International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 4 ǁ April 2023 ǁ PP. 347-352

Assessing the current status of domestic solid waste generation and forecasting domestic solid waste quantity in Cao Bang city, Cao Bang province in Vietnam until 2035

Gioi Ngo Van[1], Tuat Nguyen Thi Nham[2*]

[1]*Faculaty of Natural Resources and Environment, Thai Nguyen University of Sciences (TNUS), Tan Thinh Ward, Thai Nguyen City, Thai Nguyen 250000, Vietnam*

2*[1]*Faculaty of Natural Resources and Environment, Thai Nguyen University of Sciences (TNUS), Tan Thinh Ward, Thai Nguyen City, Thai Nguyen 250000, Vietnam*

Corresponding Author: Tuat Nguyen Thi Nham

ABSTRACT
The aim of this paper is to assess the current situation of solid waste generation and forecast the amount of domestic solid waste in Cao Bang city, Cao Bang province in Vietnam by 2035. The study used a number of main research methods such as collecting primary and secondary data, actual investigation methods, using mathematical formulas to calculate and process data to get the results. The results show that the source of domestic solid waste in Cao Bang city is very diverse, mainly from urban areas, accounting for 93.09%. Emission coefficient in urban area is 1.13 kg/person/day and in rural area is 0.51 kg/person/day. Domestic solid waste composition is mainly organic solid waste (58.17%) while non-recyclable solid waste accounts for the lowest rate (7.2%). The amount of generated domestic solid waste in the city is forecasted to be 32,225.42 tons/year by 2035. The research results also show that the estimated amount of domestic solid waste generation in 2035 will increase by 1.13 times compared to 2022. The management of domestic solid waste in the study area in the past years has achieved many positive results. The current domestic solid waste treatment system basically meets the treatment requirements This result is a necessary and important scientific basis to propose solutions to improve the efficiency of domestic solid waste management in the future.
Keywords: *Solid waste, environmental management, waste, pollution, Cao Bang*

Date of Submission: 02-04-2023 Date of acceptance: 14-04-2023

I. INTRODUCTION

Urbanization and economic development often lead to increased resource consumption and solid waste generation rate per capita. Urban residents in developed countries generate six times more waste than in developing countries. It is estimated that in developed countries the amount of solid waste can reach 2.8 kg/person/day, in developing countries it is about 0.5 kg/person/day [1]. The average rate of domestic solid waste (DSW) generation worldwide is about 0.74kg/person/day; in which, the rate in the lowest country is 0.11kg/person/day and the rate in the highest country is 4.54kg/person/day. In 2016, the total volume of municipal solid waste generated globally was about 2 billion tons. In which, the largest amount of urban solid waste is in the East Asia - Pacific region with 468 million tons; The lowest was in the Middle East and North Africa with 129 million tons [2].

In Vietnam, the amount of generated DSW is about 25.5 million tons in 2018, of which urban DSW is about 38,000 tons/day and rural domestic waste is about 32,000 tons/day [2]. DSW in urban areas currently accounts for more than 50% of the total DSW of the country and accounts for about 60-70% of the total amount of urban solid waste [2]. It is forecast that the amount of DSW in Vietnam will increase to 54 million tons by 2030 [3].

The average waste generation standard per capita for each type of waste is specific to each locality and depends on the standard of living, civilization and population in each area. However, regardless of the region, there is a general trend in the world that the higher the standard of living, the more waste is generated. According to a report by the World Bank, in big cities, the rate of solid waste generation in New York is 1.8 kg/person/day while in Singapore and Hong Kong it is 0.8 - 1.0 kg/person/day. In Vietnam in 2015, the total amount of DSW generated in cities was 38,000 tons/day. Estimation of DSW amount generated by 2030 will be 2.59 billion tons, and by 2050 it will be 3.4 billion tons [1].

Domestic solid waste is generated more and more and the rate of non-biodegradable solid is increasing in Cao Bang city, Cao Bang province. In the past years, the city's economy has grown strongly, the socio-economic infrastructure has continued to be invested; socio-cultural aspects have many positive changes; life, material, spiritual is constantly being raised. In addition to the very encouraging results from economic development, environmental problems have arisen: wastewater and DSW arising from communes and residential clusters have not been collected and treated to ensure environmental sanitation. From that situation, this study was conducted to assess the current situation of domestic solid waste generation and treatment as well as to forecast the amount of domestic solid waste in Cao Bang city, Cao Bang province to 2035. This result is an important scientific basis to propose solutions to improve the efficiency of DSW management in the coming time.

