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ENVIRONMENTAL AND ENERGY MANAGEMENT

Insights of healthcare waste management practices in Vietnam

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Abstract

Nowadays, together with the economic development, public health activities have gained substantial attention with increasing number of hospitals during the past decades. A multi-method approach involving site visits, questionnaires, and interviews, in combination with secondary data revealed that the healthcare waste (HCW) generation, varied with different specialties (general or pediatric/obstetric hospitals) and different level of hospitals (central, provincial, district levels). The HCW generation from different kinds of surveyed hospitals varied from 0.8 to 1.0 kg/bed/day for domestic waste, 0.15 to 0.25 kg/bed/day for infectious and hazardous waste, and less than 0.1 kg/bed/day for recycled waste. Only 94.3% of central hospitals, 92% of provincial hospitals, and 82% of district hospitals complied with national regulation in hazardous medical waste treatment. For healthcare wastewater treatment, the actual operating rates were 91%, 73%, and 50% for central, provincial, and district hospitals, respectively. The cost for HCW management accounted for only 10–15% of the total budget allocated for the medical facilities. Most of the provincial hospitals spent about $0.2–$0.4/bed/year for HCW management. This is the root cause of ineffective HCW management.

Keywords Healthcare solid waste · Wastewater treatment · Waste management cost · Policy compliance

Introduction

In general, poor healthcare waste management (HCWM) could result in negative impacts to the environment and community health (Sharma and Gupta 2017; Romero and Carnero 2017; Mardani et al. 2019; Alam and Qiao 2019). The most commonly noted issues in HCWM are often unsafe disposal of wastes, occupational health, and unsafety for healthcare workers. Safe disposal of HCW involves key stages such as segregation, collection and storage, treatment, transport, safe disposal, waste mitigation, and recycling (WHO 2014). Despite its importance, the proper management and disposal of healthcare waste are significant challenges in many developing countries (Aung et al. 2019). A study in Nanjing, China, revealed that only 73% of the hospitals in the area conducted the segregation, 20% used unqualified staffs for collection, 93.3% had storage area, and 93.3% had conducted training (Yong et al. 2009). In Dhaka City, Bangladesh, untrained waste handlers, inadequate personal protection equipment (PPE), inadequate storage rooms, no segregation, lack of management and education, and uncontrolled dumping in many hospital were reported (Patwary et al. 2009). In addition, all surveyed hospitals in Amravati City, India, generated hazardous biomedical waste, but no hospital had treatment and disposal mechanism; leakage of waste during collection and transportation occurred in every medical facilities (Tippat and Pachkhade 2015). In Punjab, India, the situation was better with 85% of the public sector and 64% of private sector facilities among primary healthcare facilities had no credible biomedical waste management system in place (Devi et al. 2019). The challenge was the most prominent in developing countries due to the lack of resources to both physically managing the waste and developing a legal system to ensure everyone abides by the rules of its safe management (Wolff 2018).

Like other developing countries, healthcare waste (HCW) generation and control has been of the most concern in Vietnam. The amount of medical solid waste generated was 600 tons/day in 2015 and will be expected to increase to about 800 tons/day in 2020 (MONRE 2016). According to the latest regulation by the Ministry of Health in 2016, HCW is divided into three main categories including infectious ones (sharps,

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blood-containing waste, high risk of infection, surgery waste), hazardous ones (waste chemicals and pharmaceuticals, cytotoxic, mercury or heavy metal–containing broken devices, amalgam dental fillings), and regular waste (domestic waste and recycled one). The segregation of these medical wastes was complied with national regulations to some certain extent, but the storage and treatment remained substantial concerns. In addition, the inspection, monitoring, and supervision of these medical wastes have not been regularly and continuously implemented in many localities. Most of the studies on medical waste management in Vietnam only focused in such megacities as Hanoi City (Nguyen et al. 2014) or Ho Chi Minh City (Nguyen 2015; Nguyen 2018). While improper treatment of medical wastes with no official recycling activities was found an issue in Hanoi City (Nguyen et al. 2014), loose management and poor treatment technology (i.e., landfill and incineration) were a problem in Ho Chi Minh City. Nevertheless, there have not been any official studies on healthcare waste management in other cities and provinces in Vietnam. Likewise, healthcare wastewater collection and treatment, as well as the management cost, have not been investigated in detail.

Therefore, the objectives of this paper were to review and evaluate the insights of healthcare waste management for a wider scope, assess its constraints, and propose priorities in enhancing the HCWM situation. In particular, the financial issue would be discussed in detail as one of the highlights of this paper.

Materials and methods

Sources of data

The study employed data from "Northern East and Red River Delta Regions Health System Support Project" which covers central, provincial, and district hospitals from the Northern East and Red River Delta Regions of Vietnam. Seventy-two beneficial hospitals from 13 provinces plus 4 central hospitals in Hanoi City were surveyed on HCW management. In addition to the questionnaire surveys, supporting documents provided by all hospitals, periodical site investigation, and in-person interviews were conducted during project monitoring and evaluation. The structure of the questionnaire includes 04 main parts including (1) general information (i.e., name of hospital, bed capacity, bed occupancy rate, solid waste, and wastewater generation), (2) waste collection and treatment (i.e., solid waste classification, transportation and treatment, wastewater treatment), (3) environment safeguard compliance (periodical monitoring and reporting, valid permission check), and (4) cost for waste management.

In addition, secondary data from environmental reports of other healthcare projects (World Bank funded) were used such as "Central North Region Health Support Project" with 30 beneficial district hospitals in 6 provinces of Central North of Vietnam (Nguyen 2016) and "Hospital Waste Management Support Project–Final Report" with about 225 beneficial provincial and district hospitals nationwide (MOH 2019).

Brief information of surveyed sites

The subjects for surveying were provincial and district hospitals in 14 out of 63 cities/provinces nationwide and 4 central hospitals in Hanoi City (Table 1). At district level, all subjects were general hospitals. At central and provincial levels, some were general hospitals, and some were obstetric and/or pediatric hospitals. This study did not attempt to include private hospitals in the survey as the private sector accounts for only less than 5% of healthcare service in Vietnam.

