CONCISE COMMUNICATION

Hospital Waste Generation During an Outbreak of Severe Acute Respiratory Syndrome in Taiwan

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During the SARS outbreak in Taiwan, the number of ambulatory patients and inpatients treated at one medical center decreased by 40%-70% because of the increasing number of SARS patients. At the peak of the epidemic, the amount of hospital infectious waste had increased from a norm of 0.85 kg per patient-day to 2.7 kg per patient-day. However, the hospital was able to return the generation of waste to normal levels within 10 days.

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The severe acute respiratory syndrome (SARS), a highly contagious disease associated with a high mortality rate, originated in Gung-dong, China, in November 2002 and quickly spread to other parts of the world.[1] In March 2003, Taiwan was struck by an outbreak of the newly emerging disease. The first case of SARS in Taiwan was formally confirmed by the study hospital (National Taiwan University Hospital) on March 10; the outbreak lasted for 144 days. The Center for Disease Control, Taiwan, officially announced that there had been a total of 3,032 isolated SARS case patients, including 668 with probable cases, 1,320 with suspected cases, and 1,044 with cases that tested negative for SARS.[2] In this study, we evaluated the impact of this outbreak on the generation of infectious waste at a 2,000-bed hospital in Northern Taiwan.

METHODS

Waste classification scheme. The waste routinely generated by the hospital in this study can be divided into 3 main categories: general waste, recyclable waste, and infectious waste. The guidelines for waste disposal currently enforced by the Environmental Infection Agency of Taiwan[3] basically follow those of the US Medical Waste Tracking Act.[4] Infectious waste includes pathological waste, medical needles and other sharp devices (ie, sharps), surgical waste, waste contaminated by blood and body fluid, and laboratory waste. General waste is household-type waste. Recyclable waste consists of uncontaminated waste that can be recycled according to the regulations of the Taiwan Department of Health,[5] such as used paper, glass, plastic, and metal packages.

In this study, all materials used to care for patients with SARS were designated as "SARS waste"; this waste included gloves, tubing, syringes, food boxes, and even clothes worn by patients.[6] Bedpans were wrapped in plastic bags so that the cleaning effort could be minimized. Excreta were submerged in 5% chlorinated bleach for 30 minutes before being flushed (at a dilution ratio of 1/100) into the sewage treatment system.

Statistical methods. The quantity of waste was determined for 4 time periods: period 1, before the SARS outbreak; period 2 (SARS1) and period 3 (SARS2), during the outbreak; and period 4, after the outbreak. SARS waste was collected separately from general infectious waste during period 2, but no effort was made to separate the waste during period 3. The one-way analysis of variance (ANOVA) tool of the SPSS software package (SPSS) was used to compare the daily rate of waste generation and the daily generation factor in the 4 periods. Statistical significance was set at $P \leqslant .05$. Data gathered on Saturdays, Sundays, and holidays were excluded from the statistical analysis because waste was not collected and, consequently, not recorded on those days. The remaining data were used to calculate waste generation factors (in kilograms per patient-day) on the basis of total shipping days and total calendar days (excluding Sunday and holidays).

RESULTS

Numbers of inpatients and ambulatory patients. The first case of SARS was formally reported on March 10, and the outbreak at the study hospital abruptly increased from 10 cases in early April to a peak of 90 cases in mid-May. Because of the increasing number of SARS patients, by the end of May the number of inpatients at the facility had decreased by 70% ($P < .001$) from its norm of nearly 2,000 patients. The number of daily outpatient visits also decreased by 40%-70%, from its norm of 7,000-8,500 patients per day before the outbreak to 2,000-4,000 patients per day during the outbreak.

General and recyclable waste. The mean daily generation rate of general waste decreased by 19.2% during period SARS1 and by 25.3% during period SARS2 ($P < .001$; see Table). However, the mean daily production rate of recyclable waste did not change significantly from its normal level of approximately 2,000 kg/day. Interestingly, the generation factors were not significantly affected by the outbreak: the levels remained fairly constant at 4.0 kg per patient-day for general waste and 1.2 kg per patient-day for recyclable waste.

