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Solid waste management associated with the development of 3R initiatives: case study in major urban areas of Vietnam

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Abstract The purpose of this article is to describe the application and progress of the Reduce–Reuse–Recycle (3R) initiative and its gradual implementation and development in solid waste management in Vietnam through the study of the municipal solid waste management (MSWM) systems of eight major urban cities and provinces. The resulting survey and studies showed that there are big challenges for MSWM in the study areas due to the absence of an appropriate master plan for MSWM; there is a clear need to set up indicators for waste reduction and greenhouse gas emission reduction from waste generators and enterprises involved in MSWM, especially in terms of using 3R activities in the management of industrial waste. The strength and organic combination of institutional frameworks, support measures, and technologies for 3R promotion need to be applied as soon as possible in order to implement MSWM practices using more effective measures; in particular, a reduction in the amount of hazardous substances discarded and improvements in the handling of hazardous waste are required.

Key words 3R initiative in Vietnam · Municipal solid waste (MSW) management · Hazardous waste · Recycling

Introduction

According to the results of the population census of April 1, 2009, the population of Vietnam was 85,789,573 persons, distributed throughout six socioeconomic regions covering the whole country. The rural population growth rate was only 0.4% per year, but the urban population growth rate was 3.4% per year.[1] In 1999, only 23.5% of the population lived in urban areas, but in 2009 this figure had risen to 29.6%. In October 2009, there were 223 industrial parks (IPs) in the country. IPs play a very important role in the formation of a strong industrial force for economic development in the country. In 2008, total industrial output from industrial zones reached US$33.2 billion (accounting for 38% of GDP), of which $16.2 billion was the value of exports, accounting for 25.8% of the country's exports. In addition, the IPs paid about $2.6 billion to the state budget, creating about 1.2 million jobs.[2] Each hectare of land used by IPs generates $1.68 million per year.[2]

The purpose of this article was to introduce the progress made in applying Reduce–Reuse–Recycle (3R) initiatives and the gradual implementation and development of the 3R initiative in municipal solid waste management (MSWM) in Vietnam and to analyze the performance of MSWM and the challenges of 3R. The implementation and development of the 3R initiative will be based on the existing survey results on MSWM in Hanoi and other major urban areas in Vietnam.

Methods

Eight major urban cities and provinces (Hanoi, Haiphong, Hue, Da Nang, and Ho Chi Minh cities and Dong Nai, Binh Duong, Ba Ria–Vung Tau, Fig. 1) were selected as study areas. Existing data were collected from the Statistics Yearbook of Vietnam, Healthcare Statistics Yearbook 2008, National/Provincial Report on the Environment, and the solid waste management (SWM) survey in Hanoi for 2008 and 2009. Surveys at landfill sites, interviews with city/provincial Departments of Natural Resources and Environment (DONREs), Urban Environmental Companies (Urenco), and other related studies have been referenced.

The collective population of the target areas was 22 344 811 (April 1, 2009), accounting for 26.05% of the total population of Vietnam. These areas included 99/223 established Industrial Parks (IPs)[2] covering 9137 ha and accounting for 57%–59% of total land for IPs in the nation; the industrial output value of the 99 IPs accounted for 63.1%

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Fig. 1. The study areas were located in eight major urban cities and provinces (Hanoi, Haiphong, Hue, Da Nang, Ho Chi Minh, Ba Ria–Vung Tau, Dong Nai, and Binh Duong)

of the total national industrial output (General Statistics Office – GSO, Vietnam). The healthcare services lead nationally, with 61 081 public beds in total, accounting for 42.76% of the total public beds throughout the central, provincial, and district levels.[3]

Results and discussion

Legal framework on solid waste management and the 3R initiative

Vietnam is now facing a worsening SWM problem, resulting in shortages of resources and energy. These facts emphasize the need to instigate the 3R initiative based on the 3R model from Japan with focus on promoting 3R activities. Such activities include cooperation and implementation involving stakeholders, revision of the policies and regulations on SWM and waste separation at source (WSS) in order to reduce the volume of waste going to landfill (LF) sites, saving and utilizing natural resources, and solving the problem of environmental and sanitation issues related to waste to promote public health. The Government of Vietnam has recognized the role of the 3R initiative and considers