The bed occupancy rates at most of the surveyed hospitals were over 100%. Specifically, the bed occupancy rates were 125%, 127%, and 147% for central, provincial, and district

Table 1 Site information

No.	Provinces	Total hospitals*	Total beds*	Bed occupancy rate (%)	Surveyed hospitals	Number of beds in surveyed hospitals	Service population* (Persons)	Income per cap* ($/person)
1	Hai Duong	20	3880	126	9	1550	1,800,000	1662
2	Hung Yen	17	2460	101	6	1450	1,097,000	1408
3	Thai Binh	20	4035	166	6	1760	1,786,000	1382
4	Ha Nam	11	1545	141	5	1030	785,057	1295
5	Nam Dinh	19	3645	137	6	1700	1,833,500	1334
6	Ninh Binh	13	2055	115	5	1300	907,800	1331
7	Tuyen Quang	14	1570	130	5	980	730,800	741
8	Yen Bai	15	2015	94	5	1010	790,000	790
9	Thai Nguyen	19	3145	180	7	2390	1300,000	1614
10	Lang Son	13	2065	113	5	1150	800,000	811
11	Bac Giang	16	4453	121	5	1530	1,574,300	1246
12	Phu Tho	16	3638	95	3	1550	1,329,300	1221
13	Hoa Binh	14	1910	90	5	1000	800,000	856
14	Hanoi	40	10,980	125	4	3660	2,350,000	3020

*Data of the whole province from General Statistic Office of Vietnam (GSO 2016)

hospitals, respectively. It is quite a common practice in Vietnam to occur the overloading at hospitals. It was reported officially in Vietnam Health Statistics Yearbook annually that the rates were 120–125% for central and provincial hospitals, respectively, in 2016. The high occupancy rate has put the government in the "hot pot" for the past 10 years. Millions of dollars of funds were used for upgrading and expansion (increase numbers of beds and human resources) of hospitals of different levels.

HCW generation and management

Waste generation was calculated based on the data provided from the survey questionnaires, and supporting documents from the hospitals. Comparison was made between the data from this study and those from other reference studies by Vietnam Ministry of Health (MOH) and World Health Organization (WHO). Basically, the bed capacity of the hospitals and the overall waste generation per year were considered to understand the magnitude of healthcare waste generated. The characteristics and composition of waste such as percentage contribution of general domestic wastes, recycled waste (i.e., plastics), infectious waste, and hazardous waste were also determined. The HCW management was reviewed in all aspects including HC *solid waste* collection and treatment, HC *wastewater* collection and treatment, policy compliance, training necessity, and budget for HCW management in general.

Data analysis

The statistical analysis was conducted to evaluate the impact of types of hospitals (general or specialty) and level of hospitals (central, provincial, and district) on HCW types. This step was performed using one-way analysis of variance (ANOVA) for each variable (type of hospitals or level of hospitals). The level of significance was $\alpha = 0.05$ in all cases. The software StatPlus:mac LE version 6.7.1 (AnalystSoft Inc., USA) was used for this statistical analysis.

The Spearman correlation coefficients were also calculated for all pairwise comparisons of HCW generation with service population, personal income, and number of beds in studied provinces. This was performed using XLSTAT (Addinsoft, USA).

Results and discussions

Healthcare solid waste generation and management

Healthcare waste generation is depicted in Fig. 1. The domestic waste accounts for 73–78% of total wastes, followed by infectious and hazardous wastes (15–20%). Recycled waste at provincial hospitals was the highest (11%) in this study. The finding was somewhat similar to data reported by the WHO (2018), in which about 85% the total waste generated by healthcare activities was general, non-hazardous waste.

Certainly, the amount of regular/general waste varied with countries, with different specialties and different level of hospitals (national, provincial, district, or commune). Among some Asian countries, the regular wastes accounted for 74%, 69%, 67%, and 12% for Vietnam, Thailand, Laos, and Mongolia, respectively, while the infectious wastes were 9.9%, 21%, 27%, and 38% with the same order (Ananth et al. 2010). A recent review by Ali et al. (2017) for 20 developing countries rendered that the average non-risk waste was from 60 to 70%, and the average risk waste was from 15 to 30%.

In this study, the HCW generation varied from 0.8 to 1.0 kg/bed/day for domestic waste, 0.15 to 0.25 kg/bed/day for infectious and hazardous wastes, and less than 0.1 kg/bed/day for recycled waste. Blenkharn (2015) revealed that in the

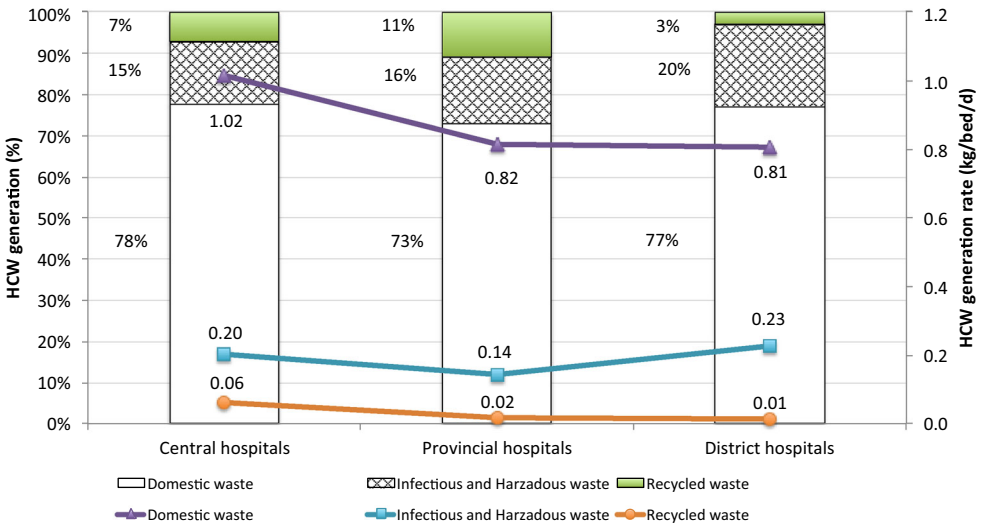

Fig. 1 Healthcare waste generation rate

UK, the healthcare waste output varies from < 0.1 to 5.9 kg/bed/day. On average, low-income countries generate about 0.2 kg/bed/day of HCW (WHO 2018) while it was ranging from 1.18 to 4.4 kg/bed/day for different European (high-income) countries (Minoglou et al. 2017). Hence, the HCW generation in Vietnam was higher than average number reported by the WHO, but lower than that of European countries.

In consideration of the correlation between the annual HCW generation and serviced population, it was found that there was a positive correlation (Spearman coefficient = 0.78, significant level = 5%). The positive relationship was also found between the annual HCW generation and personal income (Spearman coefficient = 0.49, significant level = 5%). It meant as the number of people using healthcare service increases, the waste generation would increase as well. Moreover, the personal income increases would lead to the increasing HC waste generation. It is apparent that when the income increases, people have more conditions to take care of their health; the demand for healthcare service would be higher, resulting in higher HCW generation. Ansari et al. (2019) also rendered the positive relationship of gross domestic product (GDP) per capita and HCW generation rate in many developing countries.