II. SUBJECTS, SCOPE AND RESEARCH METHODS

2.1. Object and scope of the study

- DSW in Cao Bang city, Cao Bang province. This study selected 3/11 representative wards and communes to directly investigate, survey and collect research samples: Hop Giang ward, De Tham ward, Vinh Quang commune. In which, Hop Giang ward represents the area generating a lot of solid waste in Cao Bang city. Hop Giang ward is the central ward that can be considered as the largest commercial center of the city. De Tham ward represents an area with a medium level of DSW generation. De Tham ward is the new administrative center of Cao Bang city, 5 km from the city center. There are many educational institutions located in the area. Vinh Quang commune represents an area that generates little DSW in Cao Bang city.
- People, environmental sanitation workers, environmental managers in Cao Bang city, Cao Bang province.
- Research scope:

+ About space: Cao Bang city, Cao Bang province.
+ About time: From September 2021 to May 2022.
+ About the content: research on waste composition, emission coefficient, waste load in Cao Bang city.

2.2. Research Methods

This study was carried out by using a combination of methods such as primary and secondary data collection and use, field survey using questionnaires and collecting opinions of 165 households using household questionnaires, particularly:

+ Hop Giang ward: The number of questionnaires is 60 votes for 12 residential groups.
+ De Tham ward: The number of survey questionnaires is 60 votes for 12 residential groups.
+ Vinh Quang commune: The number of questionnaires is 45 votes for 9 villages.

Investigate 16 officials and workers of the environmental sanitation team using agency questionnaires. The questionnaire focused on asking about volume, composition, collection, classification, transportation and treatment of DSW...

- The method of determining the emission coefficient and the composition of DSW is done as follows: Households are randomly selected in 3 wards or communes to perform the DSW weighting method. The total number of samples to be studied is: 33 samples (11 samples/town/commune) to determine the emission coefficient per day.

+ All DSW generated in 24 hours will be stored in specialized tools.
+ Weigh the volume of DSW obtained during the day (the process is repeated 7 times in 7 different days during the study period of 1 week).
+ Calculation of DSW emission coefficient:

$$E = A/B$$

E: DSW emission coefficient (kg/person.day)
A: Volume of DSW of a household (Kg/household)
B: Number of members in the family (person/household)

- The DSW classification method is used to classify in terms of volume percentage of different solid waste components for management and treatment purposes. The method of classifying solid waste must reflect the basic components of solid waste in four categories: organic solid waste, inorganic solid waste recyclable solid waste, reusable solid waste, hazardous solid waste.
- Method of forecasting population and amount of DSW generated:

The population in years is estimated based the flowing equation:

$$N = N_0(1 + r)^n$$

N: population in target year (people).
N_0: population in base year (people).
r: population growth rate (%)

n: number of years.
- The amount of DSW generated from households is calculated according to the following formula:

$$S = E \times N$$

S: Amount of DSW generated (kg/day).
E: DSW emission coefficient (kg/person.day)
N: Population (person)
All documents collected during the research are processed and evaluated using current specialized software.

III. RESEARCH RESULTS AND DISCUSSION

3.1. Current status of domestic solid waste generation in Cao Bang city

3.1.1. Sources of domestic solid waste

Domestic solid waste arises from many different sources, they differ in quantity, size, composition, spatial distribution... DSW can arise in individual activities as well as in social activities such as from residential areas, restaurants, hotels, companies, offices, industrial plants, agricultural production activities... Specific survey data is shown in Table 3.1.

Table 3.1. Sources of domestic solid waste in Cao Bang city

Source	Types of solid wastes
Residential (De Tham ward, Duyet Trung ward, Hoa Chung ward, Chu Trinh commune...)	Food wastes, paper, cardboard, plastics
Service (The Kim Dong walking street and food market, Song Bang Market, Ngoc Xuan Market	plastic bags, plastic bottles, food waste…
School (Cao Bang Pedagogy College, Cao Bang High school boarding Ethnic school, Cao Bang High School, De Tham Secondary School, Song Bang Primary School...)	plastic bags, carton covers, plastic, paper…
Administrative Agency (City People's Committee, People's Committee of ward/commune, Cao Bang Traditional Medicine Hospital...)	plastic, paper, plastic bags, leftovers...
Agricultural production area (mainly from fields after crops, breeding areas ...)	Food wastes, feces of cattle, agricultural by -products ...
Public area	plastic bottles, plastic bags, food wastes, leaves ...
Industrial production area (Cao Bang Manganese Industry Joint Stock Company, Cao Bang Iron and Steel Joint Stock Company, Cao Bang Mineral Company, ...)	Glass, Metal, Plastic, Carton Cover,..