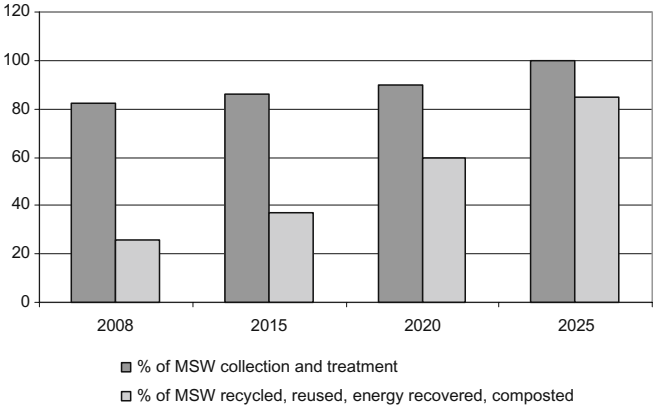

Fig. 2. Target municipal solid waste (*MSW*) collection rates and percentage of MSW recycled to the year 2025

the 3R plan as a key factor in a successful SWM policy. The Government confirmed and expressed its determination to improve SWM through properly implementing WSS, reducing the amount of waste landfilled, and recovering valuable materials from waste. These were all introduced in the Law of Environmental Protection (LoE), which was amended in 2005 with 14 provisions added in order to promote 3R activities.[4] In addition, in Governmental Decree 59/2007/ND-CP, dated April 9, 2007, the Prime Minister issued detailed regulations and instructions on implementing SWM as regulated in the LoE. WSS was referred to in Article 19 and Article 21, and these guide the recovery and reuse of the most useful materials in waste. The roles and obligations of partners and stakeholders in SWM include responsibility for hazardous solid waste (HzSW) management, disposal, and treatment by arrangement of color-coded waste collection bins according to the nature of the waste, and were specified in Article 67, LoE 2005, and in Article 26 and Article 27 of Governmental Decree 59/2007/ND-CP on SWM.

Decision 1440/2008/QD-CP of the Overall Master Plan of SWM for three key economic regions in Vietnam proposes a main policy of 3R solutions to reduce waste throughout the WSS system. The National Strategy on Integrated Solid Waste Management until 2025, with a vision up to the year 2050, was approved by the Prime Minister on December 17, 2009.[6,7] The Prime Minister expressed the Government's determination to overcome the current problems in SWM and to implement WSS. The basic principle for the application of 3R in SWM was expressed as "Polluter pays." The strategy involves the simultaneous implementation of integrated measures to prevent and reduce waste and to increase waste recycling and reuse, thereby decreasing the waste dumped in landfills. The target is to increase MSW collection and treatment as well as to increase the percentage of MSW being recycled (Fig. 2). MSW collection and treatment is targeted for 2015 as 80% of the total MSW generated with 35% of MSW being recycled, reused, composted, or having energy recovered. In 2020, these figures increase to 90% of the total MSW generated with more than 60% of MSW being recycled, reused, composted, or

having energy recovered, and then, in 2025, reaching the collection and treatment of 100% of MSW generated, with more than 85% being recycled, reused, composted, or having energy recovered.

Decision No. 47/2007/QD-BYT on the regulation of Health Care Waste Management (HCWM) has been revised based on the conception of 3R implementation. With the new regulation on HCWM, the categories of each type of waste have been clearly identified; the multi-solution and technical option on Health Care Solid Waste (HCSW) treatment have been introduced for use toward environmentally friendly treatment of HCSW. Disinfection with autoclaves, microwaves, and wet stream, and safe treatment and disposal in sanitary pits or safe recycling of waste have been introduced. Subsequently, the amount of general healthcare waste has been gradually reduced. Throughout 2010, it has been predicted that there will be only 25 000 tons/year of hazardous HCSW generated nationwide from the total planned number of public beds of 166 362.[3]

The technical standards and requirements on solid waste disposal technology have been detailed. Vietnam has issued landfill technical standard TCVN 6696-2000 and TCXDVN 261: 2001 on domestic landfill waste design and requirements. TCVN 6706: 2000 and TCXDVN 320: 2004 cover the technical standards and requirements of hazardous waste landfill design. Circular No. 174 on fees and sanctions of SWM violations has been delivered. Technical regulation QCVN 02: 2008 covers emission outlet gas from medical solid waste incinerators, QCVN 07: 2009 establishes technical regulations for hazardous waste thresholds, and QCVN 25: 2009 details technical standard requirements and characteristics of leachate from MSW landfills.

The Law and Governmental Decree No. 59/ND-CP defined the differences between domestic waste (MSW, i.e., garbage generated as a consequence of household activities) and industrial waste (IW) generated from industrial production activities and craft villages, while holding the municipal authorities responsible for the disposal of domestic waste and the waste generators responsible for the disposal of industrial waste.

With respect to the disposal of HzSW, Vietnam has Decision No. 23/2006 of the Ministry of Natural Resources and Environment (MONRE), giving a list of hazardous wastes, and Circular No. 12/2006/TT-B-TNMT dated December 26, 2006, giving guidelines on the conditions and procedures for application preparation, registration, and license granting to practice and issuing the code for hazardous waste management. However, Vietnam does not have particularly strict standards imposed on the final disposal of sludge and slag containing mercury, cadmium, and other harmful substances; the country should apply the experiences and regulations of developed countries in this area.

