■Ngày nhận bài: 04/5/2022 ■Ngày sửa bài: 20/6/2022 ■Ngày chấp nhận đăng: 14/7/2022

Research Characteristics of Ho Chi Minh City Construction Waste and Propose Solutions for Treatment and Recycling

Nghiên cứu đặc tính rác xây dựng khu vực TP. HCM và đề xuất các giải pháp xử lý, tái chế

> **VINH-TRONG BUI[1], HUNG-THE VO[1,2], NGOC-LOI DANG[3], VAN-THONG PHAM[1], HAI-BANG NGO[1]**
[1] Faculty of Geology and Petroleum Engineering, Ho Chi Minh City University of Technology
[2]Technology Center for Water and Environment Research, HCM city, Vietnam
[3]Urban Infrastructure Faculty, Mien Tay Construction University, Vietnam
Email: vthung.sdh21@hcmut.edu.vn

ABSTRACT

Urbanization and rapid population growth lead to considerable growth in generating municipal solid waste (MSW), with more than 20 % construction solid waste (CSW). Recycling CSW can save natural resources, land, social resources and reduce environmental pollution. This study presents methods for treatment and recycling of CSW for a case study in Ho Chi Minh city. To achieve the objective, the following approaches are implemented. First, construction solid waste in HCM city, including source, amount, and composition, is briefly described. Second, two ways of classification for treatment and recycling of CSW are introduced. Last, treatment technology for CSW components is presented. The result shows that the proposed technique is promising to be applied for treating and recycling CSW for long-term operation and minimizing environmental impacts.

Keywords: Construction waste; recycled waste; waste treatment; waste management.

TÓM TẮT

Đô thị hóa và gia tăng nhanh dân số dẫn đến sự gia tăng đáng kể chất thải rắn đô thị, với hơn 20% là chất thải rắn xây dựng. Việc tái chế chất thải rắn xây dựng có thể tiết kiệm tài nguyên thiên nhiên, đất đai, tài nguyên cho xã hội và làm giảm ô nhiễm môi trường. Nghiên cứu này trình bày các phương pháp xử lý và tái chế chất thải rắn xây dựng cho một nghiên cứu điển hình tại TP.HCM. Để đạt được mục tiêu đề ra, trình tự các bước thực hiện như sau. Thứ nhất, chất thải rắn xây dựng trên địa bàn TP.HCM bao gồm nguồn, lượng và thành phần rác được mô tả một cách tóm tắt dựa vào dữ liệu thực tế thu gom tại thành phố này. Thứ hai, hai cách phân loại rác hiện hành đang sử dụng cho việc xử lý và tái chế chất thải rắn được giới thiệu. Cuối cùng, công nghệ xử lý cho các thành phần chất thải rắn xây dựng được đề xuất. Từ kết quả phân tích cho thấy công nghệ xử lý này có triển vọng được áp dụng để xử lý và tái chế chất thải rắn nhằm mục đích hoạt động lâu dài và giảm thiểu tác động đến môi trường xung quanh.

Từ khóa: Chất thải xây dựng; chất thải tái chế; xử lý chất thải; quản lý chất thải.

1. INTRODUCTION

For annually growing about 80 million people, the world's population is predicted about 8.5 billion people by 2030 and 9.7 billion people by 2050 [1]. As an increasing population, it leads to urbanization levels and consumption of goods, thereby resulting in more produced waste [2, 3]. By 2050, the amount of municipal solid waste (MSW) worldwide is estimated at about 3.40 billion tons a year, which is 1.7 times larger than that produced in 2016 [4].

Generally, government and local authorities are responsible for the MSW management from the collection to final processing. However, most local governments fail to provide good service due to some reasons [5, 6]. Especially in developing countries (e.g., Vietnam or India), urbanization and speedy population growth have led to a significant increase in MSW. It raises some important issues that are safe collection, transportation, and treatment of MSW for municipal management. Poor management of MSW could result in a negative influence on public health and the environment. As an example, in India, only 21% of MSW was treated, while the remaining waste was disposed of without treatment technologies [7].

As a simple and cost-effective method, a landfill is commonly used to dispose of MSW [8-10]. Every year, thousands of landfills are active, closed, and abandoned [11], such as nearly 100000 in the U.S, more than 150000 in Europe, and more than 20000 in

China. According to the Statistics Yearbook of 2018, China has about 660 sanitary landfills, with a treatment capacity of 3.5 million tons per day. Long-term risk assessments [8] show that landfill disposal has experienced environmental harm, in which soil pollution via leachate leakage is one of the most common environmental hazards in MSW landfill sites [12].

