

# Medical waste production at hospitals and associated factors

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## Abstract

This study was conducted to evaluate the quantities of medical waste generated and the factors associated with the generation rate at medical establishments in Taiwan. Data on medical waste generation at 150 health care establishments were collected for analysis in 2003. General medical waste and infectious waste production at these establishments were examined statistically with the potential associated factors. These factors included the types of hospital and clinic, reimbursement payment by National Health Insurance, total number of beds, bed occupancy, number of infectious disease beds and outpatients per day. The average waste generation rates ranged from 2.41 to 3.26 kg/bed/day for general medical wastes, and 0.19–0.88 kg/bed/day for infectious wastes. The total average quantity of infectious wastes generated was the highest from medical centers, or 3.8 times higher than that from regional hospitals (267.8 vs. 70.3 Tons/yr). The multivariate regression analysis was able to explain 92% of infectious wastes and 64% of general medical wastes, with the amount of insurance reimbursement and number of beds as significant prediction factors. This study suggests that large hospitals are the major source of medical waste in Taiwan. The fractions of medical waste treated as infectious at all levels of healthcare establishments are much greater than that recommended by the USCDC guidelines.

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## 1. Introduction

Although medical wastes represent a relatively small portion of the total waste generated in a community, medical waste management is considered an important issue worldwide. In Taiwan, the total amount of medical waste was estimated to increase from 61,343 Tons in 2002 to 117,544 Tons in 2004, including 10,943 and 22,326 Tons of hazardous waste, respectively (TEPA, 2004, 2006). There are proven techniques for the medical industry to provide safe and proper medical waste treatment (Malkan and Nelson, 2005; Diaz et al., 2005). The outbreak of severe acute respiratory syndrome (SARS) in 2003 has called for the authorities to take more serious steps in man-

aging medical waste. During that period, most of the waste produced from urgent and intensive medical care was classified as infectious. The procedures for handling, treatment and disposal of this waste were required to comply with the most stringent standards (Chiang et al., 2006). The health authority in Taiwan was alerted to re-examine the current status of waste production for further management planning. The types of medical establishments and the waste management capacity at hospitals have been recognized as important factors in waste treatment. Studies have reported that the quantity of waste generated by hospitals varied by changes in local legislation (Askarian et al., 2004; Fisher, 2005; Mohee, 2005; Bdour et al., 2007). Studies have also discussed the opportunities for waste reduction through better management practices for both infectious and general wastes (Almuneef and Memish, 2003; Tudor et al., 2005). For better knowledge of medical waste generation and management, we conducted a survey to investi-

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gate the types and quantities of medical waste generated from healthcare related establishments in Taiwan. The quantities of medical waste produced were evaluated using selected factors.

## 2. Methodology

### 2.1. Facilities selection and National Health Insurance system

National Health Insurance (NHI) is a government supported program linking the social security system to the general public. All citizens are obligated by law to join this universal program. Using a conditional comprehensive contract system, any qualified medical establishment may apply to become a contracted care institution to provide services to beneficiaries. The medical establishment applies to the Bureau of NHI for services reimbursement by the official fee schedule. As of the end of 2003, over 96% of the population was enrolled in the NHI program. The Department of Health in Taiwan has categorized approximately 18,700 medical establishments into four levels: medical centers, regional hospitals, local (community) hospitals, and independent clinics and others (including dental clinics, psychiatric treatment facilities, institutions for training and special functions, long-term care centers, postnatal care centers, and care centers for the elderly) (BNHI, 2004).

For this survey, we included all 17 medical centers and 63 regional hospitals by considering that most medical waste in Taiwan are generated from these 80 healthcare establishments. We also randomly selected some local hospitals (30/375) and independent clinics (30/18155), including internal medicine and pediatrics (5), dialysis centers (4), surgery and dermatology (6), obstetrics and gynecology (5), dentistry (3), medical labs (5), and Chinese medicine (2). The remaining 10 establishments involved mental treatment and retarded person care, nursing homes for the elderly and postnatal care centers, which were selected to cover major services provided by medical institutions. Representative and balanced geographical distribution of these facilities were also considered in the selection process (Table 1). However, all 17 medical centers were located in the 8 counties with higher populations.