Guidelines for resource productivity and indicators for waste reduction from households and business entities with 3R practices have not yet been established. Targets should be set for waste reduction in short-, medium- and long-term plans and experience of advanced technologies from other countries should be acquired. Relevant technologies in the field should be introduced so that Vietnam can reduce the amount of waste going to landfills and move toward a material-recycling society.

Actual MSWM in major urban areas in Vietnam

Vietnam has established a target to increase the recycling of MSW; however, challenges may arise in the coming years, just as they have during past years. The amounts of waste generated were 1.3, 12.8, 16.0, and 22.5 million tons/year, respectively, for the years 2002, 2003, 2004, 2005 (SoE, 2002-2005). This waste generation continued to increase, with over 28 million tons generated in 2008.[4] The rate of MSW collection in the nation increased from 70% in 2000 to 80% in 2008. The levels of valuable and recyclable materials in waste that are recovered and reused have reached 20%–25%. The forecast total solid waste generated in 2015 will be approximately 43.6 million tons, in 2020 approximately 67.6 million tons, and in 2025 approximately 91 million tons.[4,5] The population and economic growth rate, urbanization, and increases in living standards and the waste collection rate play importance roles in the rapid increase of waste generation in Vietnam, especially in the big cities.

MSW generation rate

According to the survey on SWM in Hanoi in 2008, the average rate of domestic waste generated was 545–572 g/person/day[8,9] at six sites in Hanoi during summer (the rainy season). Another study was done in the winter of 2009 (the dry season) and this gave a result of 462 g/person/day.[1] The per capita domestic waste generated in the city was higher than the household waste generation rate and depends very much on the urbanization and the level of the urban population. Urban municipal solid waste volume analysis of Hanoi and Ho Chi Minh cities revealed a generation rate of 0.98–1.0 kg/person/day[2] for the urban area and an average of 0.73–0.85 kg/person/day for whole cities during the years 2008–2009.[3] Table 1 and Fig. 4 present MSW generation in Hanoi and Ho Chi Minh cities from 2003 to 2009. Data from other study areas showed that waste generation rates were about 0.65 kg/person/day in Danang,[4] Hai Phong, and Binh

[1] Report of NIES, June 3, 2010, on MSWM toward 3R activities, Hanoi
[2] Report of SWM in Hanoi 2008. Hanoi city: 4 inner core districts, 1,135,500 inhabitants, waste collection rate 100% by four Hanoi Urenco enterprises (XN1, XN2, XN3, XN4); total amount was 1,117 tons/day
[3] Ho Chi Minh DONRE, Hanoi Urenco data based on actual waste amount at weight bridges 2002–2009
[4] 08 (eight) URENCOs's report. 2008: Danang city, 818,300 inhabitants; the waste collection rate was over 96%, total amount 1,941,800tons/year; Dong Nai province: 2,290,200 inhabitants, collection rate 71%-75%, amount 1,254 tons/day; Hue city: 334,900 people, collection rate 90%, 180–200 tons/day; Baria-Vung Tau: 961,200 inhabitants; waste collection rate 75%; 700 tons/day; Haiphong: 1,845,900 inhabitants, collection rate 85%, amount of 1,020 tons/day; Binh Duong: 1,072,000 inhabitants, waste collection rate 70%, amount of 700 tons/day; Ho Chi Minh city: 6,611,600 inhabitants, waste collection 95%; 5,527 tons/day; Hanoi: population 3,445,000 inhabitants December 31, 2007, waste collection rate 95%, amount of 2,511 tons/day (Source: URENCOs; GSO, Vietnam)

Table 1. Waste generation in Ho Chi Minh and Hanoi during 2002–2009

Year	Ho Chi Minh					Hanoi				
	Population	Urban population	MSW (tons/day)	Growth in MSW (%)	Per capita MSW (kg/pers/day)	Population	Urban population	MSW (tons/day)	Growth in MSW (%)	Per capita MSW (kg/pers/day)
2003	5554.8	4860.4	4556	5.68	0.82	3007	1834.3	1900	5.26	0.63
2004	5730.8	4886.8	4833	5.73	0.84	3082.9	1999.7	1979	3.99	0.64
2005	5911.6	5035.3	4781	–1.09	0.81	3149.8	2056.8	2100	5.76	0.67
2006	6107.8	5194.1	5173	7.58	0.85	3236.4	2111.1	2200	4.55	0.68
2007	6342.5	5397.7	5393	4.08	0.85	3288.2	2145.5	2347	6.26	0.71
2008	6611.6	5634.6	5527	2.43	0.84	3445	2570.9	2511	6.53	0.73
2009	6891.9	5882.5	5854.1	5.58	0.85	3565.6[a]	2660.9[a]	2673	6.06	0.75

