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Potential Dioxin and Furan Sources from Hospital Solid Waste Streams : A Pilot Study

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Abstract

This Pilot study identifies potential dioxin and furan sources and medical plastic wastes produced from hospital solid waste streams. In this study, air emissions of dioxins and furans from sources in the U.S., which were estimated by the U.S. Environmental Protection Agency (EPA), were summarized. Potential loading routes of dioxins and furans to the U.S.-Canada Great Lakes region have also been identified in recent surveys. In addition, medical and hospital solid wastes produced in typical large city hospitals were characterized as important potential sources of dioxins and furans.

Plastic contents in medical and hospital wastes were much higher than in municipal solid wastes. In this study, the Massachusetts Medical Plastics Characterization Survey (MMPCS), plastics composition data were obtained from a survey of five Massachusetts Hospitals and Medical Centers. By identifying plastic wastes as a percentage of total hospital wastes, we were able to use data from a preliminary study that analyzed the waste stream of 16 major New York City hospitals (NYCMWS) characterizing the plastic content of the wastes. This study determined the types of plastic wastes included in each medical waste stream (regulated medical waste or non regulated medical waste) and it discussed the potential for recyclibility of hospital plastic wastes. The combination of the NYCMWS and the MMPCS surveys provides for the first overview of the size of the recycling task of hospital plastic wastes and the potential of dioxin elimination if dioxin generating plastics were to be eliminated from hospital use.

1. INTRODUCTION

Incinerated medical waste has been identified as the principal source of dioxin contamination in the U.S. The U.S. Environmental Protection Agency (EPA) estimated dioxin emissions to the Great Lake area and identified potential sources (U.S. Environmental Protection Agency, 1994). The Center for the Biology of Natural System (CBNS) conducted a similar evaluation that paralleled the EPA findings (Cohen *et al.*, 1995). The CBNS also identified in more detail the potential major sources of dioxin in the Great Lakes area. Medical waste incineration appears as an important contributor of dioxin in all five Great Lakes (Cohen *et al.*, 1995).

In order to identify and characterize the dioxin sources from medical waste two surveys were used: the result of a study of Medical Waste Management in the New York City Hospitals (NYCMWS) (Waste-Tech and Konheim and Ketcham, Inc., 1991) and the Massachusetts Medical Plastics Characterization Survey (MMPCS). The MMPCS is a pilot study of the composition of plastic waste, as potential sources of dioxins and furans, based on evaluations in five Massachusetts hospitals. The NYCMWS study characterized, described and analyzed all medical wastes generated by the New York City Health and Hospitals Corporation (HHC) and New York City Department of Health (DOH) facilities. Sixteen major hospitals were investigated in the New York City area for medical waste analyses.

1.1 NYCMWS Study

NYCMWS study classified medical waste as follows:

"True RMW is waste that is both defined and handled as RMW by the current waste management system.

Fugitive RMW is waste that may be defined as RMW under a broad interpretation of current regulations, but that is not handled as RMW by the current waste management system and is disposed of as NRMW.

Entrained NRMW is waste that is improperly collected, boxed and shipped as RMW even though it is NRMW.

NRMW is waste that is neither defined nor handled as RMW."

Incineration appears to be the predominant method of choice for disposal of RMW (CEC Fact Sheet, 1993). The NYCMWS study identifies plastic items as the majority of the RMW waste stream. Therefore, the identification of the plastic composition of the RMW incineration is a logical first step to identify dioxin sources from incinerated medical wastes.

1.2 MMPCS Study

RMW and NRMW from five Massachusetts Hospitals were physically examined. The plastic wastes of RMW and NRMW were identified and classified. The five public hospitals surveyed were of sizes comparable to the hospitals in the NYCMWS study. This information combined with site visits to the hospitals, analyses by catalog of medical supply firms and interviews with: hospital officials and medical waste plastics recycling companies permitted this preliminary qualitative characterization.