Infectious waste and SARS waste. The mean generation factor for regular infectious waste increased significantly, from 0.85 kg per patient-day before the outbreak to 1.2 kg per patient-day during period SARS1 ($P < .001$ Table 1). In contrast, the mean generation factor for SARS waste during period SARS1 was 4.5 kg per patient-day, or approximately 4 times higher than the mean generation factor for regular infectious waste during periods SARS1 and SARS2. Moreover, the coefficient of variation of the generation factor for SARS waste was 174%, much greater than that of the generation

TABLE. Results of a Statistical Analysis of the Daily Generation of Four Types of Waste During an Outbreak of Severe Acute Respiratory Syndrome (SARS) at a Hospital in Taiwan

Time period and type of calculation or statistic	Regular waste		Recyclable waste		Infectious waste		SARS waste	
	Generation rate	Generation factor	Generation rate	Generation factor	Generation rate	Generation factor	Generation rate	Generation factor
Period 1 (before SARS outbreak)								
Calendar day	68	68	68	68	68	68	...	...
Shipping day	67	67	47	47	55	50	...	...
S/C, in %[a]	98.5	98.5	69.1	69.1	80.9	73.5	...	...
Mean value ± SD	7951 ± 2779[b]	4.1 ± 1.5[c]	2195 ± 1234[b]	1.1 ± 0.67[c]	1606 ± 716[b]	0.85 ± 0.31[c]	...	...
CV (%)	34.9	37.0	56.2	62.1	44.6	36.4	...	...
Period 2 (SARS1)								
Calendar day	83	83	83	83	83	83	83	83
Shipping day	83	83	63	63	72	62	83	83
S/C, in %[a]	100	100	75.9	75.9	86.7	74.7	100	100
Mean value ± SD	5940 ± 2330[b]	3.9 ± 1.5[c]	2232 ± 1406[b]	1.5 ± 1.2[c]	1574 ± 652[b]	1.2 ± 0.54[c]	41 ± 16[b]	4.5 ± 7.8[c]
CV (%)	39.2	38.2	63.0	83.4	41.4	44.3	40.1	174
Period 3 (SARS2)								
Calendar day	61	61	61	61	61	61	...	...
Shipping day	59	59	40	40	51	49	...	...
S/C, in %[a]	96.7	96.7	65.6	65.6	83.6	80.3	...	...
Mean value ± SD	6424 ± 3370[b]	4.0 ± 1.9[c]	1981 ± 1495[b]	1.2 ± 1.1[c]	1709 ± 601[b]	1.1 ± 0.38[c]	...	...
CV (%)	52.5	47.9	75.4	85.1	35.2	34.2	...	...
Period 4 (after SARS outbreak)								
Calendar day	31	31	31	31	31	31	...	...
Shipping day	30	30	22	22	26	26	...	...
S/C, in %[a]	96.8	96.8	71.0	71.0	83.9	83.9	...	...
Mean value ± SD	7779 ± 2879[b]	3.9 ± 1.4[c]	2079 ± 1634[b]	1.0 ± 0.80[c]	1721 ± 529[b]	0.85 ± 0.26[c]	...	...
CV (%)	37.0	36.6	78.6	78.7	30.7	30.2	...	...
P value[d]	<.001	.901	.830	.113	.597	<.001		

NOTE. SD = standard deviation; CV = coefficient of variation.

[a] The value for shipping day as a percentage of the value for calendar day.

[b] In kilograms per day.

[c] In kilograms per patient-day.

[d,b] Mean differences were determined by one-way analysis of variance (ANOVA) with statistical significance set at the level of $P = .05$. Two-sample means were compared using a Bonferroni test; with statistical significance set at $P = .05$, significant differences were found for comparisons between periods 1 and 2, periods 1 and 3, periods 2 and 4, and periods 3 and 4.

factor for regular infectious waste during the entire study period (30.2%-44.3%). A nonlinear curve-fitting method was used to analyze the relationship between the generation factor and the number of isolated SARS case patients *(n)* during SARS1 (Figure1). The relationship appeared to have a weak power function (<1) and to be inversely proportional to the number of isolated SARS case patients (generation factor = $22.825 \times n^{-0.8283}$). The generation factor increased from a norm of 0.85 kg per patient-day to an overall rate of 2.7 kg per patient-day during the peak days of the epidemic. However, the hospital was able to return the generation of infectious waste to its normal level within 10 days.