According to IK Co., Ltd. Korea, MSW composition can be classified into construction solid waste, domestic waste, and industrial solid waste, as shown in Figure 1. CSW is about 48% (examined data in 2016) compared with other waste components in MSW. The automatic technological lines have been applied for treating and recycling CSW, as well as in many countries around the world (e.g., Bezner waste management solutions in UK). As a result, 98.1 %, 1.5%, and 0.4% of CSW is recycled, buried, and burn 1.5 %, respectively.

Figure 1. Percentage of CSW in MSW in South Korea

In Vietnam, rapid urbanization, and population growth lead to increasingly high amounts of waste. The amount of waste in 2015 is estimated to be over 27 million tons. The yearly growth rate of MSW is about 8.4% for urban areas and about 5% for rural areas. By 2030, MSW volume in the whole country is predicted to be about 54 million tons.

In Vietnam, most CSW is classified using manual methods, as examined at CITENCO (Ho Chi Minh City Urban Environment Co., Ltd) Ho Chi Minh (HCM) city. It is obvious that the quality of waste classification is dependent on workers' workmanship. Moreover, construction waste comprises inert materials (e.g., sand, bricks, and concrete) and non-inert materials (e.g., bamboo, plastics, glass, wood, and paper). CSW is usually a mixture of both inert and non-inert materials, thus challenging the segregation of the two portions for waste treatment and recycling process.

As reported by CITENCO (2017), the components of reusable materials after manual sorted CSW components still have various impurities (e.g., small wood pieces, plastic, and paper), and it is commonly used for backfill. It could lead to potential environmental risks, as reported in the previous studies [12, 13]. Moreover, an increasing amount of CSWs and higher requirements for the citizens and city administrators require studies on treatment and recycling technology for CSW to ensure long-term operation, cost-effectiveness, and minimization of environmental impacts. In this study, a method for the treatment and recycling of construction solid waste is proposed. To achieve the objective, the following approaches are implemented. First, construction solid waste in HCM city, including source, amount, and composition, is briefly described. Second, methods for treatment and recycling of construction solid waste are introduced. Last, treatment technology for construction solid waste components is presented.

2. INTRODUCTION OF CONSTRUCTION SOLID WASTE IN HCM CITY

2.1 Sources and amount of construction solid waste

HCM City is one of the major centers of economy, culture, education, training, science, and technology in Vietnam. It is also known as an industrial center and multi-sector services of the region and Southeast Asia. According to 2017 statistics, HCM has an area of 2,095.6 km^2 with 24 administrative units. Accounting for one-third of Vietnam's GDP, this dynamic city of over 10 million inhabitants is on widely seen as one of the fastest growing markets for technology and manufacturing in the region and the top emerging property market in Asia-Pacific. CSW thus emerges as an urgent problem that needs to be handled in order to create favorable conditions for economic and infrastructure system development of the city.

As estimated in 2017 (by CITENCO, the daily municipal solid waste generated in the city is about 9500 tons, in which domestic solid waste and CSW are about 8000 tons and 1500 tons, respectively. In HCM, an increasing waste rate is about 5.5% per year. Moreover, a small amount of CSW is collected for treatment or recycling while a large amount is discharged into the surrounding environment or freely transferred to local markets.

Sources and construction solid waste can come from activities of new constructions or repairing housings. Currently, CSW (data in 2016 by CITENCO) was collected and transferred to 02 transferring stations about 1250 tons per day. It meant that a significant amount of CSW had not been collected yet.

It is estimated that domestic solid waste could reach more than 11000 tons per day (after 2022), in which the CWS is predicted about 20% with an increasing rate of 5%. Moreover, daily CSW is estimated can reach 2550 tons by 2025. Furthermore, the daily mud from construction sites is about 250 m^3. The mud volume is forecasted about 500 tons per day by 2025 (according to the plan for solid waste treatment in HCM city up to 2025 with a vision to 2050).

2.2 Components of construction solid waste

Currently, the proportion of CSW components in HCM City has not been statistically surveyed. It is assumed that the composition of CSW has similar parameters to the one at Dong-Nai province, a relatively close region, and similar properties to HCM city.