1.3 Medical Plastic Waste Disposal and Recycling

Currently the Most popular disposal method of municipal solid waste (MSW) as well as the ash residue from incineration of medical wastes is landfilling. However, since the number of active operating landfills has decreased by 75% during last two decades and construction of new landfill is very difficult (Ehrig and Curry, 1993), we are faced with landfill crisis. Therefore, to save landfill space and to preserve natural resources, it would be desirable to recycle plastic wastes. Plastic has a high volume occupancy of landfill (about 20% of MSW by volume) (U.S. Environmental Protection Agency, 1992). In addition, the composition percentage of plastics of medical wastes estimated, based on air-dry weight, by the Minnesota Pollution Control Agency (MPCA), was about 46.3% (Minnesota Pollution Control Agency, 1991). That is, since the proportion of plastic wastes in medical wastes is much greater than that in MSW, a recycling of plastics in the hospitals should be also considered. Therefore, to evaluate the recyclibility of plastic medical wastes and to reduce disposal cost of medical wastes, a study of types of plastic medical wastes as well as exact classification of True RMW, Fugitive RMW, Entrained NRMW and NRMW is required.

This paper combines the NYCMWS and MMPCS studies in order to identify potential sources of dioxins and furans, describes the composition of medical wastes, and characterizes the types of plastics wastes reported as constituents of medical wastes. The combination of the NYCMWS and the MMPCS surveys provide for the first overview of the size of the recycling task of hospital plastic wastes and the potential of dioxin elimination if dioxin generating plastics were to be eliminated from hospital use. Finally, a discussion on the need for further studies in medical plastic waste recycling practices is presented as a means of reductions of dioxins and furans originated by incineration of plastic wastes.

2. MATERIAL AND METHODS

2.1 Collection of Field Data

In order to classify the hospital plastic wastes this study reviewed the typical records of plastics materials purchased by hospitals. Also we obtained data on hospital wastes from site visits to hospitals, interviews with managers, survey letters sent, and medical suppliers. Site visits to five Massachusetts hospitals (University of Massachusetts Medical Center, Boston University Medical Center, Saint Memorial Medical Center, Lowell General Hospital, and Massachusetts General Hospital) were conducted to have a first hand examination of plastic wastes. These visits evaluated typical hospital plastic wastes generating sources, i.e., cafeterias, administration, emergency rooms and clinics. Physical examination of plastic wastes as well as interviews with managers and personnel of waste generating departments were performed in the five hospitals surveyed.

2.2 Classification of Identified Plastics

After identifying the plastics disposed in the waste streams of the five surveyed hospitals, a plastics engineer consultant was engaged to identify the plastic composition of the collected samples. This was followed by evaluation of composition of materials from medical supply catalogs. Interpretation of bar codes of wasted plastics was also obtained. Interviews were also conducted with two companies engaged in plastics recycling as well as interviews with medical supplies to confirm composition data.

3. RESULTS AND DISCUSSION

3.1 Potential Sources of Dioxins and Furans

Table 1 shows the estimated air emissions of dioxins and furans from sources in the US reported by EPA (U.S. Environmental Protection Agency, 1994). Most of dioxins and furans resulted from incineration of medical and municipal wastes as well as combustion of wood and coal. It is evident that medical waste incineration (MWI) is a remarkably predominant source of dioxin and furan emissions.

Table 2 and Figure 1 show sources of dioxins and furans loading to each of the Great Lakes. Sewage treatment plants and paper mills are primary sources of dioxins and furans loading to Great Lakes the through water. Main sources through the air route were also due to incineration of medical and municipal wastes.

Careful analysis of Tables 1 and 2 and Figure 1 is indicating there is a need for a quantitative study of potential sources of dioxins and furans as well as a study of characterization of their components and analysis of medical wastes.

3.2 Composition Characterization of Medical Wastes

Tables 3, 4 and 5 represent a summary on data of medical wastes obtained from typical large hospitals of New York City (Waste-Tech and Konheim and Ketcham, Inc., 1991). Table 3 shows the total quantities of hospital and medical waste streams based on weight and volume for total 10,616 hospital beds under study in New York City. The average medical waste production per hospital bed for a year was 7,037 lbs. This value is a relatively lower value than that of the US average generation value, 8,395 lbs/bed-year, of medical wastes produced per bed for a year (Bartholomew, 1993). This is probably due to continuous efforts of recycling and reduction of medical was-