### 2.2. Questionnaires and on-site visits

A questionnaire was sent to each selected medical establishment by mail from July to September 2003, to collect information on waste generation over the previous 12 months. The project team members made on-site visits from October to December 2003 with the returned questionnaire to confirm the provided information, waste management system, waste segregation and separation practices, waste reduction and recycling, and disposal methods (disinfection and incineration) and other operational conditions. The hot spots for the on-site checkup were inpatient rooms, nursing stations, labs, dialysis

Table 1

Total number of medical establishments available in Taiwan and number of establishments selected for this study by establishment type

Medical establishment	Total establishments <sup>a</sup>	No. of counties located <sup>b</sup>	No. selected
Medical centers	17	8	17
Regional hospitals	63	20	63
Local hospitals	375	24	30
Independent clinics	18,155	25	30
Others	36	13	10
Total	18,646	25	150

<sup>a</sup> Number of establishments are based on the records from Department of Health as of 2004.

<sup>b</sup> Number of counties in which selected establishments were located illustrate the geographical and administrative coverage of survey samples in this study.

rooms, radiology rooms, waste disinfection equipment and waste storage, handling and treatment. We also verified the questionnaire data against the waste management records of the medical establishment.

### 2.3. Data analyses

We first calculated the average yearly generation rate and the average daily weight per bed for infectious and general wastes by the type of medical establishment. Types and quantities of waste generated from medical establishments may vary with the medical specialties and their waste management practices (Prüss et al., 1999; UNEP, 2002). Data analysis measured the potential factors associated with the amount of waste production, such as the capacity of services and the medical specialties provided by the medical establishment. It has been statistically justified that the type of medical establishment affects the production of infectious and general waste. Multiple variable regression analysis was applied to predict the factors associated with waste generation. The amount of infectious waste and the number of inpatients can be associated with the total number of beds and bed occupancy. Reimbursement from the NHI to individual medical establishments could be an interesting indicator reflecting the capacity of services provided. Therefore, factors including NHI payment, total number of beds, rate of bed occupancy, number of beds for infectious diseases, number of outpatients per day and amount of waste recycled (in Tons) were included in the multivariate model to examine their association with waste production.

## 3. Results

### 3.1. Waste production and production rate

The waste generated at medical establishments in Taiwan consisted of infectious and general medical wastes. Table 2 shows that the annual average amount of infectious waste generated yearly was the highest (267.8 Tons)

Table 2  
Average amount of infectious waste and total general medical waste by type of medical establishment in Taiwan

Type	Infectious waste <sup>a</sup>		General medical waste <sup>a</sup>		% Infectious	No. of beds
	Tons/yr	kg/bed/day	Tons/yr	kg/bed/day	%	
Medical centers	268 (282)	0.60 (0.36)	1287 (1060)	3.26 (1.01)	17.2	21,586
Regional hospitals	70.3 (48.4)	0.44 (0.22)	456 (310)	3.04 (2.63)	13.4	36,817
Local hospitals	18.8 (11.2)	0.88 (1.34)	131 (114)	2.41 (1.37)	12.6	6,276
Clinics and others	7.6 (23.0)	0.19 (0.38)	108 (128)	2.60 (0.96)	6.6	3,456

<sup>a</sup> Numbers in parentheses are standard deviations.

at medical centers, accounting for 17.2% of all medical wastes. The annual average infectious waste production was 3.8 times higher than that by regional hospitals. However, the average amount of infectious waste generated daily per bed was the highest at local hospitals (0.88 kg/bed/day), followed by medical centers, regional hospitals and the least at independent clinics (0.19 kg/bed/day). Only 6.6% of all wastes generated from the independent clinics were infectious. Table 3 shows the annual amount of infectious wastes generated by clinical departments at a regional hospital in Taipei area. The dialysis clinic disposed the largest amount of infectious waste, approximately 0.739 kg/bed/day.

### 3.2. Influencing factors

Table 4 demonstrates factors that predicted the amount of medical wastes in medical establishments with the multivariate regression model. These variables explained 64% ( $p = 0.0002$ ) for general wastes and 92% ( $p < 0.001$ ) of infectious wastes disposed from medical establishments in Taiwan. Insurance reimbursement and number of beds were the significant factors predicting infectious waste generation.

