

EQUIPMENT REPORT

Emission of viable bacteria in the exhaust flue gases from a hospital incinerator

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Accepted for publication 5 October 1988

Summary: The exhaust gases from an oil-fired hospital waste incinerator were examined during normal incinerator operation. The design-specified operating temperature was 800°C in the primary combustion chamber and 1000°C in the secondary chamber. Flue gas temperatures, measured from the sampling point at the base of the exhaust stack, varied over the range 186-305°C, and bacteria were recovered from this position in numbers up to 400 cfu m⁻³ (mean 56 cfu m⁻³). No sampling was performed at the top of the stack where flue gases were discharged to the atmosphere. Isolates were predominantly gram positive, i.e. *Bacillus* spp., coagulase negative staphylococci and *Staphylococcus aureus*, although low numbers of gram negative species (*Pseudomonas fluorescens* and other pseudomonads) were also recovered. Our results suggest that incineration may not constitute an absolute method of sterilization for clinical waste.

Keywords: Incinerator; waste disposal; sterilization.

Introduction

The safe disposal of clinical waste from hospitals, from other health care facilities including clinics, general practitioner consulting rooms and dental surgeries, and from veterinary establishments, is a matter of considerable public and professional concern (Health and Safety Commission, 1982). Large quantities of clinical waste are generated each day. Estimates vary from 0.6 kg bed⁻¹ d⁻¹ (Althus, Sauerwald & Schrammeck, 1973) up to 5.9 kg bed⁻¹ d⁻¹, with even greater volumes recorded from large hospitals and from teaching hospitals (Rutala & Sarubbi, 1983).

Disposal of clinical waste is costly; in the United States the expenditure in 1985 exceeded \$450 million for an estimated 2.2 × 10⁸ kg waste (Nelson, 1987). Methods of disposal must conform to accepted safety standards (British Standard, 1987). Staff must be provided with safe working

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conditions, particularly where waste of different types requires segregation before disposal. Whenever possible, transportation for disposal at distant sites must be avoided to reduce the risks of environmental contamination. Combining clinical and domestic wastes for codisposal in licensed land-fill sites is unsatisfactory and appropriate only in emergency situations (Working Party, 1983). This method is further contra-indicated by low cost-effectiveness and for aesthetic, ecological and political considerations (Norris & Young, 1978).

The need for safe, yet economic, procedures for disposal of clinical waste supports the view that incineration provides the only acceptable method and most authorities recommend this approach (Norris & Young, 1978; Rutala & Sarubbi, 1983; Working Party, 1983). Much attention has been directed toward techniques for the collection and transport of infective clinical waste. However, the efficacy of incineration procedures has received only minimal attention. In view of the current awareness about hazards associated with clinical waste disposal, we have examined the microbiological emissions from a modern hospital incineration installation.

Methods

Incinerator

The incinerator plant consisted of a newly constructed conventional oil-fired, two-chamber controlled air installation. The primary chamber was designed to operate at a minimum temperature of 800°C and the secondary chamber at 1000°C. Gaseous emission from the incinerator was via a 140 m vertical stack (Figure 1).

The incinerator was used primarily for disposal of clinical waste. Additionally, small amounts of other general waste generated from within the hospital were disposed of by incineration using this plant. The incinerator installation was equipped with an automatic loading facility comprising conveyor belt and hydraulic ram feed. The minimum design loading rate of the incinerator was 350 kg h⁻¹.

Bacteriological and physical sampling

Exhaust flue gases were sampled during a period of normal incinerator operation. Gases were sampled via a stainless steel sampling hose positioned at right angles within the horizontal exhaust duct, just prior to the base of the vertical exhaust stack. This hose, sealed within the duct using glass fibre matting to minimize the ingress of ambient air, was connected directly to a Casella slit sampling apparatus operating at an airflow velocity of 30 l min⁻¹. The distance between the sampling point within the exhaust duct and the Casella apparatus was approximately 2.5 m. Samples of flue gases were collected over intervals of 0.5 to 20 min (15–600 l air) throughout a three-hour test period.