Table 1. Estimated air emissions of dioxins and furans from sources in the United States.*

Class of Source	g TEQ / year emitted to air the (g)		Relative Percent. of total air emissions of TEQ (%)	
	CBNS	EPA	CBNS	EPA
Medical Waste Incineration	4,200	5,100	54	53
Municipal Waste Incineration	1,900	3,000	24	31
Cement Kilns Burning Hazardous Waste	400	210	5	2
Secondary Copper Smelting	270	230	3	2
Wood Combustion	230	360	3	4
Iron Ore Sintering Plants	210		3	
Coal Combustion	200	<300	3	<3
Cement Kilns Not Burning Hazardous Waste	160	140	2	1
Heavy Duty Diesel Vehicles	120	85	2	1
Forest Fires		86		1
Hazardous Waste Incineration	70	35	0.9	0.4
Sewage Sludge Incineration	24	23	0.3	0.2
Secondary Copper Refining	6	negligible	0.1	negligible
Vehicles Using Unleaded Gasoline	2	2	0.03	0.02
Secondary Lead Smelting & Refining	1.3	1.3	0.02	0.01
Kraft Black Liquor Boilers		2.7		0.02
Drum and Barrel Reclamation		1.7		0.03
Carbon Reactive Furnaces		0.1		0.001
Total	7,800	<9,600	100	100

TEQ : Amount of 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) that is equivalent in toxicity.
* Source : Cohen *et al.*, 1995.

Table 2. Analysis of loading routes and sources of dioxin and furan loading to each of Great Lakes.*

Rank	Lake Superior	Lake Ontario	Lake Erie	Lake Huron	Lake Michigan
1	Paper Mill[W]	Sewage Treatment[W]	Paper Mill[W]	Paper Mill[W]	**Med.** Waste Incineration[A]
2	Paper Mill[W]	Sewage Treatment[W]	Sewage Treatment[W]	**Mun.** Waste Incineration[A]	Paper Mill[W]
3	Petroleum Refinery[W]	**Mun.** Waste Incineration[A]	**Mun.** Waste Incineration[A]	Sewage Treatment[W]	Paper Mill[W]
4	Paper Mill[W]	Paper Mill[W]	**Mun.** Waste Incineration[A]	**Med.** Waste Incineration[A]	Paper Mill[W]
5	**Med.** Waste Incineration[A]	Hazard. Waste Burning[A]	**Med.** Waste Incineration[A]	**Mun.** Waste Incineration[A]	Iron Sintering[A]
6	**Med.** Waste Incineration[A]	Chemical Manufactur[A]	**Med.** Waste Incineration[A]	**Med.** Waste Incineration[A]	Sewage Treatment[W]
7	**Med.** Waste Incineratn[A]	**Med.** Waste Incineration[A]	Chemical Manufactur[A]	**Med.** Waste Incineration[A]	Paper Mill[W]
8	**Mun.** Waste Incineration[A]	**Med.** Waste Incineration[A]	**Mun.** Waste Incineration[A]	**Med.** Waste Incineration[A]	**Med.** Waste Incineration[A]
9	**Med.** Waste Incineration[A]	**Mun.** Waste Incineration[A]	Sewage Treatment[W]	**Mun.** Waste Incineration[A]	Iron Sintering[A]
10	Paper Mill[W]	**Med.** Waste Incineration[A]	**Med.** Waste Incineration[A]	**Med.** Waste Incineration[A]	Paper Mill[W]
Total /year	4.6 g TEQ	5.7 g TEQ	9.4 g TEQ	5.6 g TEQ	14.2 g TEQ

TEQ : Amount of 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) that is equivalent in toxicity.
Mun. stands for municipal and **Med.** stands for medical. [W]stands for water route and [A]stands for air route.
* Modified from the CBNS study (Cohen *et al.*, 1995).