In addition, the waste generation and types varied depending on department type and clinical performance. For instance, waste generation from the pediatric and intensive care was 3.37 kg/bed/day, and from the anesthetics was 5.96 kg/bed/day (Vaccari et al. 2017). More specifically, the infectious waste generated from a group of orthopedic, gynecology, surgery, dermatology, and ophthalmology was 0.155 kg/day/bed, while it was 2.9 kg/bed/day from the radiology and pathology group (Dehghani et al. 2019). Results of one-way ANOVA (Table 2) confirmed at the same level of provincial hospital, there were only substantial differences on infectious and regular wastes from general to specialty hospitals ($p < 0.05$), but not hazardous waste. While all kinds of wastes changed significantly at different level of hospitals (central, provincial, and district hospitals) (Table 3). That makes sense as the scale of the hospitals (number of beds) differs considerably at different levels. The central hospitals often have more than 1000 beds, provincial hospitals have 500–1000 beds, and district ones have only less than 500 beds. This variation was confirmed in previous studies elsewhere (Korkut 2018).

In terms of solid waste treatment, currently, there are some major forms, including (1) hiring an outside unit/company with an authorized license; (2) handling at centralized SW treatment clusters; and (3) using on-site waste treatment systems located inside the medical facilities (Fig. 2). The most common method for handling infectious waste in provincial and district hospitals was on-site incineration, followed by landfilling. Review of HC solid waste treatment in developing countries showed several methods to be used including incineration, landfilling, microwave, steam sterilization, and chemical disinfection (Ansari et al. 2019). The use of incinerators has not been recommended to apply due to the dioxin, furan, and mercury emissions (Mbongwe et al. 2008; Yang et al. 2009). This inappropriate waste treatment has been still an issue of causing air pollution in many countries (Ananth et al. 2010; Windfeld and Brooks 2015). A study showed that only 75%, 66%, and 50% of HCW was treated properly in Bangladesh, Brazil, and Serbia, respectively (Caniato et al. 2015) while the rest still applied incineration and landfilling. Incinerations are not allowed to apply in some big cities of Vietnam due to the threat of air pollution to the surrounding environment; the hospitals were enforced by law to employ a more environment-friendly (non-burn) technology, for instance, the high-temperature steam-based autoclave integrated with waste cut-and-grind equipment. This alternative treatment method was in fact a process using dry heat or steam to raise the temperature of infectious waste to a level (between 121 and 163 °C) that was sufficient to kill microbial contamination (Windfeld and Brooks 2015). This approach was considered to emit fewer pollutants, and being cost-effective, compact, and reliable (Ananth et al. 2010). With regard to low-pollutant release, minimum land required, and environmental protection, Chen et al. (2013) recommended the application of microwave as the best available environmental techniques in China. This treatment technique however is still costly and only applies in central hospitals in the big cities in Vietnam, while at provincial and district hospitals, the incineration method still plays the key role. This leads to the

Table 2 Mean and standard deviation results of waste types depending of type of hospitals and results of one-way ANOVA statistic (*F*-ratio)

Parameters	Unit	General hospitals ($n = 7$)		Specialty hospitals ($n = 4$)		*F*-ratio	*p* value
		Mean	SD	Mean	SD		
Infectious waste	kg/day	82.5	33.0	28.5	26.1	7.76	*0.0212*
Hazardous waste	kg/day	0.6	0.7	0.8	0.9	0.27	0.6167
Regular waste	kg/day	776.6	258.2	193.6	157.4	16.42	*0.0029*

Specialty hospitals are obstetric and pediatric hospitals

$p < 0.05$: significant difference

Table 3 Mean and standard deviation results of waste types depending of level of hospitals and results of one-way ANOVA statistic (*F*-ratio)

Parameters	Unit	Central hospitals ($n = 3$)		Provincial hospitals ($n = 7$)		District hospitals ($n = 18$)		*F*-ratio	*p* value
		Mean	SD	Mean	SD	Mean	SD		
Infectious waste	kg/day	289.0	68.2	82.5	33.0	14.9	9.8	141.18	*0.0000*
Hazardous waste	kg/day	6.6	4.3	0.6	0.7	2.2	3.1	4.65	*0.0192*
Regular waste	kg/day	1456.7	585.1	276.6	158.2	101.6	89.7	60.78	*0.0000*

serious requirement of frequent system maintenance and monitoring of air quality to guarantee the lowest impact of emissions to the surrounding environment.

To reduce the cost of treatment, a regional treatment cluster has been introduced for HCW management in Vietnam. This is the new trend of HCW treatment recently (Caniato et al. 2015). Instead of employing on-site treatment at an individual hospital, the infectious and hazardous wastes were transported to a regional treatment cluster, where they were handled by incineration or autoclaves. The pilot of this treatment model was implemented in some provinces; however, risk issues occurred with transportation and overloading at the clusters. Eventually, it was appearing that the cost was not likely lower, but higher risk was ascertained. This resulted to the reconsideration of this model by the Ministry of Health. Direct investigation at sites showed that the regional treatment cluster was more appropriate for commune-level medical centers due to limited waste production and narrow budget. Most of the hospitals from district level and above chose on-site treatment as the most convenience and economic efficiency.

Healthcare wastewater generation and treatment

HC wastewater is generated from medical establishments, including medical examination and treatment establishments; preventive medicine facilities; and medical and pharmaceutical research, training institutions, and drug manufacturing facilities. In HC wastewater, besides the common pollution factors such as organic matter, animal fat, and vegetable oil, there are also minerals and specific organic matters, pathogenic bacteria, medicinal preparations, and reducing agents. In addition, chemical solvents, antibiotic residues, and radioisotopes are often used in the diagnosis and treatment of diseases. Typical pollution components in HC wastewater are shown in Table 4.