3.1.2. Composition of domestic solid waste

Determining the composition of DSW is very important for the selection of processing equipment, processing technology, reuse as well as planning management programs for the technical system of DSW management.
The volume of all kinds of solid waste is not the same due to different needs. The demand in the life of households is different, so the DSW component in groups is also different The composition of DSW is quite diverse, the research results are shown at Table 3.2.

Table 3.2. Composition of domestic solid waste in Cao Bang city

Classification of domestic solid waste	Domestic solid waste components	Percentage by mass (%)			
		Hop Giang Ward	De Tham Ward	Vinh Quang Commune	The average value (%)
Recyclable waste	paper, nylon, plastic, rubber, metal…	25.6	35.5	42.8	34.63
Non-recyclable waste	Soil, building materials…	5.7	6.3	9.6	7.20
Organic waste	Leaves, vegetables, tubers, fruits, leftovers, animal carcasses	68.7	58.2	47.6	58.17
Total		100	100	100	100

Domestic solid waste generated in Cao Bang city has a very diverse composition (waste papers, clothes, plastics, metals, construction materials, leftovers...). The study has classified DSW in this city into three main groups:

recyclable DSW (paper, fabric, cardboard, nylon...), non-recyclable DSW (earth, stone, building materials…) and organic DSW (leaves, vegetables, leftovers...).

The DSW generated in the study area has the largest percentage of organic waste by weight (58.17%). Non-recyclable solid waste accounts for the smallest percentage of the three groups of solid waste (7.2%). The DSW arising in the area has not been classified by the people at the source or the classification programs are only experimental, have not been implemented in a synchronous, drastic manner and have not been formalized. Households have not taken advantage of or have no need to take advantage of these valuable waste sources.

The areas of Hop Giang ward, De Tham ward and Vinh Quang commune were selected to represent the study area, showing that the composition of DSW in different areas is different.

- The organic component in the DSW of Hop Giang ward accounts for the highest percentage by weight while this waste component of Vinh Quang commune accounts for the lowest percentage. This is relatively suitable for the actual characteristics of each area. Currently, Hop Giang ward is the largest commercial center of Cao Bang city. The number of households engaged in agricultural production is less than in rural areas, so people make less use of organic waste and dispose of it into the environment.

Meanwhile, Vinh Quang commune is a commune located in the north of Cao Bang city, so people mainly participate in agricultural and forestry production activities. Here, the amount of organic waste is classified and utilized by people for their agro-forestry production process (such as animal feed, composting). Therefore, the percentage by weight of organic waste generated in Hop Giang ward is relatively large compared to rural areas.

- The percentage by weight of recyclable solid waste components in the amount of DSW generated in Hop Giang ward is the lowest and in Vinh Quang commune has the highest rate. In some areas in the central areas, people have conducted waste separation at source. For the recyclable solid waste components that have been used by households to sell to collectors or street collectors, separate and selectively sell to collectors. For areas far from the city center, access to the contents related to DSW management has not been extensive, so people have hardly conducted the classification of DSW right at the source. Therefore, the proportion of components in DSW arising in different areas is different.

Thus, depending on the natural, socio-economic characteristics of each area, state managers of the environment need to have appropriate solutions for the characteristics of each area in order to bring the highest efficiency.

3.1.3. Domestic solid waste volume

The volume of DSW generated in the wards/communes of Cao Bang city is shown in Table 3.3.

Table 3.3. The volume of domestic solid waste generated in Cao Bang city in 2021 [4]

No	Area	Rate (%)	The total amount of DSW (tons)
1	Urban area	93.09	26,542
2	Rural area	6.91	1,970
3	Cao Bang city	100	28,512

The data in Table 3.3 shows that there is a huge difference in the amount of DSW generated in 2021 in urban areas and rural areas in Cao Bang city. The volume of DSW in urban areas is 13.47 times larger than the volume of DSW in rural areas. The volume of solid waste depends on the level of socio-economic development of each region. From these characteristics, environmental state management agencies need to have flexible solutions, suitable to the characteristics of each region to be able to thoroughly solve this DSW problem.

According to the 2020 census data, Cao Bang city has about 86% urban resident and about 14% rural resident. Solid waste in urban areas arises in large volume and has a very diverse composition. Therefore, it is also necessary to have a plan to implement, guide and legalize the classification of solid waste at source in order to reduce the load on the process of collecting, transporting and treating them.