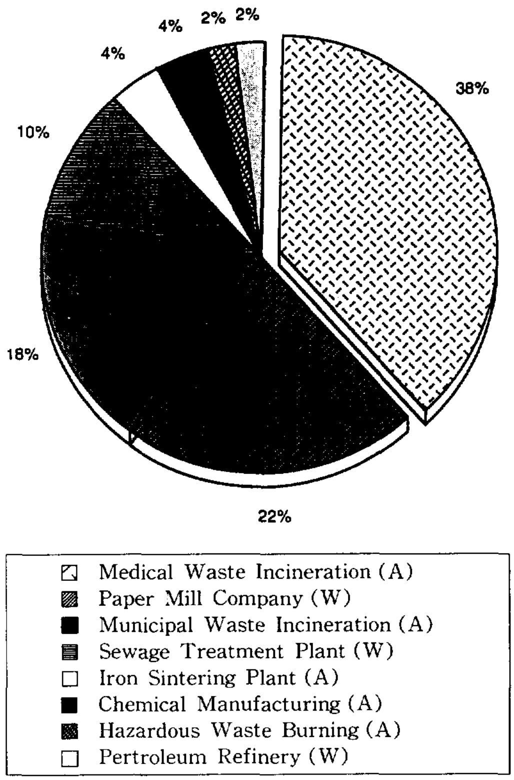

Fig. 1. Analysis of Loading Routes and Sources of Dioxins and Furans Loading to all Great Lakes (A: Air Route, W: Water Route).

Table 3. Total quantities of typical hospital waste streams produced from 16 New York City hospitals.*

Type of Waste	Weight (tons/year)	Relative Percentage (%)	Volume (ft^3/year)
Bulk Waste	87	0.2	2,347(24.7%) (Red Bag Waste)
RMW	9,056	24.2	
Hazardous	10	0.03	
RMW Shipping Box	1,307	3.5	
Pathological	33	0.08	
Low Level Radioactive	6	0.02	
NRMW	26,858	71.9	7,156(75.3)**
Total	37,357	100.0	9,503(100%)

* Modified from the NYCMWS.
** Volume of Clear Bag Waste.

tes of New York City.

Table 4 and Figure 2 show the composition parameters of medical wastes based on weight of red bag and clear bag wastes. The compositions of plastics and moisture (free water) of the red bag wastes represent about 1.5 to 1.6 times higher values than those of clear bag wastes. This means that the incineration of red bag wastes has a higher possibility of emissions of dioxins and furans due to incineration of plastics containing chlorine, such as PVC. Also, at low temperature below 300°C incomplete combustion possibility due to moisture (free and bound water) remaining in waste bags can not be excluded and thus it can be a potential source of dioxins and furans generated from medical waste disposal.

Table 5 shows the comparison of waste components of red bag (RMW) and clear bag (NRMW) medical wastes. The proportions of I.V.'S, apparatus and bloody items of red bag wastes are much higher than those of clear bag wastes. In these items strong physical properties, such as high flexibility and tough strength, are required due to a releasing possibility of infected materials obtained through patient-care. Therefore, a substantial number of plastics such as PVC and HDPE are used for

Table 4. Composition parameters of typical medical wastes from 16 New York City hospitals.**

Waste	RMW(Red Bag)		NRMW(Clear Bag)	
	Weight (tons/year)	Relative Percentage (%)	Weight (tons/year)	Relative Percentage (%)
Cellulosic	3,680	40.6(48.0*)	11,652	54.6(59.7*)
Plastic	**3,035**	**33.5**(39.6*)	**4,782**	**22.4**(24.5*)
Inert	514	5.7 (6.7*)	1,573	7.4 (8.1*)
Putrescible	448	4.9 (5.8*)	1,701	8.0 (8.9*)
Moisture (Free Water)	1,393	15.4(0*)	2,019	9.5(0*)
Total	9,070	100(100*)	21,727	100(100*)

* Calculation based on dry-weight (without free water) of medical wastes.
** Modified from the NYCMWS.

