Medical Waste Incineration:
A Mismatch Between Problem and Solution

by Dr. Paul Connett

While the industrialised world has started to phase out their toxic incinerators, India is poised to acquire these out-dated and dangerous equipments. Unfortunately, decision makers are all too often ill-informed and it is crucial that every means at our disposal are used to prevent them from poisoning the public.

Introduction

The problem of medical waste disposal is essentially *biological*: we wish to minimize the risk of disease causing bacteria and viruses moving from the hospital or research institution into the community. While the notion of burning this waste might appear, at first sight, to be a rational solution to this problem, in my view, it represents a very poor mismatch between solution and problem. High temperature incineration changes the issue from a biological problem into a set of formidable *chemical* problems. The reason for this is simple: while incineration is certainly capable of destroying the bacteria and viruses, it forces on itself the extra task of having to destroy the material on which the pathogens are sitting: the paper, cardboard, plastic, glass and metal. It is in this process that *acid gases* are generated (from the chlorinated organic plastics present), *toxic metals* are liberated (from the pigments and additives in the paper and plastic products as well as other miscellaneous items like batteries, discarded thermometers, etc.) and dioxins and furans are formed (from any chlorine present in the waste). None of these formidable chemical problems is inherent to the medical waste "problem" itself; instead, they all result. from the supposed "solution".

In recent years, largely as a result of concerns generated by the discovery that medical waste incinerators are a significant source of dioxins entering the environment (see below) there have been two very different approaches to solving the medical waste problem. One approach, what I call the *"back-end" approach*, is to seek to retrofit the existing medical waste incinerators (or build new regional facilities) with more advanced air pollution control technology. The other approach, the *"front-end" approach*, has been to seek out technologies (some old and some new) which are capable of destroying the bacteria and viruses, without attempting to destroy chemically the materials on which they are sitting After discussing the seriousness of the dioxin emission issues, I will compare these two approaches.

Medical waste incineration and dioxin. Today when the word dioxin (or dioxins) is used it is usually meant to refer to two families of compounds called polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Of the total of 210 compounds (whose differences depend upon the number and location of the chlorine atoms on their structure) in these families, 17 are extremely toxic. Ironically, these extremely toxic substances can be made simply by burning anything containing chlorine, and this includes medical waste.

Dioxins were first discovered in the emissions of trash incinerators by Olie and co-workers in 1977[1]. In 1987, Hagenmaier and co-workers in Germany reported that the levels of dioxins and furans in the fly ash collected from medical waste incinerators could be two orders of magnitude higher than the levels found in the fly ash in municipal waste incinerators[2]. Table I lists the data presented by Hagenmaier et al.

Table 1[2].

Concentrations of Dioxins and Furans in Fly Ash from Municipal and Hospital Incinerators.

(Units: ng/g, equivalent to parts per billion).

	Incinerator type	
Constituent	Municipal	Hospital
2,3,7,8-TCDD	0.03 - 0.34	1.4 - 3.4
Tetra CDD	0.6 - 7.5	94 - 404
Penta CDD	1.2 - 13.2	208 - 487
Hexa CDD	1.4 - 15.8	271 - 411
Hepta CDD	1.8 - 25.6	189 - 307
Octa CDD	1.9 - 23.1	123 - 245
Total dioxins	6.9 - 80.3	1155 - 1737
Tetra CDF	9.0 - 32.1	199 - 376
Penta CDF	10.2 - 38.3	285 - 647
Hexa CDF	8.0 - 31.7	253 - 724
Hepta CDF	3.4 - 15.9	125 - 286
Octa CDF	0.7 - 4.6	25 - 134
Total furans	31.3 - 119.5	895 - 2140

In September 1994, the U.S. Environmental Protection Agency (USEPA) published a draft report which examined the known sources of dioxin in the U.S., and concluded that medical waste incineration was the largest identified source: 5100 grams out of a grand total of 9300 grams of dioxin toxic equivalents per year.[3]