The volume of DSW generated in rural areas is less than in urban areas. But this can still become a concern for the environment if collection and treatment are not done well. In rural areas, the terrain is wide and diverse, with many different ethnic minorities living sparsely, and the infrastructure is less developed, so the implementation of this waste management is relatively difficult. Therefore, authorities at all levels need to have timely and necessary solutions for rural areas.

3.2. Forecasting domestic solid waste volume in Cao Bang city, Cao Bang province to 2035

According to the Report on the implementation of socio-economic development in 2021 – Targets and key tasks in 2022 of the People's Committee of Cao Bang City, the natural population growth rate of the city is 0.8 - 0.9 % [5]. This study has chosen an increase rate of 0.9% to calculate and predict the population growth

rate of the city in the following years. According to the 2020 census data, the city's population is 73,940 people; in which, urban population is 63,598 people and rural population is 10,432 people.
According to the population forecast formula in section 2.2, the population estimate of Cao Bang city until 2035 is shown in Table 3.4.

Table 3.4. Population forecast of Cao Bang city until 2035

No	Year	Urban population (person)	Rural population (person)	Total (person)
1	2022	64,748	10,621	75,369
2	2023	65,331	10,716	76,047
3	2024	65,919	10,813	76,731
4	2025	66,512	10,910	77,422
5	2026	67,110	11,008	78,119
6	2027	67,714	11,107	78,822
7	2028	68,324	11,207	79,531
8	2029	68,939	11,308	80,247
9	2030	69,559	11,410	80,969
10	2031	70,185	11,513	81,698
11	2032	70,817	11,616	82,433
12	2033	71,454	11,721	83,175
13	2034	72,097	11,826	83,924
14	2035	72,746	11,933	84,679

According to data reported by the Department of Natural Resources and Environment of Cao Bang City, the DSW emission coefficient in the city in urban areas is 1.13 kg/person/day and in rural areas is 0.51 kg /person/day. Although, the DSW emission coefficient varies according to the level of development. In this study, the author still uses this waste emission coefficient and considers it unchanged in the next forecast years to estimate the volume of DSW generated in the city in the coming time.

Table 3.5. Forecasting the volume of DSW generated in Cao Bang city until 2035

No	Year	Urban (tons/year)	Rural (tons/year)	Total DSW generation (tons/year)
1	2022	26,705.31	1,977.10	28,682.41
2	2023	26,945.77	1,994.78	28,940.55
3	2024	27,188.29	2,012.84	29,201.13
4	2025	27,432.87	2,030.90	29,463.77
5	2026	27,679.52	2,049.14	29,728.66
6	2027	27,928.64	2,067.57	29,996.21
7	2028	28,180.23	2,086.18	30,266.42
8	2029	28,433.89	2,104.98	30,538.87
9	2030	28,689.61	2,123.97	30,813.58
10	2031	28,947.80	2,143.14	31,090.95
11	2032	29,208.47	2,162.32	31,370.79
12	2033	29,471.20	2,181.86	31,653.07
13	2034	29,736.41	2,201.41	31,937.82
14	2035	30,004.09	2,221.33	32,225.42

The data in Table 3.5 shows that the volume of DSW generated in the city by 2035 will be 32,225.42 tons/year. Thus, within only 14 years (2022 - 2035), the amount of DSW in the city increased by about 3,713.42 tons (1.13 times). With the current municipal solid waste management capacity, this is a relatively large number. Not to mention, in reality, with the increasing development speed and people's living standards, the DSW emission coefficient will increase, not keep the fixed level according to this calculation. The volume of DSW generated in the city next year is higher than the previous year.

3.3. Current status of domestic solid waste treatment

Currently, DSW in the area is transported to Na Lan landfill, Chu Trinh commune, Cao Bang city for treatment. Na Lan waste treatment area has been invested to build waste burial cells in accordance with regulations. The land use area is 17,323 ha. Starting date of operation is July 31, 2013. The number of laborers and managers is 05 people (04 workers operating the yard) [6]. In August 2019, Environment and Development Investment Co., Ltd signed a contract for Nga Hai Co., Ltd. to manage and operate the waste treatment yard under the economic contract No. 79/2019/HDKT on leasing premises and assets of Na Lan waste treatment yard, Chu Trinh commune, Cao Bang city. Until January 1, 2021, Environment and Development Investment Co., Ltd. will continue to manage and operate the landfill.