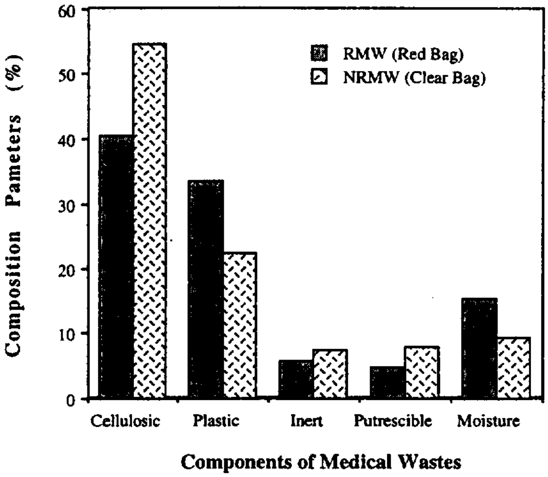

Fig. 2. Composition Parameters of Typical Medical Wastes.

their components. However, the amount of plastic bags of red bag wastes are less than that of clear bag wastes. This is apparently opposite to the result of composition parameters of plastics shown Table 4. This is due to the amount of plastic bags shown in Table 5; not data of whole plastics, but data of only plastic bags. Since a lot of plastics are included in packaging, sharps, I.V.'s, apparatus and bloody items, the result of whole plastics contents in shown Table 5 is same as that of Table 4. Content of food service of clear bag wastes is much greater than that of red bag wastes. This means a lot of plastics included in food service item, such as PS, is generally not infected and thus there is a high recycling possibility of those plastics.

3.3 Types of Plastic Wastes related to Classification of Medical Wastes

Tables 6 and 7 combine the results of from the New York hospital waste mass analysis (NYCMWS) with the classification of plastics wastes from Massachusetts five hospitals (MMPCS). It is assumed that there is no substantial difference between the nature of plastics used in large city hospitals in New York or in Massachusetts, since hospital supplies are generally standardized in the U.S. It is assumed that these findings are generalizable to all U.S. large city hospitals.

Table 6 shows classification and components of RMW and major plastics types of each component based on the analysis of plastic wastes in Massachusetts Hospitals. The New Yo-

Table 5. Red bag and clear bag medical waste composition from 16 New York City hospitals.*

RMW Composition	Weight (tons/year)	Relative Percent.%	NRMW Composition	Weight (tons/year)	Relative Percent.%
Paper	435	4.8	Office Paper	699	3.3
Packaging	699	7.7	Packaging	1,420	6.7
I.V.'s	641	7.1	I.V.'s	427	2.0
Apparatus	1,924	21.2	Apparatus	1,281	6.0
Bloody Items	337	3.7	Bloody	46	0.2
Linens	2,034	22.4	Linens	3,583	16.8
Food Service	1,258	13.9	Food Service	4,972	23.3
Paper Towel	418	4.6	Paper Towel	1,888	8.8
Cloth	188	2.1	Cloth	391	1.8
Plastic Bags	**304**	**3.4**	**Plastic Bags**	**919**	**4.3**
Other	813	9.0	Mixed Paper	2,068	9.7
			News Paper/ Magazines	1,390	6.5
			Computer Printout	412	1.9
			Other	1,838	8.6
Sub Total	9,051	100	Sub Total	21,334	100
Total	RMW	29.8	Total	NRMW	70.2

rk City data shows that the fugitive RMW, which is not handled as a true RMW but is disposed of as NRMW, is about 30% of total RMW. This means true RMW is not as much as amounts of red bag waste or RMW generally reported in a literature or study of medical wastes. This indicates that improper disposal of fugitive RMW as red bag wastes or RMW could require an unnecessary-additional disposal cost. That is, disposal cost of infected waste or RMW can become more than ten times that of non infected waste or NRMW. This is due to the application of a broad definition of infected medical wastes.

Table 7 also shows the classification and components of NRMW from New York City hospitals and major plastics types of each component based on Massachusetts hospital plastics classification. The entrained NRMW, which is improperly collected as RMW even though it is NRMW, is about 17% of total NRMW. That is, since entrained NRMW is not infected medical wastes, it should be collected as clear bag wastes and considered as municipal solid waste (MSW). Therefore, authorities of hospitals could save disposal expense due to reasonable classification of medical wastes.