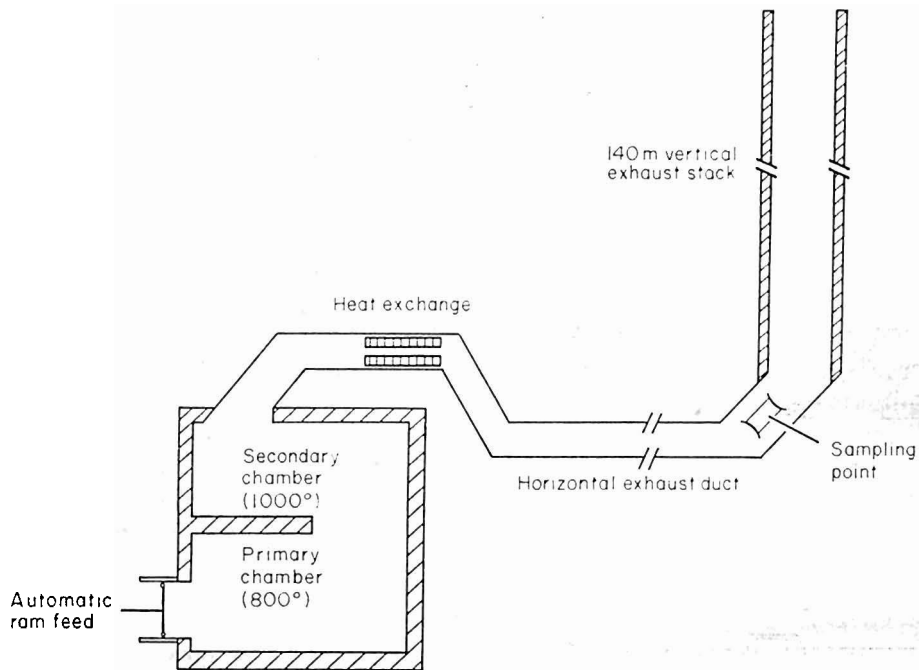


Figure 1. Clinical waste incinerator

Blood agar plates (Oxoid Blood Agar Base, CM55, containing 5% v/v defibrinated horse blood) were used for all air samples. These were incubated in air at 37°C for 5 days prior to examination. Anaerobic cultures were not performed. Additionally, ash and clinker samples were randomly collected from the incinerator chamber following an overnight cooling period. Approximately, 1 g samples of these were aseptically transferred to 200 ml peptone water and incubated at 37°C for 5 days prior to subculture to blood agar medium. All isolates were identified using conventional techniques according to the scheme of Cowan (1975).

Physical measurements of incinerator operation performed during the study period included temperature measurement in the combustion chambers, and at the sampling point within the exhaust duct, using a K-type thermocouple. Mass air flow at the sampling point was measured using 'pitot' pressure apparatus connected to a digital micromanometer.

Results

Temperatures in both incinerator chambers indicated that the installation was operating broadly in line with design specification. During the test period, the mean temperature of the flue gases at the sampling point was 216°C (range 186°C–305°C). The temperature within the Casella apparatus

was not measured but appeared only marginally above ambient temperatures. Discoloration of culture media was observed on only three occasions and appeared to be due to the chemical composition of flue gases. Flow measurement using a 'pitot' pressure apparatus and digital micromanometer, volume corrected to 273°K (0°C) and 1013 m bar, revealed a mass airflow through the exhaust duct of $1.3 \text{ m}^3 \text{ s}^{-1}$.

Culture of flue gases revealed small numbers of viable bacteria, averaging 56 cfu m^{-3} (range 0–400 cfu m^{-3}). The number of bacteria recovered varied widely with time. Due to the automatic operation of the incinerator plant, this variation could not be correlated with any specific event or variation in the nature of the load. Gram positive spore-forming bacilli resembling *Bacillus* species predominated. Lesser numbers of coagulase negative staphylococci and *Staphylococcus aureus* were also recovered. Gram negative bacteria, *Pseudomonas fluorescens* and other pseudomonads were isolated on only two occasions in low numbers ($< 10 \text{ cfu m}^{-3}$).