** Status of the management and operation of the waste landfill from 2013 to present:*

- The domestic solid waste burial area consists of 02 landfill cells. The area of each cell is 8,000 m2 with the underground wasre storage capacity is 57,000 m3. The cell has a depth of 11.5m (the depth of the garbage is 10m; the height of the top layer of soil is 1.5m). In the cell, there is a system of leachate collection wells D = 1m around the stone fence to prevent garbage and the D70 pipeline to collect leachate to the regulation lake. In 2017, the treatment station built one more landfill cell with an area of 10,800 m2, underground waste storage capacity is 80,000 m3. The cell has a depth of 10 m below the ground, the height of the waste above the ground is 2 m, the bottom and the entire wall of the cell are covered with 2mm thick geotextile (HDPE). In the cell, there is a system of leachate collection wells D = 1.5m around the stone fence to prevent garbage and the D70 pipeline to collect leachate to the regulation lake [6, 7].

The second cell has been filled with waste about 1/3 of the cell's capacity. The amount of waste that has been dumped into the 3rd cell occupies 1/2 of the cell's capacity, and the uncovered waste occupies an area of about 3/4 of the area of the cell. Waste is not compacted and the dumping is not concentrated, so there are flies and mosquitoes.

-Waste disposal methods: waste is dumped into the cell by the method of encroachment. After that, the waste is leveled by bulldozers, leveled and compacted. After 1 day, spray microorganisms, EM or EMUNIV, Bokasi. When the height of the waste layer reaches 1m, then cover with a layer of soil 0.1m thick. After covering the soil, bulldozers, excavators travel many times over the entire surface. Sprinkle lime once a month around the cell. Spray biological fly killer periodically 02 - 03 times / month (depending on the weather) in the landfill and along the way in the landfill.

+ The volume of waste receiving from the beginning of operation to March 2021 was 150,996 tons.

+ The capacity to meet the receipt and treatment of waste in the next time will be 140,773 tons. In there:

The second landfill cell will be 72,765 tons.

The third landfill cell will be 68,058 tons.

Measures to treat leachate: Use PAA, PAC, microorganism, lime powder. The leachate treatment system uses chemical, physical and biological technology by means of a block treatment system with a treatment capacity of 100 m3/day.night.

- The CNC500 natural gas solid waste incinerator with a capacity of 500kg/h meets the National Technical Regulation QCVN 61:2016/BTNMT on DSW incinerators promulgated according to Circular No. 03/2016/TT-BTNMT dated March 10, 2016 of the Ministry of Natural Resources and Environment. The results of the research and trial operation project, the CNC500 domestic waste incinerator with the capacity and efficiency of the furnace are suitable for replicating the model with other districts in the province [8].

IV. CONCLUSION

The source of DSW generation in Cao Bang city is very diverse, mainly from urban areas, accounting for 93.09%. Emission coefficient in urban area is 1.13 kg/person/day and in rural area is 0.51 kg/person/day, DSW component is mainly organic solid waste (58.17%), non-recyclable solid waste accounts for the lowest rate (7.2%). The DSW quantity of this city is forecasted to be 32,225.42 tons/year by 2035. And the DSW volume in 2035 will increase by 1.13 times compared to 2022. The management of DSW in Cao Bang city in the past years has achieved many positive results. The current DSW treatment system basically meets the treatment requirements The research results are a necessary and important scientific basis for the locality to propose solutions to improve the efficiency of the collection, transportation and treatment of domestic solid waste in the next decade.

REFERENCES

[1]. Ministry of Natural Resources and Environment (2015), National State of the Environment Report 2011-2015, Chapter 3: Waste generation and treatment.
[2]. Vietnam Environment Administration (2019), Workshop document Model of domestic solid waste management and treatment in Vietnam.
[3]. World Bank, Solid and industrial hazardous waste management assessment: Options and action area to implement the national strategy, Hong Duc Publishing House, Hanoi, 2018.
[4]. Department of Natural Resources and Environment of Cao Bang Province (2021), Report on the State of the Environment of Cao Bang Province for the period 2016 - 2020.
[5]. Cao Bang City People's Committee (2021), Report on implementation of socio-economic development in 2021; Goals and key tasks in 2022.
[6]. Department of Natural Resources and Environment of Cao Bang province (2021), Report on management and operation of Khuoi Kep - Na Lan garbage treatment yard in hamlet 5, Chu Trinh commune, Cao Bang city.
[7]. Cao Bang City People's Committee (2020), Report on collection, transportation and treatment of rural solid waste in Cao Bang city.
[8]. Cao Bang City People's Committee (2021), Report on environmental protection in 2020, Cao Bang city, Cao Bang province.