There have been two explanation as to why medical waste incinerators should produce more dioxins and furans, per ton of waste burned, than municipal waste incinerators. The first suggestion is that medical waste contains more plastic per volume (approximately 30% versus 7%) than municipal waste, and much of this plastic is chlorinated (e.g. PVC). The second suggestion is that when the comparisons cave been made, the municipal waste incinerators were fitted with much more advanced air pollution control than the medical waste incinerators. Moreover, the municipal waste incinerators were operated by professionally trained staff whereas the medical waste incinerators were frequently run by the janitorial staff of the hospital. It is quite possible, that both explanations are correct. However, those who emphasize the former explanation advocate removing PVC and other chlorinated plastics from the hospital. In Austria, hospitals have been set up which use no PVC whatsoever[4]. In India, the Pollution Control Authority is considering requiring hospitals who wish to install incinerators to remove PVC prior to burning[5]. Those who emphasize the latter explanation advocate the upgrading of hospital waste incinerators with the kind of expensive and advanced air pollution control equipment currently being used on modern municipal waste incinerators. While both approaches will probably reduce (but not eliminate) the overall emission of dioxin going into the environment, neither in my view, represent the appropriate and cost effective solution to the fundamental problem involved. ***Simply put, dioxin production is not inherent to the problem of medical waste.*** If the waste was not burned, dioxins would not be formed. The fact that there are commercially available and cost effective technologies which can deal with infectious waste without burning them, should end the argument. However, before discussing these technologies I think it is important to discuss the limitations of the strategy of using the expensive and advanced air pollution control equipment as practiced in Germany and Holland.

Problems with the advanced pollution control of dioxin emissions (the back end approach). The most advanced pollution control used to limit dioxin emissions from incinerators involved the injection of activated carbon and a slurry of lime (calcium hydroxide) into the flue gases emerging from the furnace or the heat exchanger, and collecting the resultant particulate in a fabric filter (sometimes called a baghouse). This is sometimes followed by a wet scrubbing system prior to exhausting the gases into the environment. In the case of very large incinerators operating in areas where nitrogen oxides pose a problem (large cities and those which have an inversion problem) an expensive de-NO_x system may also be required.

The first problem. It is not enough to have the pollution control equipment. It is also critically important to have the professionally trained personnel to operate it. Currently, hospitals do not have such personnel. This is one of the reasons that Germany no longer allows on-site incineration of medical waste, instead it has to be sent to municipal waste incinerators equipped with advanced air pollution controls and run by professionally trained staff.[6]

The second problem. The air pollution control (APC) equipment is extremely expensive. In Holland about half the capital cost of building new *municipal* waste incinerators is going into the APC. For example, the new incinerator in Amsterdam (2000 tons per day) cost approximately $600 million, with about $300 million spent on APC[7]. To be able to recover the kind of financial investment involved it is necessary to build these facilities larger and larger. This reasoning would eliminate the hospital waste incinerator which in comparison is very much smaller. In the U.S. the smallest hospital waste incinerators burn less than one ton per day and the largest (Hampton, South Carolina - a regional facility) burns 50 to 100 tons per day. If a small incinerator is built by a hospital or research institution it usually involves swallowing the capital cost or getting it funded by some other means. For example, the Cornell University College of Veterinary Medicine is considering the building of an incinerator to burn 1 or 2 tons of medical waste a day (a combination of research animals and regulated medical waste). The project is expected to cost $3 million, but is being paid for by a grant from a different body[8].

The third problem. Even when these incinerators are fitted with advanced APC they still generate a huge outcry from the public. Frequently, this public opposition is enough to halt the project. For example, the Cornell University project mentioned above has triggered off the biggest environmental debate in recent years at the university[8]. As of this writing, the Dean of the Veterinary College has promised to put the permitting process on hold until the public has had a chance to become involved[9]. By contrast, the nonburn technologies excite very little public opposition.

The fourth problem. There is no way that any incinerator can be continuously monitored for dioxin or toxic metal emissions. To measure dioxin emissions requires collecting a flue gas sample for 5 to 8 hours and sending the filter off to a laboratory. This process is very expensive and time consuming. Typically, the smaller incinerators are very seldom, if ever, monitored for dioxin. Of the approximately 5000 medical waste incinerators operating in the U.S. in 1993, less than 20 have had their emissions monitored for dioxin[3]. Furthermore, the facility operators are given about a month's notice before the measurements are made, and have ample time to optimize their operations, and possibly adjust their waste stream, on the days they are being tested. It is stretching credulity to the limits that such measurements are truly indicative of what dioxins are emitted during routine operation. In essence, once a medical waste incinerator has been granted a permit it is largely unaccountable as far as dioxin emissions are concerned.