DISCUSSION

A study conducted at our hospital in 1993 found that the average daily generation factor for infectious waste was 0.43 kg per patient-day.[7] The results of the present study indicate that the generation factor at the hospital has nearly doubled during the past 10 years. It is unclear whether the 1993 study used shipping days or the calendar days in the calculation of the generation factor. If that study used calendar days, its generation factor would have been underestimated, in comparison with that of the present study, by 34% (240 days divided by 365 days = 0.66). A large regional hospital in Central Taiwan with 1,394 beds reported that its generation factor for infectious waste ranged from 1.04 to 1.42 kg per patient-day during 12 consecutive months in 2000.[8] Their hospital's intensive care unit initiated a waste segregation program that reduced the generation factor to 0.78 kg per patient-day (as calculated using shipping days) after 8 months. We conclude, on the basis of current practices in waste disposal, that regional hospitals in Taiwan generate infectious waste at a rate of 0.8 kg per patient-day, if shipping days are used for the calculation. A national survey of US hospitals in 1987 found that the median rate of infectious waste generation ranged from 0.68 to 1.24 kg per patient-day.[9] The

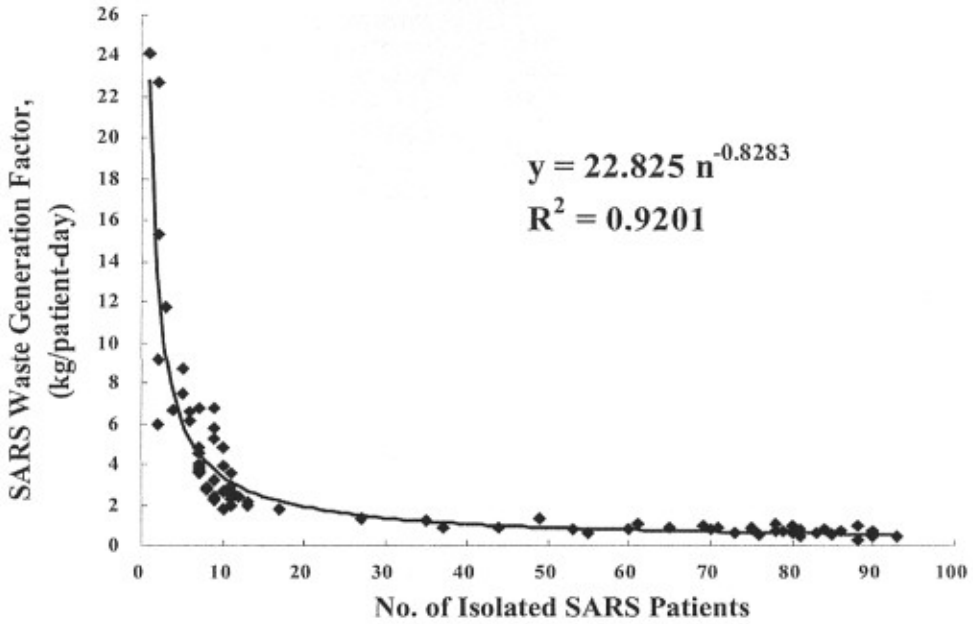

FIGURE. Generation factor as a function of the number of isolated patients with severe acute respiratory syndrome (SARS) during an outbreak at a hospital in Taiwan.

American Hospital Association has committed to reduce this rate by one-third by 2005 and by 50% by 2010.[10,11]

Our main goal was to assess the impact of the SARS outbreak on the production of infectious waste. The decrease in the number of regular inpatients during the most severe portion of the outbreak in May was assumed to be linear, with an estimated decrease of 2.3% per day ([2000 − 600 persons] / 2000 persons, divided by 30 days). This decrease suggests that, because of their fear of the SARS outbreak, potential patients might have avoided elective or even necessary medical care at the hospital. The corresponding increase in the generation factor of all infectious waste, including SARS waste, was estimated at 3.7% per day ([1.9 − 0.9 patient-days] / 0.9 patient-days, divided by 30 days). Given the 70% reduction in the number of inpatients and the 40%-70% reduction in the number of ambulatory patients at the study hospital, the amount of infectious waste generated by the care of SARS patients alone was enormous, particularly in May. The fact that the overall generation factor of infectious waste returned to normal levels within 10 days (Figure 1) indicates that the hospital was effective in managing SARS-associated waste after a short period of chaos.

We realize that the stress on the public's attitudes and the disruption in normal waste-treatment practices at the hospital were tremendous during the SARS outbreak. However, this analysis is not intended to suggest standard practices for hospitals in other nations, because the impact pattern at those facilities may be different. We predict that the impact of a future SARS outbreak at this hospital, should one occur, will be less severe, because we have learned the nature of the disease. We believe that hospital managers dealing with future similar waste-treatment events should not be frightened by emergencies such as this outbreak.

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