## 4. Discussion

### 4.1. Type of medical establishments

The total amount of medical wastes generated from a medical establishment is associated with the type or the size of the institution. In Table 4, the coefficient of the establishment type depicted that the overall annual average general waste production differed by 30.3 Tons between types of medical establishments. The corresponding difference for the annual average amount of infectious waste was 0.47 Tons. The generation rate of medical waste is also dependent on the regulations and economic status of a country with a large variation expressed as the amount of waste per bed/day or per capita/day, etc. (Prüss et al., 1999; UNEP, 2002; Sakaguchi, 2001; Shaprio et al., 2003). The average medical waste generation rates (2.79–3.86 kg/bed/day) in Taiwan were much greater than that in Poland (2.6 kg/bed/day), in Japan (0.25 kg/bed/day), in Jordan (0.1–3.0 kg/bed/day) and in Korea (0.48 kg/bed/day) (Gluszynski, 1999; Shaprio et al., 2003; Mohee, 2005; Jang et al., 2006).

Table 3  
Amount of infectious wastes generated at a regional hospital in Taipei County by department

Department <sup>a</sup>	Yearly weight kg/yr (%)	Daily weight kg/bed/day <sup>b</sup>
Dialysis	5667 (22.7)	0.739
Intensive care unit	4429 (17.8)	0.467
Bacteriological laboratory	2902 (11.7)	NA <sup>c</sup>
Biochemistry and immunology	2629 (10.5)	NA <sup>c</sup>
Surgery	2006 (8.0)	1.023
Emergency care	2987 (12.0)	0.411
Emergency lab <sup>c</sup>	1429 (5.7)	
Out-patient clinics	2883 (11.6)	NA <sup>c</sup>
Total <sup>d</sup>	24932 (100)	0.91

Note: NA: not applicable.

<sup>a</sup> These were departments where infectious waste was recorded.

<sup>b</sup> Rate of infectious waste production is calculated by dividing the quantity of infectious waste by number of beds provided in the department.

<sup>c</sup> The department did not provide patient beds.

<sup>d</sup> This is the summation of the departmental data in the list, not the total infectious waste generated from the hospital.

In this study we found that the total amount of infectious wastes generated was much higher at medical centers, because medical centers generally care for more patients. On the other hand, local hospitals yielded the highest rate of infectious waste (0.88 kg/bed/day), followed by medical centers (0.60 kg/bed/day) and regional hospitals (0.44 kg/bed/day). This could be attributed to the practices in local hospitals, which may provide services of the same nature as larger establishments. Our observation in the survey found that local hospitals spent less effort in waste management.

The fractions (12.6–17.2%) of medical waste generated in hospitals treated, as if it were infectious were much greater than the USCDC guidelines of 6.0% (Tunis et al., 1991). This is partly because more components of hospital waste were considered as infectious under Taiwan's Act (TEPA, 2003).

### 4.2. Total number of beds, bed occupancy, and number of beds for infectious disease

As to the influence of individual factors, for every percent increase of bed occupancy, the annual general waste production increased 2.48 Tons and infectious waste 0.23 Tons (Table 4). The number of beds installed for infec-

Table 4  
Potential factors associated with production of infectious waste and general waste in multivariate regression analysis<sup>a</sup>

	Infectious waste (Tons/yr)			General waste (Tons/yr)		
	$\beta$	SE	P	$\beta$	SE	P
Intercept	-2.37	44.4	0.96	-214.7	416.3	0.61
Level of facilities	0.47	11.9	0.97	30.3	103.4	0.77
NHI payment <sup>b</sup> (NTD)	$8.00 \times 10^{-8}$	$1.33 \times 10^{-8}$	<0.0001	$1.33 \times 10^{-7}$	$1.05 \times 10^{-7}$	0.22
No. of beds	-0.13	0.06	0.04	0.44	0.46	0.34
Bed occupancy <sup>c</sup> (%)	0.23	0.38	0.56	2.48	4.05	0.55
No. of specialty beds	0.21	0.13	0.12	-0.24	1.00	0.81
No. infectious disease beds	0.19	0.50	0.71	-5.29	4.80	0.28
No. of outpatients per day	0.001	0.001	0.25	-0.01	0.01	0.20
Waste recycled (Tons)	-0.14	0.09	0.14	3.30	1.69	0.07
R <sup>2</sup>	0.92		<0.0001	0.64		0.0002

Note:  $\beta$ : beta parameter; SE: standard error; P: P-value; NHI: National Health Insurance; NTD: New Taiwan Dollars; No.: number.