From tables 6 and 7 we can generalize estimates of hospital disposed plastics containing chlorine, such as PVC, that could be potential sources of dioxins and furans upon incineration of medical wastes. Also, these data can provide us with guidelines of how much and what kind of plastics can be considered for recycling in medical wastes. However, to quantitatively identify recycling potential of disposable hospital solid plastics and sources of dioxins and furans produced from medical waste incineration, it is strongly necessary to conduct a more detailed study of the proportion and types of plastics of each medical waste component. In addition, it would be also necessary to develop the recycling program of medical plastic wastes and to survey the technology of plastics recycling currently applied to the hospital solid waste streams.

Table 6. Total waste stream components and classification of regulated medical wastes (RMWs) from 16 New York City hospitals and types of plastics based on Massachusetts hospital survey.

Component	True RMW		Fugitive RMW		Major Plastics
	tons/year	Rel. %	tons/year	Rel. %	
I.V.	641	16.1	427	24.3	PVC, PP, ABS, HDPE
Sharps	405	10.1			PP, PE, PTFE
Sharp Container	135	3.4			PP, HDPE
Bloody	301	8.4	46	2.7	PVC, ABS, PS
Apparatus	677	16.8	1,281	73.0	PC, ABS, PP
Drug Container	316	7.9			PVC, HDPE
Solution Container	166	4.1			PVC, HDPE
Gauze	166	4.1			
Medical Cups	60	1.5			PS
Plastic Bags	**308**	**7.5**			PVC, PE, PP
Other	814	20.2			PVC, PES, PS
Sub Total	3,989	100	1,754	100	
Total	True	69.6	Fugitive	30.5	

PVC : Polyvinyl chloride, PP : Polypropylene, PE : Polyethylene
ABS : Acrylonitrile-butadiene-styrene terpolymer
PTFE : Polytetrafluoro ethylene
HDPE : High density polyethylene, PS : Polystyrene, PES : Polyester.

Table 7. Total waste stream components and classification of Nonregulated medical wastes (NRMWs) from 16 New York City hospitals and types of plastics based on Massachusetts hospital survey.

Component	NRMW		Entrained NRMW		Major Plastics
	tons/year	Rel. %	tons/year	Rel. %	
Food Service	4,972	19.8	1,258	25.1	PS, LDPE
Linens	3,591	14.3	2,034	40.6	PVC
Mixed Paper	2,068	8.2	418	8.3	
Paper Towels	1,888	7.5	436	8.7	
Kitchen	2,833	11.3			PVC, PE, PS
Packaging	1,421	5.7	699	14.0	PVC, PE, PS
Corrugated	2,674	10.6			
News/Magazines	1,390	5.5			LDPE
Office Paper	699	2.8			
Computer Printout	412	1.6			
Plastic Bags	**919**	**3.7**			PVC, PE, PP
Cloth	391	1.6	187	3.7	PP, PES, PS
Other	1,838	7.3			
Sub Total	25,096	100	5,009	100	
Total	NRMW	83.3	En.NRMW	16.6	

PS : Polystyrene, LDPE : Low density polyethylene, PES : Polyester
PVC : Polyvinyl chloride, PE : Polyethylene, PP : Polypropylene.

4. CONCLUSION AND RECOMMENDATIONS

- Predominant sources of air emissions of dioxins and furans are incineration of medical (53~54%) and municipal wastes (24~31%).
- Dioxins and furans loading to the Great Lake mainly due to incineration of medical and municipal wastes (air route) as well as paper mill and sewage treatment plants (water route).
- Medical waste generation rate per bed for a year, which is based on data of medical wastes of typical large hospitals of New York City, 7,037 lbs/bed-year.
- Composition parameter of plastics of red bag (RMW) and clear bag (NRMW) medical wastes based on weight were 33.5% and 22.4% of total RMW and NRMW, respectively.
- Plastic sources of dioxins and furans from incineration of medical wastes appear to be originated mostly by RMW waste, i.e., I.V.'s, sharp, apparatus, bloody items, drug container and plastic bags. The plastics identified in RMW wastes are PVC, HDPE, PP, and PS. NRMW waste seems to contain less plastic materials than that of RMW.
- To identify potential sources of dioxins and furans produced from medical waste incineration, it is necessary to conduct a quantitative a study of composition of plastic wastes.
- For reduction of emissions of dioxins and furans and disposal cost of medical wastes, it is necessary to establish a program of source reduction, substitution and recycling of plastic wastes.

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