From multiple 1g samples of ash and clinker from the incinerator chamber, small numbers of coagulase negative staphylococci were recovered from only one sample. All other ash and clinker samples examined were sterile after 5 days incubation.

Discussion

Clinical waste generally contains fewer bacteria than household refuse (Althus, Sauerwald & Schrammeck, 1973; Kalnowski, Weigand & Riden, 1983; Mose & Reinthaler, 1985; Trost & Filip, 1985). However, the number of potential human pathogens present in clinical waste, including *S. aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Salmonella* spp., dermatophyte fungi and yeasts, are greater and present an increased risk of infection (Trost & Filip, 1985). Indeed, of blood-stained materials recovered from hospital waste, 2% were positive for markers of hepatitis B virus (Mose & Reinthaler, 1985). Particularly hazardous is waste from operating theatres and intensive care units, although the total microbial load may be even less than for waste from general wards (Kalnowski *et al.*, 1983).

Only one previous report has questioned the biological safety of incinerator operation. Barbeito and Shapiro (1977) examined a small scale gas- or oil-fired pathological incinerator using simulated loads seeded with *Bacillus subtilis* var *niger* spores. Temperatures of 760°C in the primary chamber and 871°C in the secondary chamber were required to ensure adequate sterilization under normal operation. Glysson, Schleyer & Leonard (1974) examined the bacterial load of dust and air in the working environment surrounding a clinical waste incinerator. Counts varied widely but were invariably high, over $75,000 \text{ cfu m}^{-3}$, and exceeded recommendations (Glysson *et al.*, 1974) for hospital air quality ($< 3.5 \text{ cfu m}^{-3}$ for critical areas; $< 750 \text{ cfu m}^{-3}$ for general areas; $< 2000 \text{ cfu m}^{-3}$ for maintenance and utility service areas). The microbiological quality of incinerator exhaust flue gases was not examined.

The results obtained from our study revealed that viable gram positive and gram negative bacteria were present in the exhaust flue gases of the incinerator, in numbers up to 400 cfu m^{-3} , despite chamber temperatures of 800°C and 1000°C and exhaust gas temperatures in the range $186\text{--}305^\circ\text{C}$. The temperature of these flue gases, sampled at the base of the 140 m vertical exhaust stack and distal to the heat exchange unit, would be expected not to fall significantly until reaching the point of discharge to the atmosphere, and bacteria recovered at the sampling point would have been subjected to further heat before emission to the atmosphere at the top of the stack. Wide airborne dissemination presumably renders these exhaust gases harmless. However, careful consideration must be given to the position of exhaust stacks relative to adjacent buildings. Exhaust stacks must also be positioned with consideration to prevailing winds and airflow characteristics around other structures in the immediate vicinity.

The safe disposal of clinical waste requires extreme care and every attempt must be made to ensure the risks of infection to hospital staff, patients, and to the general public are kept to a minimum. For this, attention is usually focused on containment and transport of waste. When incineration is used for final disposal, this is widely assumed to be totally effective. Our results suggest that bacteria may survive in an incinerator and that small numbers of these may be emitted to the environment with the exhaust flue gases. The manner in which bacteria survive the temperatures of the combustion chamber is not known. However, it is likely that this is due, in part, to rapid transit times of fine particles suspended in air within the incinerator. Inadequate combustion may also result from the presence of large volumes of liquid, often present in clinical waste from urine drainage bags etc. With older, often poorly maintained and inadequately controlled, incinerator installations the emission of bacteria to the environment may be common. It is not appropriate, however, to attribute any specific hazard to the survival and subsequent emission of small numbers of viable bacteria from clinical waste incinerators.

The help and advice of Messrs Peters, Carter and Chiverton and of Miss A. Storey, of London Scientific Services, is gratefully acknowledged.

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