According to WHO estimation, the small- and medium-sized hospitals generate about 0.3–0.5 $m^3$of wastewater/cap/day and large-scale hospitals generate about 0.4–0.7 m^3/cap/day (WHO 2014). The data obtained from this study was slightly smaller in which the district hospitals (< 500-bed capacity) generated about 20–100 m^3 medical WW/day (or approximately 0.04–0.25 m3/cap/day), while they were from 100 to 600 m^3/day for provincial hospitals (from 500 to 1400 beds) or approximately 0.1–0.5 m^3/cap/day. It is worth noting that the actual wastewater collected depended very much on the quality of the collection system in the medical facilities. In consideration of correlation between number of beds and actual wastewater (WW) generation, the positive correlation was found for both district and provincial cases; however, it showed a strong relationship for provincial (medium to large sized) hospitals, but not really the case for district hospitals (small-sized ones) (Fig. 3). The higher Spearman coefficient (0.74) was corresponding with higher linear regression constant ($R^2 = 0.834$) for the provincial hospitals. And lower Spearman coefficient of 0.34 was found for the district hospitals, implying that the WW management at district level was not stable, and influenced by many unpredicted factors such as

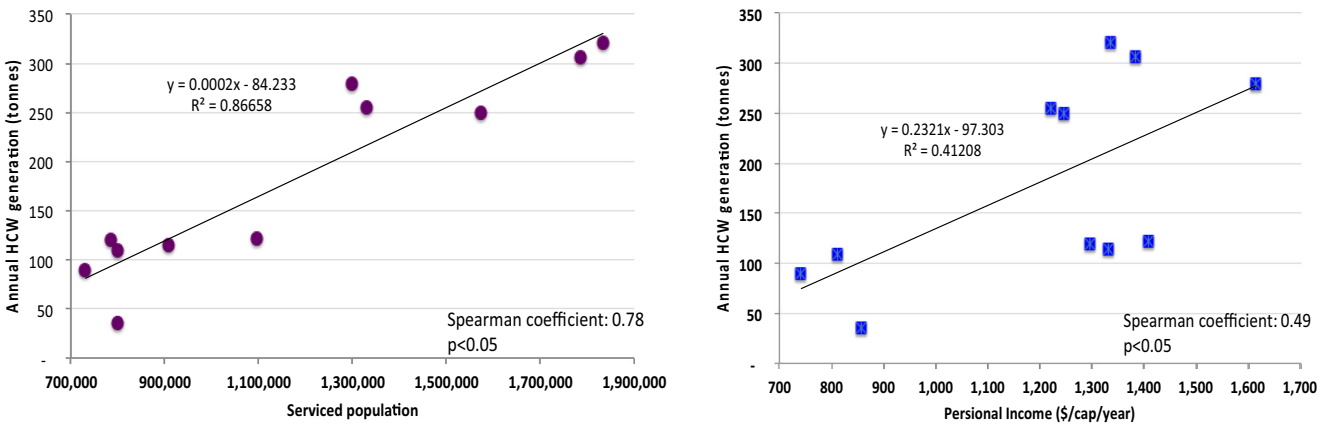

Fig. 2 Correlation of annual HCW generation and serviced population and personal income

Table 4 Characteristics of medical/healthcare wastewater

Number	Parameters	Unit	Values	QCVN 28:2010/BTNMT*	
				Column A	Column B
1	pH	–	6–8	6.5–8.5	6.5–8.5
2	BOD_5(20 °C)	mg/L	150–450	30	50
3	COD	mg/L	300–500	50	100
4	TSS	mg/L	100–300	50	100
5	H_2S	mg/L	N/A	1.0	4.0
6	NH_4–N	mg/L	15–30	5	10
7	NO_3^-N	mg/L	50–80	30	50
8	PO_4^{3-}P	mg/L	10–20	6	10
9	Oil and grease	mg/L	N/A	10	20
10	Total α radiation activity	Bp/L	N/A	0.1	0.1
11	Total β radiation activity	Bp/L	N/A	1.0	1.0
12	Total coliforms	MPN/100 mL	10^3–10^7	3000	5000

*National technical regulation on healthcare wastewater. Column A is for discharged water to supply water sources. Column B is for discharge to non-domestic water supply sources. N/A, not available. (Source: MONRE 2016)

collection system, operation, and maintenance cost and possibly patients' habit in the surveyed hospitals.

Currently, all central hospitals managed by the Ministry of Health (MOH) have on-site wastewater treatment systems thanks to the prioritized investment strategy of the government. At the local level, according to the data reported, only 81.4% of provincial hospitals and 71.7% of district hospitals had proper WW treatment systems according to the regulations. However, many of them have deteriorated due to the overload of hospital beds, lack of funds for maintenance, and upgrading, leading to poor effluent quality (MONRE 2016). A large number of hazardous substances in the WW could not be treated with conventional treatment technology (i.e., sedimentation, biological treatment with activated sludge, and disinfection). In this study in particular, the site investigation revealed a degradation of treatment facilities with time, as they were not maintained properly. Moreover, all wastewater treatment (WWT) systems at the surveyed hospitals operated under their capacity. The actual operating rates were 91%, 73%, and 50% for central, provincial, and district hospitals, respectively. The possible explanation for high percentage at central hospitals may lie in the fact that they complied more strictly with the Law of Environmental Protection and specifically Circular No. 58/2015/TTLT-BYT-BTNMT provided by Ministry of Health and Ministry of Natural Resources and Environment on HCW management in wastewater collection and treatment. They also had more funds for O&M (operation and maintenance) of these units.

The O&M of HC wastewater treatment units was mainly implemented by a part-time staff from the Office of Planning and Administration of the hospital. Ninety-seven percent of surveyed hospitals reported having no fund for hiring a professional staff in environment engineering to take care of the solid waste or wastewater treatment units.

A survey of HC wastewater quality by another project in 22 northern regional hospitals in 2014 revealed that although most of hospitals had their own HC wastewater collection and treatment systems, nevertheless, only 72.3% had a permit

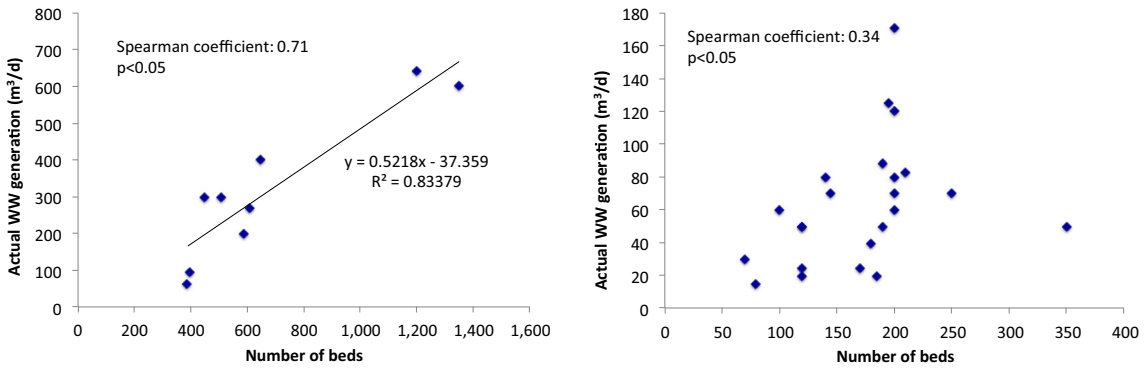

Fig. 3 Correlation of healthcare wastewater generation and number of beds for provincial hospitals (left) and district hospitals (right)