The fifth problem. Because the APC strategy puts the emphasis on capture of dioxin, rather than the prevention of its formation, the strategy hinges on the air pollution control operating correctly and it not being by-passed. Even modern incinerators cannot ensure this. For example, a trash incinerator in Rotterdam, Holland, was fitted with modern air pollution control equipment at a cost of $240 million. However, in its first 12 months of operation after the APC fitting, the equipment was by-passed 10% of the time![10] When we examine the estimated dioxin emissions from this plant, prior to the retrofit, we find that it was putting out 230 grams per year.[11] Thus a 10% by-pass would have put about 23 grams a year into the Dutch environment, which is approximately 5 times higher than the Dutch had hoped that all its trash incinerators combined would be putting into the environment by the year 2000.[11]

Table 2 lists the dioxin measurements made at several North American municipal waste incinerators using advanced air pollution control, both before and after the APC. These numbers underline how much reliance is being placed on the capture of dioxins and how serious the issue becomes when the equipment is by-passed.

Table 2[12]

DIOXIN REMOVAL EFFICIENCIES USING A COMBINATION OF A SPRAY DRIER AND FABRIC FILTER AS AIR POLLUTION CONTROL DEVICES.

FACILITY	FF INLET TEMP (degrees F)	DIOXIN FF-INLET	DIOXIN FF-OUTLET	DIOXIN REMOVAL EFFICIENCY%
Biddeford, ME	277	856	4.45	99.5
	278	866	5.18	99.4
	279	987	3.51	99.6
Commerce, CA	270	281	1.83	87.7
	270	233	25.4	89.1
	270	659	0.99	99.9
	270	446	9.59	94.5
	270	806	3.52	99.6
	270	532	3.12	99.4
	270	1010	1.71	99.8
	270	783	2.78	99.6
Hartford, CT	270	1275	1.39	99.9
	266	819	0.59	99.9
	277	963	ND	100
Marion County, OR	272	43	1.86	95.7
	293	123	3.82	96.9
	301	870	3.36	99.2
Quebec City,	280	1954	ND	100
Canada	283	1574	ND	100
	285	2685	2.52	99.9
	283	1629	ND	100

The sixth problem. Dioxin emissions greatly increase when incinerators are being started up or shut down. Table 3 gives a specific example of the huge difference this makes. Usually, incinerators are NOT tested under these conditions. Typically, medical waste incinerators are operated with frequent start-up and shut-down.

Table 3[12]

Dioxin Emissions Measured During Start-Up at Westchester County, N.Y., MSW Incinerator. Date of Testing: April 1985

Location: Peekskill, New York
Capacity: 2,250 tons per day

Technology: Mass-burn water wall.
Air Pollution Control: ESP

Run #	**ESP Inlet Temp. in degrees F**	**Inlet CDD/CDF Concentration ng/dscm 7% Oxygen**	**Outlet CDD/CDF Concentration ng/dscm 7% Oxygen**
Average of 12 tests (various loads):	452	440	179
Tests during start up:			
1.	383	13,782	11,080
2.	455	9,082	8,060
Average	419	11,432	9,570

The seventh problem. There is a very large day-to-day, year-to-year variation in the dioxin measurements from a specific plant. This underlines the problem of relying on the results of very infrequent testing. Table 4 gives a specific example of the very large increase achieved at a municipal waste incinerator operating in the U.S. It is not clear why the emissions should have increased so greatly in the 7 years between testing, but one possible explanation is that the equipment had deteriorated over time. This further underlines the need for good monitoring (expensive) and professionally trained personnel (expensive) and frequent replacement of key parts of the equipment (expensive).

Table 4.

Two Sets of Dioxin Emissions Tests from the Pinellas County, Florida MSW Incinerator, Made 7 Years Apart.

Location: St. Petersburg, Penellas County, Florida Technology: Mass-burn waterwall (Martin).
Capacity: 3,000 tons per day Air Pollution Control: ESP

A) COMPLIANCE TEST ON UNIT 3: FEBRUARY 1987[12]

Run #	**ESP Inlet Temp. in degrees F**	**Inlet CDD/CDF Concentration ng/dscm 7% Oxygen**	**Outlet CDD/CDF Concentration ng/dscm 7% Oxygen**
1.	552	103	163
2.	524	35	79
3.	536	43	127
4.	546	46	82
5.	523	31	50
6.	539	65	97
Average:	537	54	100

B) 1994 TESTS (part of US EPA's review of MSWI operating with hot sided ESPs)[13]

1.	?	?	1964
2.	?	?	3840
3.	621	?	4400
4.	543 (using water spray)	?	1500

The eighth problem. As more effort is made to capture the toxic metals and dioxin in the APC, the fly ash that is collected there becomes more and more toxic. This, in turn, presents several problems. First and foremost is the threat the ash poses to workers and others who are directly exposed to it, especially when the APC is being emptied and cleaned. Secondly, when the ash is disposed of as a hazardous waste, as it should be in my view, this adds yet another expense to the operation of the facility. Unfortunately, even responsible authorities have permitted some extraordinary things to happen to this ash, presumably to save on costs or to avoid the need for the siting of more hazardous waste disposal facilities. For example, the Dutch government has allowed 35% of the fly ash from its municipal waste incinerators to be used in asphalt to be used on the *surface* of their roads![11]