Source: Ho Chi Minh, DONRE; Hanoi Urenco actual waste amounts at weigh bridges 2002–2009
[a]Waste amount for the population of old Hanoi area, 2009

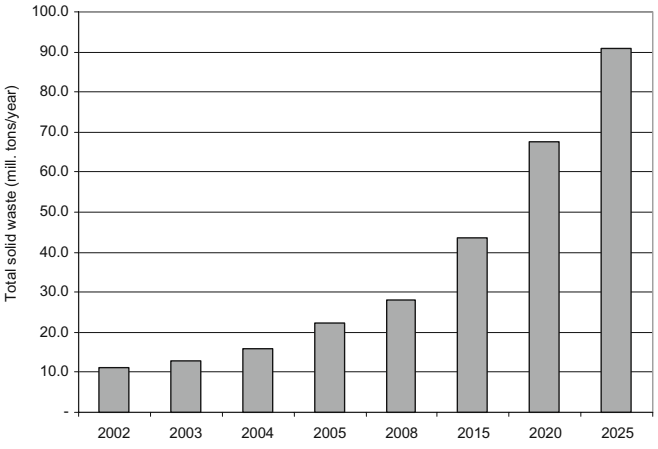

Fig. 3. Outline of solid waste trends and projections in Vietnam

Duong; 0.68 kg/per/day in Ba Ria–Vung Tau; 0.73 kg/person/day in Dong Nai; and 0.6 kg/per/day in Hue city.

Not only domestic waste has been disposed of in landfill sites for nonhazardous waste, industrial nonhazardous and hazardous waste has also been disposed of in such landfill sites due to a lack of proper control at the source and throughout the waste pathway, including transportation and treatment.

Industrial waste

IW recently accounted for 5%–32.3% of municipal waste in the study areas, of which the proportion of HzSW averaged 16.9% and varied depending on the city and IP.[2]

Hazardous waste

In 2002, the target areas generated 132809 tons of HzSW (160000 tons nationwide, compared to 73275 tons in 1999, SOE 2002–2004). This number has been increasing rapidly as a result of the high growth rate of the industrial sector. An official hazardous waste inventory is still lacking. The national planning of IP development has set the target of increasing the land for IPs to 65000–70000 ha in 2015 with the land for hiring reaching up to 60%;[2] this growth will be associated with an increase of hazardous industrial waste generation in the coming years.

Based on information on the generation rate of HzSW from some existing IPs (0.025–0.155 tons/ha/day), the hazardous industrial waste generated from IPs was approximately 0.5 million tons/year in 2000 and is predicted to become more than 1 million tons/year in 2015, of which 57% will be from IPs in the study areas; this fact requires special attention to seek urgent and suitable solutions, including enhancement of 3R activities with respect to SWM in the IPs and enterprises (see Fig. 5).

The inventory of hazardous chemical products was estimated at 37000 tons/year in 2004.[11] The amount of polychlorinated biphenyls (PCBs) alone, which has been around since the Vietnam war and has not yet been treated appropriately, made up about 19000 tons,[12,13,15] and 5.3 tons is still in use in existing electric transformers scattered across the country. In addition, 0.7 tons of PCBs still exists in insulation solvents. The production carried out in over 1200 handicraft villages in the study areas, featuring dyeing, recycling, metal production, and plating production, generate about 0.8–1 tons of hazardous waste per day.[12] Notably, waste treatment and recycling facilities for plastic and electronic wastes have grown massively in recent years. These facilities usually invested in simple equipment and use waste incinerators for waste reduction; these were put into operation without any control over exposure to toxic substances, causing serious environmental pollution.[10,12,15]

SWM in study areas

Hanoi. The amount of MSW generated is estimated at about 4200–5000 tons/day. Of this, 60% is domestic waste, 20%–25% is construction waste, 10% is industrial hazardous waste, and 5% is septic tank sludge. Five sanitary solid waste landfills are in operation, which include, Nam Son LF (3500 tons/day), Kieu Ky, Xuan Son LF (100 tons/day), Cau Dien, and Son Tay composting plant (50–140 tons/day). All these landfill sites will become full in 2011. Many illegal dumping sites have been established in the communities because of the long wait for the SWM Master Plan. There were 327 sites registered as hazardous waste generators generating a

