating a non-leachable non-polluting vitrified solid residue that has minimal environmental impact with maximum volume reduction. Plasma arc technology is a highly flexible advanced destruction technology applicable to the safe disposal of clinical and associated wastes. It can satisfactorily address all biological, chemical and environmental issues, as well as logistic and economic concerns, while being

applicable to the safe destruction and co-disposal of other waste streams from healthcare establishments including chemical, pharmaceutical and cytotoxic wastes, confidential paper waste, sharps, food wastes, and more general refuse items. Although relaxation of standards for the disposal of clinical wastes have recently been proposed, based on the high proportion of non-hazardous items typically present, other factors must be considered. In this context, plasma arc technology provides a further enhancement on high-temperature incineration, while operating at still higher temperatures to ensure the widest margin of biological safety.

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