to discharge wastewater into the environment (MONRE 2016). To be granted the WW discharge permit, the hospital must prove its capacity of handling the WW to meet the national regulation, with the direct observation of the Department of Natural Resource and Environment. Again, this is not easy for healthcare facilities to maintain the effluent quality as the budget for O&M of the treatment system is limited. In addition, data from the survey in 2014 (MONRE 2016) revealed that 52.4% of hospitals did not meet the standard for ammonium, 9.5% exceeded the BOD_5 allowable value, 4.7% exceeded the standard value for sulfur, and 38.1% did not meet the requirement for coliform indicator. Overall, only 42.9% of hospitals had wastewater quality meeting the standards of the Ministry of Health (MONRE 2016). With the support of World Bank for another dedicated project in HCW management (called "Hospital Waste Management Support Project" from 2012 to 2019), 123 hospitals (including 20 central hospitals and 103 provincial/district hospitals) were funded to construct on-site wastewater treatment systems. This contributed to the raise of treated HC wastewater up to 35.3% of total WW generation (MOH 2019).

Cost of healthcare waste management

Figure 4 presents the average unit cost for HCWM per bed per year. Most of the provincial hospitals spent about $0.2–0.4/bed/year. The highest unit cost was for Yen Bai hospital and lowest was for Hoa Binh hospital. A site visit to Yen Bai provincial hospital confirmed the surveyed data in which it was truly clean and neat with the best waste management. Nevertheless, this unit cost of $0.2–0.4/bed/year was much lower than that of European countries of 1–3 USD/bed/day (WHO 1999). This occurred in many developing countries as HCWM was not considered to be a core business activity in hospitals (Ali et al. 2017). When looking at the correlation between number of beds and unit cost for HCWM ($/bed), the relationship was only found stronger for provincial hospitals (Spearman coefficient = 0.73), but quite weak for district hospitals (Spearman coefficient = 0.12). The positive Spearman coefficient would be expected that increasing number of beds would lead to higher HCWM cost. Additionally, the high correlation can explain in a way that the budget allocated for provincial hospitals quite depends on their sizes (number of beds). While for the district hospitals, the budget relied on many factors such as serviced population, topography, and personal income in those areas or the status of private-partnership involvement (Fig. 5).

Currently, the government has still subsidized healthcare service in Vietnam. The patients pay low fee for healthcare thanks to this subsidy. It was reported by World Bank that the gross domestic product (GDP) spent by Vietnamese people for healthcare in 2012 was only $116/year, which was 5–10 times lower than that in some Asian countries and 20–40 times lower than that in European nations (World Bank Group 2015). The hospitals run their service using state budget and other sources (i.e., HC service fees, private investment). The percentage of hospitals using state budget was from 20 to 80%, except for some hospitals, often located in poor and remote areas, using 100% state budget (Nguyen 2016). The economic conditions in the country play an important factor for budget allocation, especially regarding treatment and disposal of HCW (Caniato et al. 2015).

Normally, budget is needed for buying consumable items related to waste management including plastic bags, disposable sharps boxes or containers, labels, cleaning supplies and disinfectants, personnel protective equipment (PPE) (e.g., gloves and face masks), fuel cost for incinerators or paying treatment fee to authorized treatment agencies, utilities (electricity, water), and maintenance and repair. Additional cost was administration, training, etc. that relates to waste

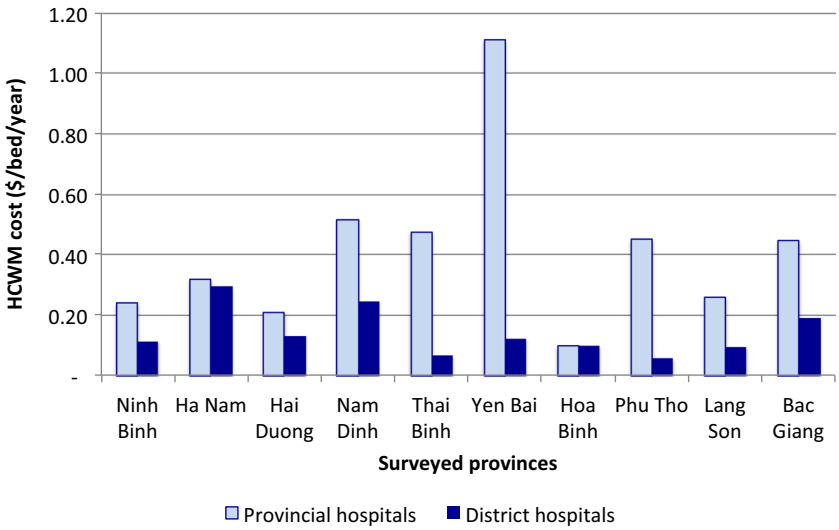

Fig. 4 Unit cost for healthcare waste management

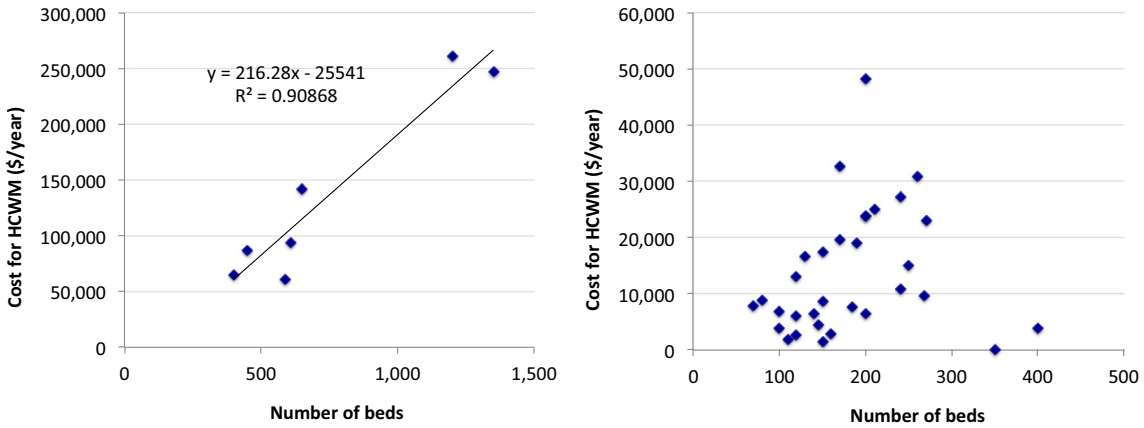

Fig. 5 Correlation of hospital budget and number of beds for provincial hospitals (left) and district hospitals (right)

management activity. Majority of surveyed hospitals, in particular district hospitals, found the budget was barely enough to cover the basic expense. The main reason obtained through in-depth interviews was that these health facilities had very limited funds from state budget. Insufficient cost for HC equipment maintenance was also found to be the main cause of ineffective HC management in Benin public health sector (Houngbo et al. 2017). In addition, they found that private hospitals in Benin were more available in financial capacity, logistics, and human resources; hence, their safety and environmental protection were in better care. This was similar to findings of Aung et al. (2019) in Myanmar's HCW management. Certainly, the HC fees at private medical facilities were significantly higher than in the public ones.