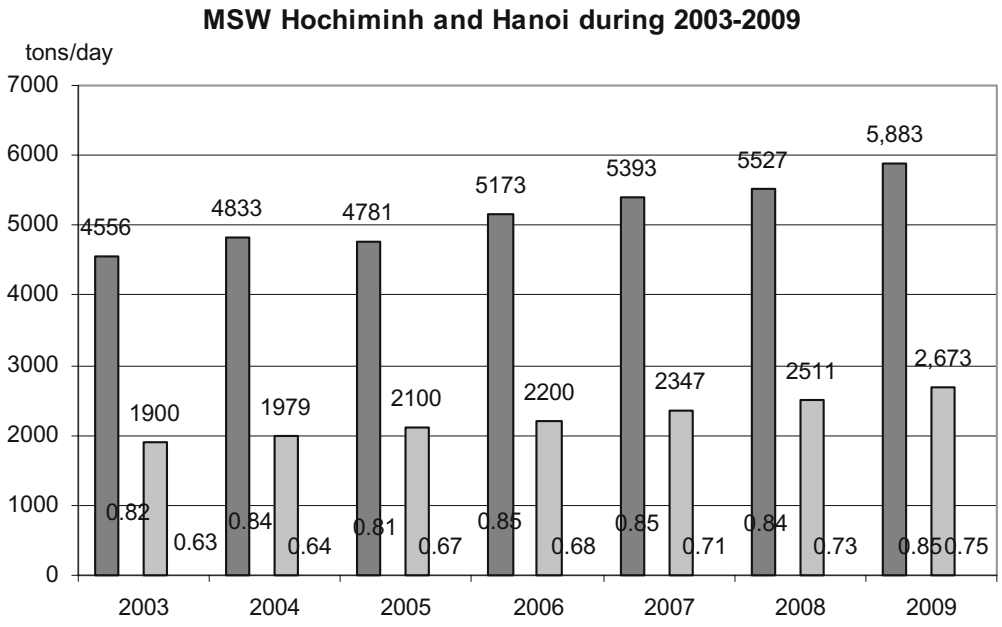

Fig. 4. MSW in Ho Chi Minh (*dark bars*) and Hanoi city (*light bars*) 2003–2009.[4] The *numbers less than 1.0* represent per capita waste generation in kilograms per day

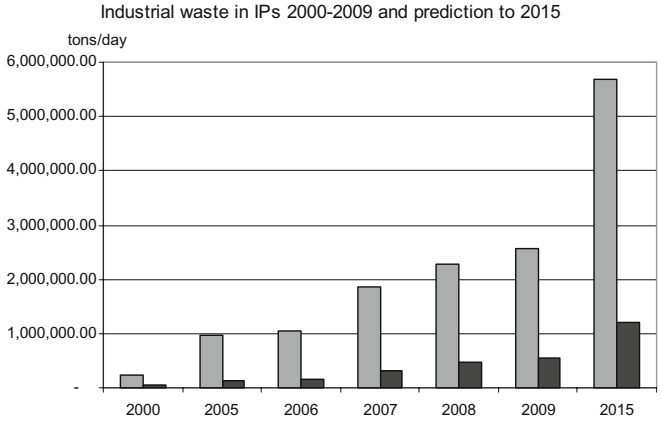

Fig. 5. Increasing trend of nonhazardous (*light gray bars*) and hazardous (*dark gray bars*) solid waste production in industrial parks (*IPs*) with a prediction to 2015

total of 371 tons/day (Hanoi, data on waste generators 2007–2009). But the actual amount of collected and managed waste was only 19.7%, or 71 tons/day. Hazardous healthcare solid waste (HzHCSW) is collected at a rate of about 4 tons/day and is treated in a small-capacity incinerator (200 kg/h) at Cau Dien treatment plant; other hazardous industrial waste is collected at a rate of more than 2700 tons/month.

Hai Phong. Hai Phong generates 1100 tons/day[5] of MSW and 800 tons of hazardous waste per year. Of the hazardous waste, more than 37 tons was sold to be reused, 363 tons of HzSW waste was electronic waste (WEE) that was recycled in craft villages, and only about 10% was handled with correct and safe handling procedures. Hazardous waste generated from the shoe leather industry accounted for 31.6% of HzSW, oil waste and oil absorbent fabric for 26.7%, and fibro roofing cement containing an asbestos compound for 26%.[5] The remainder comprised coal residues containing PbO and PbO_2, solvents, paints, and pigments, forming a toxic sludge. Only four hazardous waste transporters and treatment centers participate in this sector. No safe storage areas or treatment for hazardous waste have been developed, so illegal dumping of hazardous waste often occurs.