The ninth problem. Once built or installed, these facilities represent a long term (and very large) financial commitment to just one option for handling medical waste. For 20 years or more it removes any incentive to pursue more rational and cost effective solutions to the problem. Furthermore, it diverts attention from some of the unacceptable habits and developments which have pushed more and more throwaway objects into the medical establishment. It ignores the "front-end" of the problem. In short, it represents business as usual at a time when it has become clear that business as usual is threatening the future of our species on a finite planet.

A front-end strategy for the medical waste problem. Before getting into specific technologies for handling infectious waste it is important that we examine the whole strategy for obtaining a rational solution to the medical waste problem. I will divide this strategy into a series of steps.

Step 1. The hospital or research institution should organize a meeting to discuss their waste issue. To this should be invited administrative officials, doctors, nurses and staff. Too often, decisions on this issue are decided by the administration working in conjunction with consultants, who frequently have an over-confidence in incineration technology.

Step 2. A study team should undertake a waste analysis to determine the different kinds of waste generated and whether they are necessary or not. In this step, arguments should be entertained about switching back to reusable items, rather than disposable items. Such items run the gamut from the disposable plates in the cafeteria to the syringes used for patient treatment.

Step 3. The study team should further delineate a policy of *good housekeeping*, which involves the *separation and segregation* of different waste streams. The first order of business here is to segregate the non-infectious waste (the office waste, cafeteria waste, etc.), which is about 80-85% of the total, from the *infectious waste*, which is only about 15-20% of the total waste stream.

Step 4. Also as part of the good housekeeping, the study group should develop a *"sharps"* policy. This involves providing clearly identified and secure containers for the collection of sharp objects. While these objects represent less than 1% of the waste they represent well over 90% of the potential for transmitting disease from patient to the staff or the general public.

Step 5. The study team should research all the available technologies for handling infectious waste, both on-site and off-site. They should prepare a matrix comparing the alternatives economically, environmentally and socially.

Step 6. The study team should prepare a similar matrix for handling the *pathological waste* generated by the facility, like body parts, animal bodies, etc., which is usually only a very small percentage of the total but which is not necessarily amenable to the technologies examined in Step 5.

Step 7. With all the options on the table, representatives from the *local community* should be invited to join in the discussions and help to choose from among the options. Some might argue that they be involved from Step 1 or 2 onwards.

Step 8. In the event that there is a major argument about which of the options should be pursued, this is the point, in my view, when outside help should be sought. I would advocate equal funding for the close and detailed examination of the two options favoured by the two sides in the debate.

This approach would maximize the chance of securing a rational solution to the waste problem and minimize friction between the hospital and the local community.

Non-burn technologies for the treatment of infectious waste. Several groups have examined and compared the non-burn technologies for handling infectious waste. These include: The Recycling Council of Ontario from Toronto, Canada[14], the Citizen's Environmental Coalition from Albany, N.Y.[15], a consortium of 14 hospitals in Minnesota[16], and the group SRISHTI, from Delhi, India[17].

Three technologies commercially available are currently being used in a number of North American and European hospitals and off-site facilities. These are:
1. Steam sterilization (autoclaving);
2. Shredding followed by chemical disinfection; and,
3. Shredding followed by microwaving.

For the purpose of this article I will not select from among these options, but simply to say that a) they should each be examined carefully before selection, and certainly before selection of the incineration option; b) they all address my major concerns as a chemist, namely that they don't attempt to destroy the material upon which the bacteria and viruses are sitting and thus do not throw up formidable chemical problems which have nothing to do with the problems of infection; and c) they are all cost-effective and cheaper than an on-site or regional medical waste incinerator fitted with advanced air pollution control equipment.

The problem of pathological waste. As mentioned above the pathological waste (body parts and research animals, etc.) are not amenable to the non-burn technologies identified. Fortunately, in most cases, this pathological waste represents a very small percentage (less than 1%) of the total waste stream from a hospital or research institute. My recommendation is to use the techniques that have been used to handle whole human bodies: either crematoria or burial. The only caveats I would retain for cremation are, (1) don't wrap the body parts up in plastic, but rather use absorbent cellulose based material in heavy duty cardboard or wooden boxes; (2) don't burn bodies which have been treated with radioactive isotopes until at least 8 half-lives have transpired; and (3) remove fillings from teeth which contain mercury. Careful burial in carefully chosen sites represents the safest option, but in places where space is at a premium this may not be practical.