According to the survey in this study, the annual budget for HCWM of district hospitals was about $30,000–45,000/year, while this budget was from $60,000 to 260,000/year for provincial hospitals, accounting for about 10–15% of total provided budget. Certainly, there is no separate fund for water, sanitation, and hygiene (WASH) in healthcare facilities although WASH has been recognized as a prerequisite for quality care at the healthcare facilities (WHO-UNICEF 2019a). The insufficient budget has caused many difficulties in implementing hazardous waste management. This is the root cause of ineffective management of HCW. The question of how to raise the efficiency of HCW management in public medical facilities with limited fund still remains unanswered at present; consequently, serious actions should be implemented in particular when autonomy in hospital management (no subsidy from the Government) will become indispensable in the next 5–10 years.

Policy assessment

Policy and regulatory issues are often key weaknesses in the governance structures, particularly in low- and middle-income countries (Tudor 2012; Shannon and Woolridge 2011). One of the five key overarching global issues discovered by Caniato et al. (2015) was that the regulations, guidelines, and implementation plans were generally lacking or even absent in low- and middle-income countries. Despite poor enforcement, training programs were ineffective at both local and national levels. For the case of Vietnam, the policy on healthcare waste management (law, decrees,circulars) have been developed and taken into effect for several years, but the enforcement in policy compliance has been still at a modest level.

For the safe handling of HCW, the government has promulgated quite a few legal frameworks including law, policy, and standards to guide and support the management (Le 2016). In addition to those legal documents listed in Table 5, the Ministry of Natural Resources and Environment (MONRE) has also completed the draft of two national technical regulations/standards in which one for HC wastewater (revision) and one for HCW treatment using microwave. Besides, one technical guideline for removal of mercury from HCW has been under preparation. It is obvious that the government is fully aware and pays sufficient attention to HCWM, from the strategies stipulated in the Law of Environment Protection and related Decrees, to the detailed guidelines or standards. There are even national standards and technical guidelines to instruct on how to manage HC infectious, hazardous waste, and wastewater; prepare environmental documents; and construct a healthcare facility or healthcare waste management during operation. Only legal document regulates financial aspect of HCW management (i.e., cost norms for solid waste treatment, cost norms for wastewater treatment, or cost norms for unit HCW management) is missing. This situation is still better than the case of Myanmar where there is still no separate legislation or policy on healthcare waste management and no provision of national monitoring, record system, and funding for medical waste in the country, even though Myanmar's environmental conservation law and rules emphasize an urgent need for national and local waste management strategies (Aung et al. 2019). As a result, deficiencies were observed in waste collection,

Table 5 Summary of legal regulations

Type	Title	Issued date	Issue agency	Related content to HCWM
Law	Law of Environment Protection no 55/2014/QH13	2014	National Assembly	Guiding on environment protection activities, including HC waste management
Decree	Decree no. 18/2015/ND-CP	2015	Government	Regulating environmental protection planning, strategic environmental assessment, environmental impact assessment, and environmental protection plan, including healthcare project and HC waste management
Decree	Decree 38/2015/ND-CP	2015	Government	Guiding on solid waste management, including HC wastes
Circular	Circular 27/2015/ TT-BTNMT	2015	MONRE	Guiding the implementation of the Decree no. 18/2015/ND-CP on strategic environmental assessment, environmental impact assessment, and conservation plan environmental protection
Circular	Circular no. 58/2015/TTLT-BYT-BTNMT	2015	MONRE-MOF	Regulating collection, transport, storage, and treatment of medical waste management
Circular	Circular 36/2015/TT-BTNMT	2015	MONRE	Regulating hazardous waste collection and treatment
Decision	Decision no. 170/QD-TTg on	2019	Government	Approving the master plan on hazardous medical solid waste treatment system until 2025 nationwide
National Standard	QCVN 28:2010/BTNMT	2010	MONRE	Regulation on healthcare wastewater
National Standard	QCVN 02:2012/BTNMT	2012	MONRE	Regulation on solid HC waste incinerators
National Standard	QCVN 55:2013/BTNMT	2013	MONRE	Regulation on equipment to absorb infectious medical waste
Technical Guidance		2015	VIHEMA–MOH	Guiding on non-burn technologies for HC solid waste treatment
Technical Guidance		2015	VIHEMA–MOH	Guiding on HC wastewater treatment

MONRE, Ministry of Natural Resources and Environment; *MOH*, Ministry of Health; *VIHEMA*, Vietnam Health Environment Management Agency (under MOH)

storage, transportation, and treatment, particularly in public hospitals (Aung et al. 2019). At present, for each healthcare investment project, the capacity strengthening component (i.e., development of detailed action guidelines, new reporting mechanism, management structure revision or capacity building) is always required besides the technical enhancement.

Based on the legal framework, a summarized procedure related to environmental safety for handling HCW is present in Fig. 6, in which the medical facilities should follow before and after they start the healthcare service or HC-related projects. It can be seen that the control of HCW involves many authorities from the Department of Health, Department of Natural Resources and Environment, Department of Science and Technology, and Department of Water Resources Management. For all service hospitals, they need to report to related Ministries on a regular basis. The reporting procedure for HCW and HC wastewater was clear for all medical facilities in service and they have to comply on a regular routine and frequency.