Thua Thien – Hue. In 2010, the amount of household solid waste generation in Hue was estimated at about 600 tons per day, which includes about 29 tons of industrial waste per day and less than 1 ton of hazardous waste per day. Thuy Phuong landfill and composting plant handles about 200–220 tons/day from Hue city. The Phong Thu and Tu Ha LFs are still under construction. The planning process has identified seven additional solid waste treatment facilities to be distributed reasonably among communities and towns in Hue with an area ranging from 5 to 40 ha. There are also six landfill sites from 5 to 7 ha for dumping in subregional centers and populated areas. Hazardous healthcare waste is treated at 0.3 tons/day in a medical incinerator set up in Hue General Hospital, which is located in a residential area.

Da Nang. This city has a solid waste treatment complex, Khanh Son, with a capacity of 650 tons per day, of which 88%–89%, or 570 tons/day, is domestic waste; industrial waste makes up 11%–12%, and 1% of domestic waste is from the medical sector. HzHCSW is generated at 0.5 tons/day from 21 public medical hospitals and is incinerated in a medical waste incinerator at a rate of 200 kg/h installed at Khanh Son waste complex. Another small incinerator

[5] Hai Phong Urenco report and www.mondre.gov.vn dated 13:17 24 Dec.,2009

(100 kg/h) is also used for hazardous industrial waste burning.[6]

Ho Chi Minh City. Ho Chi Minh City is the largest urban area in Vietnam. About 6700–7200 tons of MSW is generated daily, which is made up of 6200–6400 tons of domestic waste, 250–350 tons of hazardous industrial waste from inside the city, and around 9–12 tons of HzHCSW. Nonhazardous waste from industry is generated at an estimated 1500–2000 tons/day, and construction waste at about 500–800 tons/day. Ho Chi Minh City also treats approximately 150 tons/day of hazardous waste from other provinces. At present, Da Phuoc (200 ha, compost and sanitary landfill) takes 3000 tons/day, and Landfill No 2 at Cu Chi (20 ha) receives 3000–3200 tons/day. The city manages more than 1100 hazardous waste generators, 120 vehicles for septic tank sludge transportation, 150 vehicles for industrial and medical hazardous waste transportation, and 40 hazardous waste collection and treatment enterprises. Only five enterprises handle HzSW, and these have a total treatment capacity of up to 33 tons/day: Ho Chi Minh Urban Environment (4 tons/day); Vietnam Australia Ltd. (10–12 tons/day); Green Environment Co., Ltd., (12 tons/day), Thanh Lap Environment Co., and Petrolimex Co, so the demand on HzSW treatment facilities and secure LF will be intense for city and industrial zones in coming years.[7]

Dong Nai. In 2008, the total volume of domestic waste generated in Dong Nai was 1167–1200 tons/day (Green Field compost plant receives 400 tons/day), 97.5% of which is waste from outside the industrial zones and 2.5% is from industrial zones. The household waste collection rate in Dong Nai has reached only 71%. Bien Hoa URENCO, together with eight other enterprises, was responsible for waste collection, transport, and handling. In all, 456 484 tons/year of industrial waste was generated by IPs, and there were 730 hazardous waste generators with a registered amount of hazardous waste generated of 108 000–132 388 tons/year, but only 40%–54% (51 000 tons of HzSW) were collected. Sonadezi Waste Treatment Co. (equipped with one incinerator able to handle 200 kg/h), Tan Phat Tai Co. Ltd., and twenty other interprovince waste collection companies are participating in waste services at Dong Nai.[8]

Ba Ria–Vung Tau. Currently, the total amount of MSW generated in the province is around 700 tons/day. Of this, Vung Tau City, Ba Ria town, and Tan Thanh district generated 70%–88%. The waste is collected by Ba Ria Vung Tau Urban Environmental Company and transported to the Toc Tien landfill (Tan Thanh district). The rest of the waste is dumped in small temporary landfills (1–2 ha) without proper control. The waste from six existing industrial zones and other companies outside industrial zones was estimated at 288 tons/day,[2] of which hazardous waste from oil and gas exploration industries was 72 tons/day.[2] Steel manufacturers and fertilizer producers, among others, stockpile large amounts of industrial solid waste, including HzSW such as ash, residues from steel furnaces, dust collected from furnaces, and sludge containing PbO and other heavy metals, which is estimated to be generated at over 85 tons/month.[9] MSWM has become an urgent problem because of the limited number of waste treatment enterprises and their treatment capacity, which do not meet environmental or hygiene requirements.

Binh Duong. Binh Duong generates 700 tons of waste per day; Nam Binh Duong Waste Treatment Complex handles 400 tons/day.[10] The waste collection rate is only 60%. Over 100 tons of waste, including industrial waste, is illegally discharged daily without any control measures. The amount of HzSW collected is about 60–120 tons/day, with an additional 40–60 tons/day not being collected or treated.