According to the plan for solid waste management in Dong-Nai province to 2030, the components of reusable materials in CSW are 86.8 %, including broken concrete, smashed bricks, and sand. Meanwhile, the ones of CSW in Hanoi are about 90%, as shown in Table 1 (according to the report of the ministry of construction, 2015). Figure 2 shows representative images of waste components of CSW in HCM city.

As reported CITENCO 2017, the components of CSW at a transferring station were listed in Table 2. The components used for landing backfill are a composition of soil, sand gravel, brick, mortar, and concrete. Debris used for backfilling construction sites consists of 97.62% of reusable solid materials (see Table 2), as shown in Figure 3. The components of debris still exist impurities such as packaging, small pieces of wood, plastic, and paper.

On the other hand, compared to the debris proportion (90 %) of the reusable materials of CSW in Hanoi (see Table 1), the debris proportion (97.62%) is quite high (see Table 2). It could come from a waste classification method, which depends on workmanship, quality of waste, and capacity of transferring station. Furthermore, a large amount of sludge from foundation pits, drilling bored piles, and other construction sites are also challenging for the treatment.

Currently, the collection and transportation of CSW in the internal city have been conducted by CITENCO. Waste classification can take place at transferring stations or at Da-Phuoc site. Meanwhile, the waste collection and treatment systems in the suburbs have not been completed yet. In fact, rare households voluntarily transport construction waste to CITENCO's transfer station. It meant that except daily 1250 tons of CSW collected and treated with CITENCO, the rest freely transferred on local markets or discharged into the surrounding environment could not be controlled fully. This waste is commonly dumped in the periphery areas and vacant lots.

Table 1 Components of reusable materials in CWS components in Hanoi

Order	Components	Fraction	Total
1	Soil, sand, gravel	36 %	
2	Brick and mortar	31 %	90 %
3	Concrete	23 %	
4	Metal	5 %	
5	Plastic	2 %	9 %
6	Wood	2 %	
7	Other	1 %	1 %

Figure 2. Images of waste composition of CSW in HCM City

Table 2 Components of reusable materials in CSW in HCM city (2017)

Component	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Proportion (%)
Debris (ton)	69647	87542	69087	78170	
Backfill	*14793*	*27354*	*30273*	*25756*	97,62
Da-Phuoc site	*54854*	*60188*	*38814*	*52414*	
Metal (ton)	7	25	28	33	0,03
Plastic (ton)	1	5	5	8	0,01
Wood (ton)	117	164	411	279	0,34
Trash residue (ton)	1424	1791	1419	1602	2,0

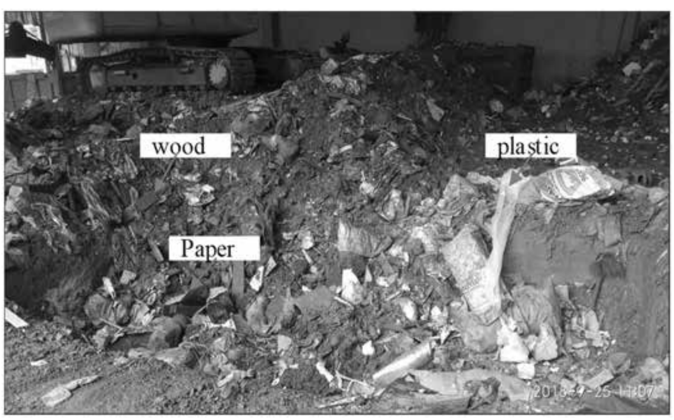


Figure 3. Manual classified CSW used for backfill (taken in 2017 at waste transfer station)