Conclusion. Having examined the problems associated with handling the problem of medical waste at the "back-end" namely, burning it in medical waste incinerators fitted with advanced air pollution control equipment - with the "front-end" approach of waste minimization, waste segregation and the use of non-burn technologies for the infectious waste, the arguments lend a great deal of support to the terse observation of Albert Einstein:

"A clever person solves a problem, a wise person avoids it."

References

1. Olie, K.P. Vermeulen and O. Hutzinger (1977). Chlorodibenzo-p-dioxins and Related Compounds are Trace Components of Fly Ash and Flue Gas of Some Municipal Incinerators in the Netherlands, *Chemosphere*, 8, 455-459.

2. Hagenmaier. H., M. Kraft. H. Brunner and R. Haag (1987). Catalytic Effects of Fly Ash from Waste Incineration Facilities on the Formation and Decomposition of PCDDs and PCDFs *Env. Sci. Tech.*, 21, 1080-1084.

3. US EPA (1994). *Estimating Exposure to Dioxin-Like Compounds,* Volumes I, II and III. Review Draft. EPA/600/688/OO5C a,b,c.

4. Green (author or publication?) (1995). *PVC in Hospitals, Use, Risks and Alternatives in the Health Care Sector*, Vienna (cited in reference 15 below).

5. Chaturvedi B., and R. Agarwal. Personal communication. In a letter dated June 11, 1996, I was informed that based on discussions at the "Peer and core group Standards Committee" of the Central Pollution Control Board, "there is a strong likelihood that PVC will not be incinerated, but shredded and either autoclaved or chemically disinfected." SRISHTI 1001, Antariksh Bhawan 22, Kasturba Gandhi Marg, New Delhi, India 10001.

6. Lahl, U. and D.O. Reimann (1995). PCDD/F-Emissions of MSWI: A Status Report on Emission Reduction Means in Germany, *Organohalogen Compounds*, 23, 413-417.

7. Information obtained during visit to the MSW Incinerator in Amsterdam, August 14, 1996.

8. Benson, S. (1996). Burning Issue: Vet School's Incinerator for Plans Elicit a heated Discussion about Waste Disposal, *Ithaca Times*, Aug 29 - Sept 4, 1996.

9. Yaukey, J (1996). Incinerator Critic Blasts Cornell Plan, *Ithaca Journal*, September 18, 1996.

10. A. Schoevers, personal communication, Aug 10, 1996. (Arne Schoevers, Stichling Afval in Milieu, Dr van der Knaaplaan 5, NL 2283 CW Rijswijk, The Netherlands).

11. H.J. Bremmer et al (1994). *Emissions of Dioxins in the Netherlands*. National Institute of Public Health and Environmental Protection (RIVM) and Netherlands Organization for Applied Scientific Research (TNO) February 1994.

12. US EPA (1989). *Municipal Waste Combustors - Background Information for Proposed Standards: Post Combustion Technology Performance*. EPA-450/3-89-27c. August 1989.

13. US EPA (1995). *Compilation of MWC Dioxin Data. Attachment 2: MWC Survey.* Office of Air Quality Planning and Standards, (July 27, 1995).

14. Brown, S.L., D.E. Kjollesdal, and M.H. Lee (1992). *Protecting Community Health: 3R's Solutions to Health Care Waste*, Recycling Council of Ontario, 489 College St., Suite 504, Toronto, Ontario. Canada M6G IA5.

15. Citizens' Environmental Coalition (1992). *Managing Medical Waste*, CED, Main Office, 33 Central Avenue, Albany, NY 12210.

16. Minnesota Health Care Partners, Inc. (1992). *Study of Non-Burn Technologies for the treatment of Infectious and Pathological Waste and Siting Considerations.*

17. Chaturvedi, B., and R. Agarwal (1996). *Be Careful with that Cure! A Critical Look at Incineration as a Medical Waste Disposal Method*. SRISHTI, 1001, Antariksh Bhawan 22, Kasturba Gandhi Marg, New Delhi, India 10001.

Dr. Paul Connett is Associate Professor of Chemistry at St. Lawrence University, Canton, NY 13617 USA.

This article was originally printed in The Ecologist Asia, Vol. 5, No. 2, March/April 1997