Potential for waste recycling

The results of the household waste composition survey carried out in the study areas indicated that household waste was made up of the following proportions: organic waste, 55.4%; inert material, nearly 19.2%; paper waste, 8.86%; plastic waste, 8.74%; glass, 4.56%; metal, nearly 2%; rubber, 1.06%; unused clothes, about 0.68%; and hazardous waste, 0.1%–0.45%.[8,15] Nylon, plastic, and paper waste were also present in relatively high proportions in household waste found in the study areas. In addition, waste from offices, schools, and high–rise accommodation has high proportions of plastic and paper within the household waste.

Capacity of composting in study areas

The existing composting plants in the study areas account for 15% of total MSW generated daily. Cau Dien composting plant handles 100 tons/day and the 3R-JICA pilot model up to 40 tons/day; others include Son Tay (100 tons/day), Gia Lam (100 tons/day), Trang Cat-Hai Phong (200 tons/day), Thuy Phuong (Hue, 200 tons/day), Bien Hoa (400 tons/day), and Ho Chi Minh composting plants (up to 1300 tons/day). However, the consumption of compost is not as high as expected for various reasons, including quality, price, market expansion, and services. Although compost production from MSW in the study areas has high potential, these plants always operate below their designed capacity. Nonetheless, the study areas need to diversify recycling promotion activities and set up more demonstration models or pilots on organic waste treatment to allow comparisons to

[6] Report of URENCO and field trip note from Hue URENCO, DNURENCO report on June 7–8, 2010
[7] Report of HCM DONRE and field trip note from Ho Chi Minh DONRE and CITENCO on June 9, 2010
[8] Report of Dong Nai DONRE, www.mondre.gov.vn dated December 24, 2009, field trip August 12, 2010
[9] Baria Urenco and www.baria-vungtau.gov.vn, November 4, 2009, 08:02
[10] Binh Duong DONDRE report;http://www.chatthainguyhai.net/index.asp?newsid=1967&PageNum=22

be made. They also need to propose the most suitable solution not only for organic waste recycling but also for other recycling materials that are well suited for processing in Vietnamese conditions.

Waste recycling in Hanoi, Ho Chi Minh, and in informal sectors of the study areas

Hanoi and Ho Chi Minh are the two leaders in waste recycling. Recognizing the importance of recycling, Hanoi supports the 3R project toward establishing a Sound Material Cycle Society, and Ho Chi Minh City supports the 3R program laid out by the budget from the City and stakeholders. In 3R–HN pilot projects, used newspapers, old magazines/books, old clothes, and end-of-life electronic items, for example, are not considered to be waste. The storage, resale, exchange, or donation of these wastes is encouraged because many of the objects still have an economic value. There are actually four waste streams in the study areas. In the first stream, waste pickers collect recyclable materials from household waste at collection points and anywhere else they can find waste. In the second stream, materials are separated and recycled by households to sell to recycle waste collector or buyers. The third stream is made up of waste collected from households every day by waste collectors, using hand carts. The last stream comes from waste pickers at the landfill sites who collect recyclable material after MSW arrival, but before compacting by compactors or trucks.

There are over 90 waste-recycling craft villages in the study areas, of which 18 are related to waste electronic equipment (WEE) villages. The turnover of recycling was over $74.8 million (2008), and is increasing at 16% per year; such villages have created jobs for about 90 000 laborers.[10,12–14] The end result of all recycled waste is recycling sites. Most of the places where recycled materials are gathered and processed, called recycling craft villages, are causing large environmental problems for the local communities due to the large amounts of pollution emitted by most of the recycling technology and equipment.[10–16]

Manual collection, treatment of solid waste in the study area, and waste collected without waste separation at source

Waste collection is almost all done manually, from putting waste into handcarts and transferring it into waste trucks to bring to landfills and treatment at the waste treatment facilities. In large areas of Hanoi, Ho Chi Minh, and other cities, hazardous waste from households and businesses was generated and mixed and agricultural and industrial waste without proper waste separation at source. The collection rate is still low because of limited manpower, facilities, technologies, and financial resources. Waste separation at source is just at the initial trial period, with many difficulties being experienced due to the waste generators' inexperience; education needs to be carried out with a view to "learning from the best" to support MSWM in the coming years.

Other hazardous wastes in the study areas

Sludge from waste treatment systems, waste from chemical handcraft villages, and household HzSW (generated at a rate of 0.01%–0.45%,[8,9] including batteries, thermometers, light bulbs, and solvents) are dumped daily with household waste and the amounts are increasing; this waste stream is not being properly handled. Additionally, the amount of WEE is now rapidly rising, with the current amount being approximately 1.0 kg of WEE/person/year (22 344 tons/year from the study areas).[13,14]

An average of 15.5–18.5 tons/day of healthcare hazardous waste is generated in the study areas and this amount could be reduced by good practices with respect to waste separation at healthcare facilities. Ho Chi Minh City has two incinerators with capacities of 4 and 7 tons/day; in other cities, the handling of HzHCSW is done in small-capacity batch-operation incinerators (normal capacity less than 200 kg/batch). The incinerators should be under strict monitoring and evaluation, especially for flue gas emission control, so that the system is assured of meeting the standard environmental requirements and utilizing measures to reduce dioxin levels generated during waste incineration.