<sup>a</sup> Data from independent clinics were not included in the above calculation.

<sup>b</sup> NHI payment of reimbursement counted in NTD.

<sup>c</sup> Ratio of bed occupancy as a percentage of total bed in each facility.

tious diseases treatment contributed only to the amount of infectious waste production. Although, in Table 2, a high standard deviation for the infectious waste production was observed at local hospitals, it may imply that there were greater variations in waste management at the local hospitals in Taiwan. The total number of local hospitals being surveyed in this study comprised only 8% (30/375) of the existing hospitals and was limited to facilities of specific specialties. However, we did observe the variation of waste production among different levels of medical establishments.

#### 4.3. National Health Insurance payment association

Using NHI reimbursement and number of beds to correlate waste production may not be entirely valid. Both factors imply the scale of a medical establishment. In Taiwan, the larger hospitals care for more inpatients and outpatients, and thus receive a greater amount of NHI reimbursement. The larger hospital has greater capacity to provide infectious disease care and more effective waste management. Therefore, NHI payment and total number of beds were significant variables in predicting the amount of infectious wastes. Although, this may not be a direct association, the increase of every 0.1 billion NT dollars in NHI reimbursement reflected an increase of 8 Tons of annual infectious waste generation ( $p < 0.0001$ ). On the other hand, NHI payment was not a significant factor to predict the general waste production rate ( $p = 0.22$ ). We also found that the generation of infectious waste could be reduced by 0.13 Tons for the increase of every unit (one bed) of total number of beds.

#### 4.4. Waste production from various specialties

The study found that waste production varied with quantities and types of services/specialties provided by the hospital. At medical centers, the three largest sources of infectious wastes were found to be surgical operation,

dialysis and laboratory services. In regional hospitals, dialysis, the analytical laboratory, ICU, the pathological laboratory, and internal medicine were major sources of infectious wastes. However, surgery remains the unit with the highest production rate per day per bed. To our knowledge, the prevalence of end stage renal disease requiring diagnosis in Taiwan is rather high (BNHI, 2004). In comparison, regional hospitals have become important establishments to provide patients with dialysis services. Dialysis is a medical specialty using a large amount of disposable materials in the care process, which rapidly increases the amount of waste (Shapiro et al., 2003).

#### 4.5. Segregation and sorting in different levels of medical establishments

The United Nations Environmental Programme (UNEP) has established that only 10% of the healthcare waste is considered to be “potentially infectious”. The proportion can be further reduced to 1–5% with proper segregation practiced at the sources (UNEP, 2002). There should be a balance between waste reduction and public threat of medical wastes (Blenkharn, 2006). Our study showed that the ratios of infectious wastes to total wastes were high in Taiwan. We are not sure there was a residual effect of up-regulation of waste management during the SARS chaos. We noted that there was a great increase in infectious waste in most medical establishments because of reduced recycling practice and the irrational reaction of society during the SARS epidemic. The increased infectious wastes were associated with eliminated segregation and segregation errors in line with precautions. Medical establishments should enhance the practice of waste segregation, sorting, and resource recycling and recovery.

## 5. Conclusion

The daily operation may imply a high cost in coping with the regulatory requirement for waste management at

medical establishments. The capacity of the medical establishment limits the availability of resources and the bargaining power for recycling and waste handling. This study found that the medical centers produce most of the medical wastes in Taiwan, but they produce less waste per bed per day. To our knowledge, they also possess better leverage to negotiate with the medical waste collectors to handle the recyclable materials. In conclusion, medical wastes in Taiwan included high amounts of infectious wastes destined for incineration. Medical centers are responsible for more than the half of the total infectious waste. A serious effort is needed to reduce waste generation and to increase material recycling.

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