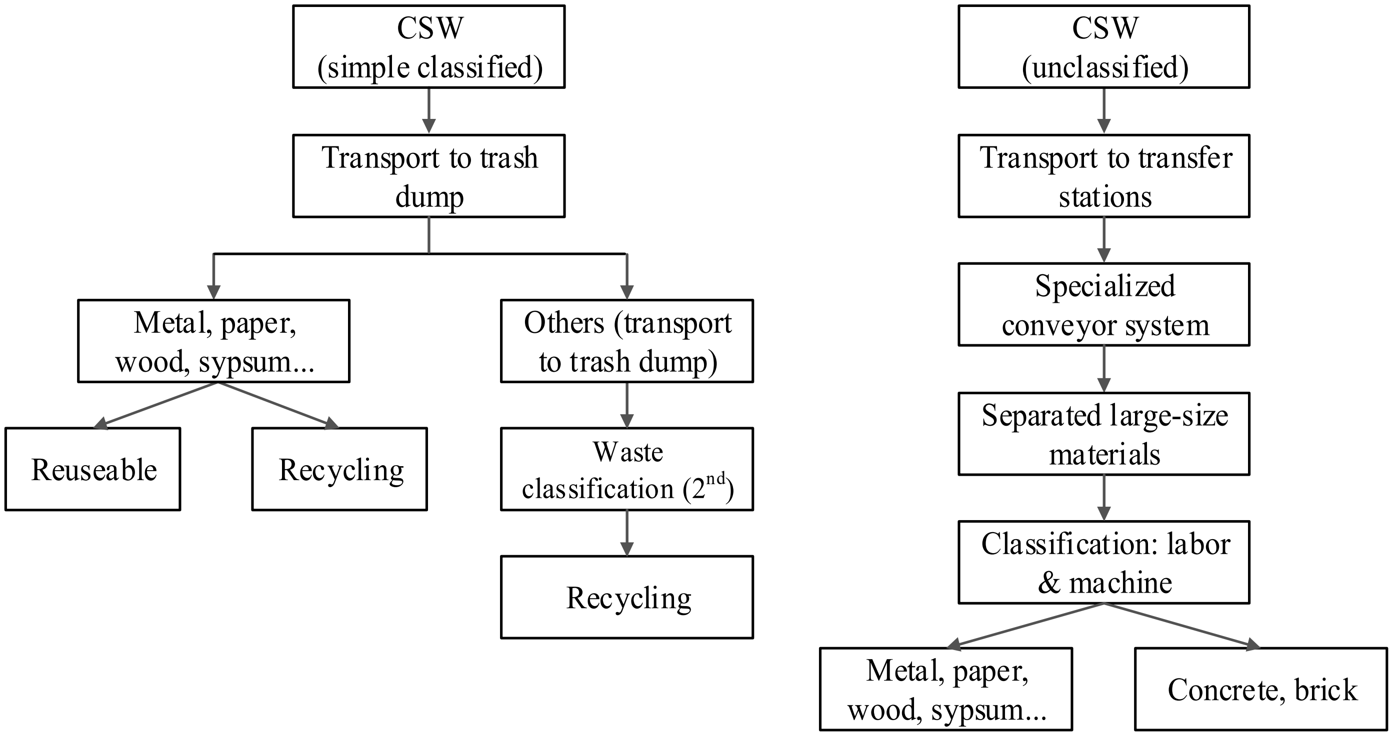
3. OVERVIEW OF METHOD FOR TREATMENT AND RECYCLING OF CONSTRUCTION SOLID WASTE

According to the physical and chemical properties of waste, manual sorting must first be completed, followed by magnetic separation, pneumatic separation, and water concentration. Figure 4 shows basic steps in the process of construction solid waste collection treatment and recycling. In general, CSW from construction sites can be collected with or without separation at the source.

For the separated CSW at the source (see Figure 4a), after demolishing construction, reusable or recyclable materials (e.g., iron, steel, paper, and carton) are collected separately to transfer to recycling firms (for recyclable materials) or specialized firms (reusable materials). The rest of the CSW volume is transported to waste dumps. Then, the remaining CSW is sorted (2^{nd} time) to pack and transport to waste recycling units. The method is applicable to a small-demolished area since recyclable and reusable materials can be collected quickly. However, the method could not be suitable for large demolished works due to time-consuming, unsafety for workers, and high environmental pollution.

For unseparated CSW at the source (Figure 4b), after demolishing construction, waste is put on large tonnages to transport to waste transfer stations. The tonnages should be covered to minimize the effects of CSW on surrounding environments during transporting process. At waste stations, CSW is put into a general classification system and/or a conveyor system to separate large and bulky materials. Then, the waste is sorted for each component based on their characteristics (e.g., soil, gypsum, flammable substance, wood, or debris) using combining manual method and machine system. After separating, each package of waste materials is packed to transport to the respective waste recycling units. Figure 5 shows images of the systematic proposal treatment and recycling strategy for CSW. The waste components after treatment can be reused for construction works or destroyed (burnt).