Dai Dong waste treatment plant (Hanoi Urenco) has invested in one incinerator with a capacity of 10 tons/day, thus becoming one of the biggest facilities in the Northern Economic Zone for HzSW treatment. The monitoring and training of the incinerator's operators should be in line with strict governmental monitoring.

Discussion and the orientation of a solution

Importance of basic schemes on planning and the legal framework

Good planning and a sound legal framework are key factors for improving SWM in the study areas. The planning of MSWM should be developed to suit the speed of development of the socio-economic status and natural resource utilization of the cities. Targets aimed at the per capita reduction of waste generation and the development of a clean production strategy in enterprises are not yet focused or clearly identified. Once each target period is clearly identified, then enforcement to reduce waste and increase recycling and reuse among waste generators can be put into place. Together with basic schemes and planning on SWM, monitoring of the regulations, implementation and strengthening of SWM capacity, and rationalization of MSWM fees charged in the study area should be codified and put in proper regulation.

Necessity of technologies

The need for advances in technologies and technological transfers to support the 3R initiative in terms of waste recycling and treatment, both for official waste treatment companies and for craft villages communities in the study area, is

an urgent problem in the big cities of Vietnam. Based on the characteristics of the waste composition, the location of the most recent users of products and the treatment facilities, and economic perspectives, the study areas need more combined technical solutions. Also needed are the appropriate technologies and support for several advanced models such as Eco cities or the "biomass cities" vision, in which total biomass and organic waste could be exchanged and converted into power/heat generation and/or ethanol and biodiesel fuel. Fertilizers/feed production and plastics/other materials require effective recycling models so that the waste generators will be involved in efficient use of the city's biomass and waste resources. This should be done step by step with subsidy programs from governmental and international institutions and stakeholder support for resource handling.

Countermeasures against toxic substances

To overcome the damage caused by hazardous waste, the technologies and measures used against hazardous substances should be addressed as soon as possible. Countermeasures are required for controlling and reducing waste and encouraging the recycling of construction waste, food waste, and incineration ash. Waste power generation, biodiesel and bioethanol production, and many other related measures would benefit from the development of intermediate treatment of waste, such as gasification technologies and melting furnaces that will also help in dioxin reduction and in ensuring complete high-temperature combustion.

A manifest control system should be developed for MSWM that will improve the transparency and accuracy when monitoring and managing waste flow. The adoption of electronic manifest control technology and a system based on Japanese experiences with waste flow control and analysis would be highly beneficial. Vietnam also needs technologies for the treatment and recycling of waste containing mercury, asbestos, and cadmium, including recycling technologies for waste batteries, fluorescent bulbs, and insulation materials and technologies facilitating reduction in the use of toxic heavy metals. Waste dioxin levels should be controlled by improvement of systems/technologies to reduce the amount of dioxins generated during waste incineration. At the same time, measures should be implemented to reduce the levels of persistent organic pollutants (POPs) and to develop a policy toward 3R MSWM in hazardous waste management.

Improvement of financial resources for MSWM

With a clear basic scheme and planning, MSWM needs financial support from the Provincial People's Committee and the Government to create favorable conditions for building new MSW treatment plants for the big cities in Vietnam. Funds will be required from many kinds of financial sources, e.g., the Build–Operation–Transfer (BOT) and Build–Transfer (BT) initiatives of the state budget, international credit, and other sources to achieve the target for an integrated MSWM strategy up to the year 2020 focusing on the restriction of landfill use and the reduction greenhouse gas emissions.

Promoting citizen and related stakeholders involvement

Promoting involvement in MSWM by the citizen and waste generators is essential to encourage participation in WSS schemes. Public awareness should be raised in terms of citizens' responsibilities, strengthening of regulations, and the requirements of waste management as well as in the monitoring and enforcement of MSW regulations.

Vietnam has adopted a legal framework for SWM for environmental protection with the guiding principles of the 3R initiative. Although there are still many barriers to effectively implementing this framework in reality, the resulting improvement in SWM marked a new step forward for the sustainability movement. Development of capacity enhancement using 3R and integrated SWM, especially in terms of hazardous pollution control, is essential in the coming period. This should limit the maximum impact and implications of solid waste and contribute to greater efficiency in the use of state and provincial budgets and international support, credit, and donations for MSWM in an efficient manner in the coming years.

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