It should be noted that the medical facilities need to apply for lots of permits before and during their operation, for instance, permits for radiation service, for wastewater discharge, and for use of underground water/surface water if any. These procedures are to guarantee proper operation and maintenance of equipment and to ensure the adequate working conditions, because all equipment, devices, and processing systems often degrade over time. In addition, the bi-annual or annual environmental monitoring reports are required by the DONRE or MONRE due to the high occupational risks from utilizing medical equipment and systems, including *air pollution* caused by radiation emissions from X-ray, computerized tomography (CT) scan, and toxic gas (dioxin, furans, and ashes) from incinerators; or *water pollution* by the improper HC wastewater treatment; or *soil contamination* due to inadequate hazardous and infectious solid waste landfilling, and maybe other *hazardous risks* in case of handling cytotoxic wastes. Not only the environment but also the HC staff, patients, and patients' families would benefit from the frequent inspection and reporting process, as the health risk exposure would be reduced to the minimum. One should be noted that besides the periodical reports to be submitted to authorized agencies, the HC staff needs to prepare *Annual HCW Management Plan* at the beginning of each year to estimate the waste loads (total HC solid waste and WW generation) per year, cost for

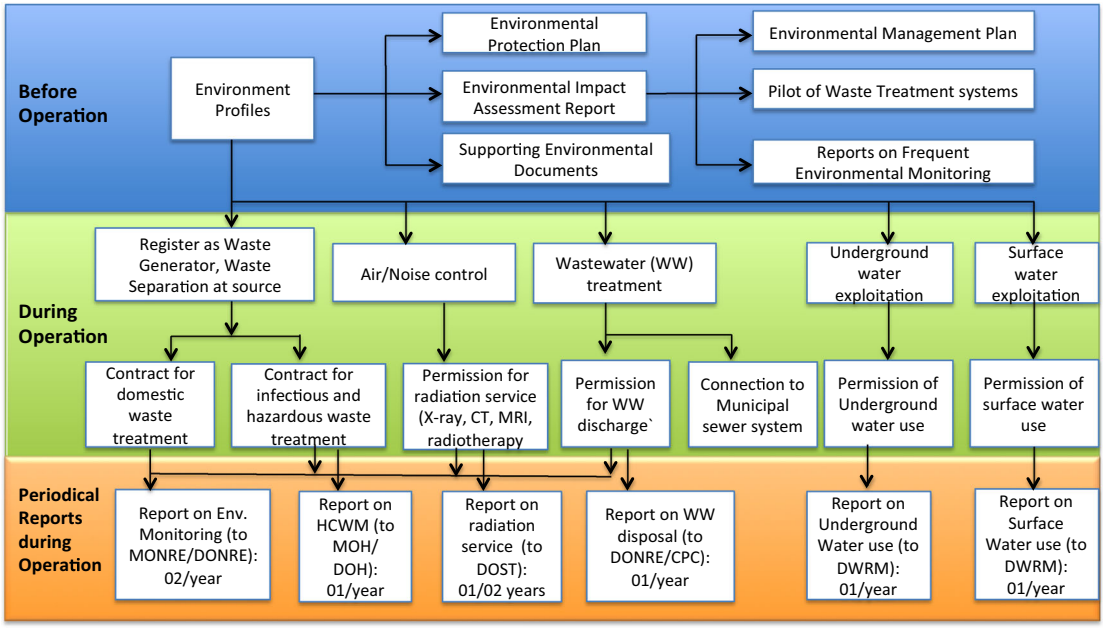

Fig. 6 HCW management diagram (DONRE, Department of Natural Resources and Environment; MONRE, Ministry of Natural Resources and Environment; DOH, Department of Health; MOH, Ministry of Health; PC, City or Provincial's People Committee; DOST, Department of Science and Technology; DWRM, Department of Water Resources Management)

treatment, number of required reports to authorized agencies, number of environmental monitoring (air, water, soil samples), and all kinds of cost (i.e., samples analysis, purchase of consumable items related to waste management). It was found from this survey that about 85% of the surveyed HC facilities prepared this plan and approved by the Director of the HC facility. The missing item in the HCW management plan is the financial resource allocation for the life cycle cost of the equipment. This cost was actually critical according to a recent review by Houngbo et al. (2017).

Even though the policy framework is ready, the enforcement was not so strict. Periodical monitoring of medical facilities in waste management from this study showed that many of them did not strictly comply with the regulations. The main cause was due to lack of funds for operation and maintenance (O&M). The inspection of local authorities in charge of healthcare and environment was not carried out regularly. The leaders of medical facilities as well as the owners of medical waste transport and treatment facilities did not strictly follow the Law on Environmental Protection. Meanwhile, not many healthcare workers, patients, and their families have yet been raised awareness of medical waste risks (MONRE 2016). A recent report on healthcare found that 42.9% of hospitals having wastewater quality that met the standards and 94.3% of central hospitals, 92% of provincial hospitals, and 82% of district hospitals complied with national regulation in hazardous medical waste treatment, as mentioned above (MONRE 2016). Poor implementation and monitoring of the rules was mentioned one of deficiencies, especially in small hospitals (Manga et al. 2011; Zhang et al. 2013).

According to Amended National Strategy on Solid Waste Management towards 2025, vision to 2050, in 2018, 100% of the total amount of hazardous solid waste generated from production, business, service activities, and healthcare must be collected, transported, and treated to meet environmental protection requirements of Vietnam. This would require the effort of all stakeholders. Not only internal stakeholders such as all levels of staff, patients, and families but also external stakeholders such as the policymakers, law enforcement authorities, waste management service providers, and researchers need to commit their responsibility for safe HCW handling for the best community health protection.

Importance of frequent trainings on HCWM

One of the findings from this study was the need of proper training on HCWM. It was rendered via direct interview of staff at the surveyed hospitals. Previous study revealed that several critical measures should be taken at the hospitals including life skill education and occupational training, good personal hygiene habits, use of safe equipment during work, and improvement of the occupational safety conditions (Ansari et al. 2019). Thus, the frequent training is quite critical to HC staff.

In order to well implement HCW management at any health facilities, it is necessary to (1) convey regular trainings to HC staff regarding making waste management plan and efficient management; (2) assign duties and responsibility to particular staff; (3) implement frequent monitoring,

inspection, and reporting; (4) organize vaccination programs where necessary; and (5) allocate financial expenditures for this activity. The training is the first and priority step. Waste minimization and avoidance should be translated as resulting in a decreased work burden on the staff. The staff should be made to realize that they are the primary stakeholders in the creation of a clean and hygienic work environment (Ali et al. 2017). Currently, managerial training only met 33%, 50%, 70%, and 33% of HCWM needs in Nigeria, Serbia, Iran, and Brazil, respectively (Caniato et al. 2015). Also in Portugal, the compliance with the law was far from ideal, and that education and training programs were seldom provided to healthcare workers in medical facilities (Botelho 2012). HCWM in Nigeria also requires urgent improvement with crucial issues being limited training and governance (Bassey et al. 2006).

The training on physical handling such as waste segregation, transportation, storage and treatment, and planning of waste management should be conducted at a regular basis. However, since HCWM was not considered a core business activity in hospitals, such provisions were limited (Zhang et al. 2013). The trainings are often offered if the medical facilities are beneficiaries of a health-supporting project. It was found from this study that without training, the health staff finds confusing in preparation of HC Waste Management Plan (HCWMP). Owing to the support of several health-supporting projects such as Hospital Waste Management Support Project, Central North Region Health Support Project, and Northern East and Red River Delta Regions Health System Support Project (NORRED), the format of HCWMP was formed and circulated to hundreds of beneficial hospitals nationwide. For instance, it was found from our study of a 5-year NORRED project that the percentage of hospital-prepared annual HCWMP increased from 55 to 85% upon having HCWM training. Many research concluded that one important way to improve the compliance of healthcare providers with current waste management regulations was to increase staff training and awareness on medical waste issues (Botelho 2012; Woolridge and Hoboy 2019).

Frequent training on health risks during infectious and hazardous waste handling should be conducted at least once per year. It was reported by the WHO (2018) that lack of awareness about the health hazards, inadequate training in proper waste management, absence of waste management and disposal systems, insufficient financial and human resources, and the low priority given to waste management are the most common problems connected with healthcare waste. Many countries either do not have appropriate regulations or do not enforce them. In Vietnam, the problems were not only due to inappropriate regulations but also regulation enforcement, and certainly plus all the root causes listed above.

Prioritized action plan

Review from surveyed HC facilities and other reports revealed the fact that to obtain the most effective HCWM is not an easy step and needs to implement step-by-step, since it involves numerous activities. The WHO and UNICEF have recommended eight (08) practical steps to improve healthcare quality including (i) assessment and establishment of the WASH program, (ii) setting of targets and defining roadmaps, (iii) establishment of national standards and accountability mechanisms, (iv) improvement and maintenance of infrastructure, (v) monitoring and reviewing of data incorporating user and community feedbacks, (vi) development of health workforce, (vii) engagement of the communities for WASH, and (viii) conduction of operational research and share learnings (WHO-UNICEF 2019b). For the case of Vietnam, besides the implementation of the WASH program in HCFs following the 8 steps, some key areas should be paid attention including:

(1) Deploying public-private partnerships in health waste management and treatment to mobilize the participation of social resources, to increase specialization in medical waste treatment, and to reduce the burden of state budget.

The multiple financial resources shall be mobilized to invest in building a HCW (solid and liquid) treatment system. These resources could be targeted aids for localities from state budget, local budgets, and funding from official development assistance (ODA) projects. Attracting international support to increase the financial resource was one of the best practices drawn by Caniato et al. (2015) upon their systematic review of scientific literature on HCWM. The privatization of waste management operations has been increasingly adopted in a number of countries as an alternative method of financing various types of public works, including health (WHO 2014). They involve in designs; build, own, and operate treatment facilities; and provide collection and disposal services to healthcare facilities through negotiated long-term contracts. Nevertheless, should the private sector manage waste treatment, it is better to avoid monopolies by having more than one company involved (Caniato et al. 2015).

(2) Notably, the health sector also needs to frequently promote propagation and dissemination of environmental protection laws and regulations to all staff, patients, and family members to improve awareness and practice on hospital environmental sanitation via regular education and training programs.

Low awareness of environmental protection has been declared one of the key reasons leading to ineffective HCW management in hundreds of reports and research (Ali et al. 2017). It was the limited fund for training and overloading work with patients that sometimes pulled away the HC staff's responsibility. Thus, a complete commitment from all HC staff from doctors and nurses, cleaners and waste collectors, and especially the HC facilities' leaders should be made. All make sure that

HCWM is a central topic for the medical facilities, the second top priority that follows only after patients' cure and care.

(3) Building a model of medical waste treatment in the selection of appropriate and environmentally friendly technologies is very critical. In particular, proposal of a proper system for complete material recycling and treatment facility, exclusively for infectious wastes, is also necessary. Life cycle tools can be used to design reusable custom packs instead of the disposable ones (Voudrias 2018). This action follows quite well step 4 recommended by the WHO and UNICEF, relating to infrastructure improvement.

Conclusions

Using a multi-method approach involving site visits, questionnaires, and interviews, in combination with secondary data, this research has evaluated the overall scene of healthcare waste management practices in Vietnam.

Firstly, the HCW generation from different kinds of surveyed hospitals varied from 0.8 to 1.0 kg/bed/day for domestic waste, 0.15 to 0.25 kg/bed/day for infectious and hazardous waste, and less than 0.1 kg/bed/day for recycled waste. Only 94.3% of central hospitals, 92% of provincial hospitals, and 82% of district hospitals complied with national regulation in hazardous medical waste treatment. For healthcare wastewater treatment, the actual operating rates were 91%, 73%, and 50% for central, provincial, and district hospitals, respectively. There was a clear positive correlation between medical waste generation and income. The positive relation between number of beds and medical waste generation, and number of beds and cost of waste management were recognized at provincial hospitals, not at district hospitals.

Secondly, the policy was established; the legal framework was ready but the enforcement and monitoring and inspection by the government was limited. Also, there was the need for frequent training of staff on healthcare waste management to improve the collection and treatment capacity of the existing waste management system.

Finally, the cost for HCW management accounted for only 10–15% of the total budget allocated for the medical facilities. Most of the provincial hospitals spent about $0.2–$0.4/bed/year for HCW management. It was strongly believed that the insufficient budget for HCWM was the main root cause of the improper HCWM. Sufficient budget would not only cover HC equipment and infrastructure but also provide expenses for operation and maintenance, periodical staff training, informative and policy dissemination, establishment of internal regulation and accountability mechanisms, performance appraisal, and research implementation, etc. Different financial sources should be mobilized in the situation of low subsidy from the government at present to meet the increasing demand in waste management.

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Abbreviations ANOVA, analysis of variance; BOD, biological oxygen demand; COD, chemical oxygen demand; DONRE, Department of Natural Resources and Environment; DOH, Department of Health; DOST, Department of Science and Technology; H_2S, hydrogen sulfur; HCWM, healthcare waste management; HW, hazardous waste; MOF, Ministry of Finance; MOH, Ministry of Health; MONRE, Ministry of Natural Resources and Environment; NH_4, ammonium; NO_3, nitrate; PC, People's Committee; PO_4^{3-}, phosphate; SWM, solid waste management; TSS, total suspended solids; VIHEMA, Vietnam Health Environment Management Agency; WB, World Bank; WHO, World Health Organization; WW, wastewater; WWT, wastewater treatment

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