The method of the unseparated CSW at a source is applicable for large construction sites where construction waste volume at the sites is huge. The advantage of the method is collecting materials quickly, thus minimizing environmental pollution. The process should be selected for collecting construction solid waste in a large city (e.g., HCM city) to minimize the environmental impact induced by the collecting and treating waste activities.



a) Classification of CSW at source   b) Un-classification of CSW at source

FIGURE 4. Overview process of construction solid waste collection using treatment and recycling

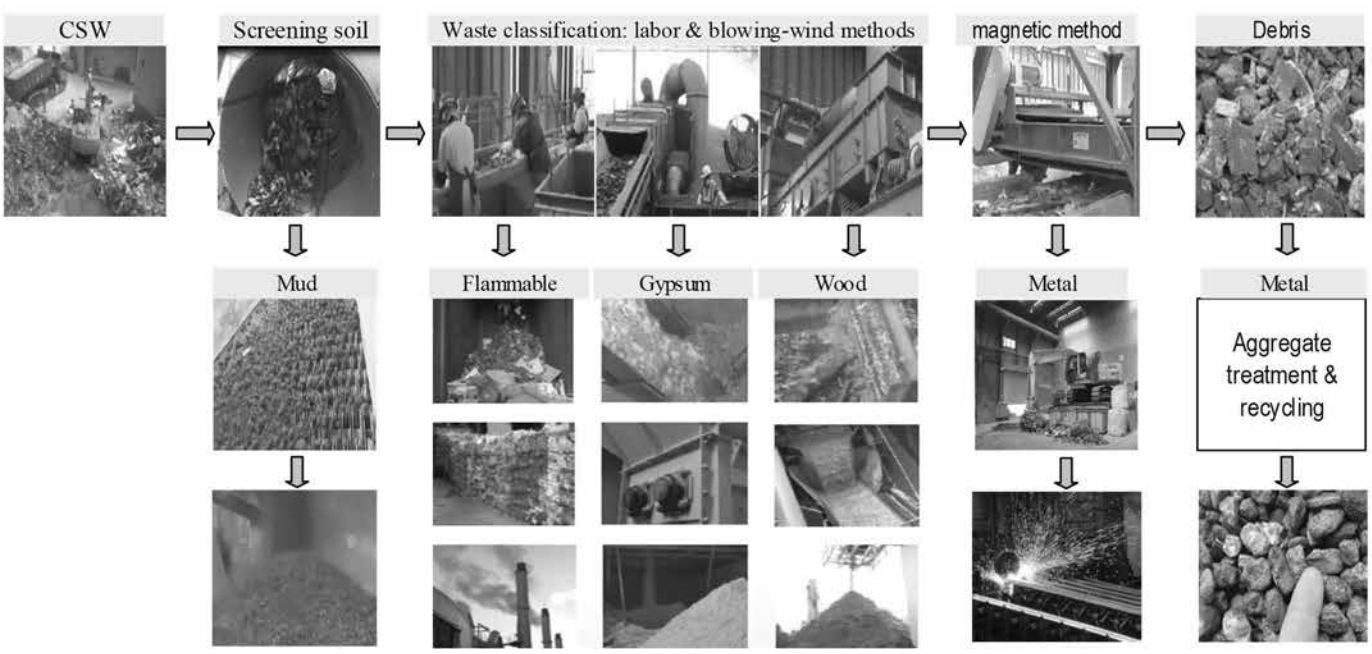


Figure 5. Proposed process for recycling construction solid waste

4. PROPOSED METHOD OF TREATMENT FOR CONSTRUCTION SOLID WASTE COMPONENTS

After manual or machine-based waste separation, each waste package component is transported to waste recycling units. This section presents treatment technology for each component, including waste concrete, wood, gypsum, metal, construction sludge, and papers.

4.1 Treatment technology for waste concrete and broken brick

For brick-type waste, the classification of undamaged bricks is necessary since it can be directly reused for retaining walls or paving brick. Meanwhile, broken bricks can be used for backfill or foundations of sidewalks. It is noted that treated broken bricks can be used for paving brick in public areas.

For concrete-type waste, it can be used for backfill or roadbeds. In addition, waste concrete is also used as raw materials to produce unburnt bricks, or it can be used for producing concrete aggregate (i.e., components of concrete mixture), or used to make roadsides, trenches, sewers, or pavement bricks.

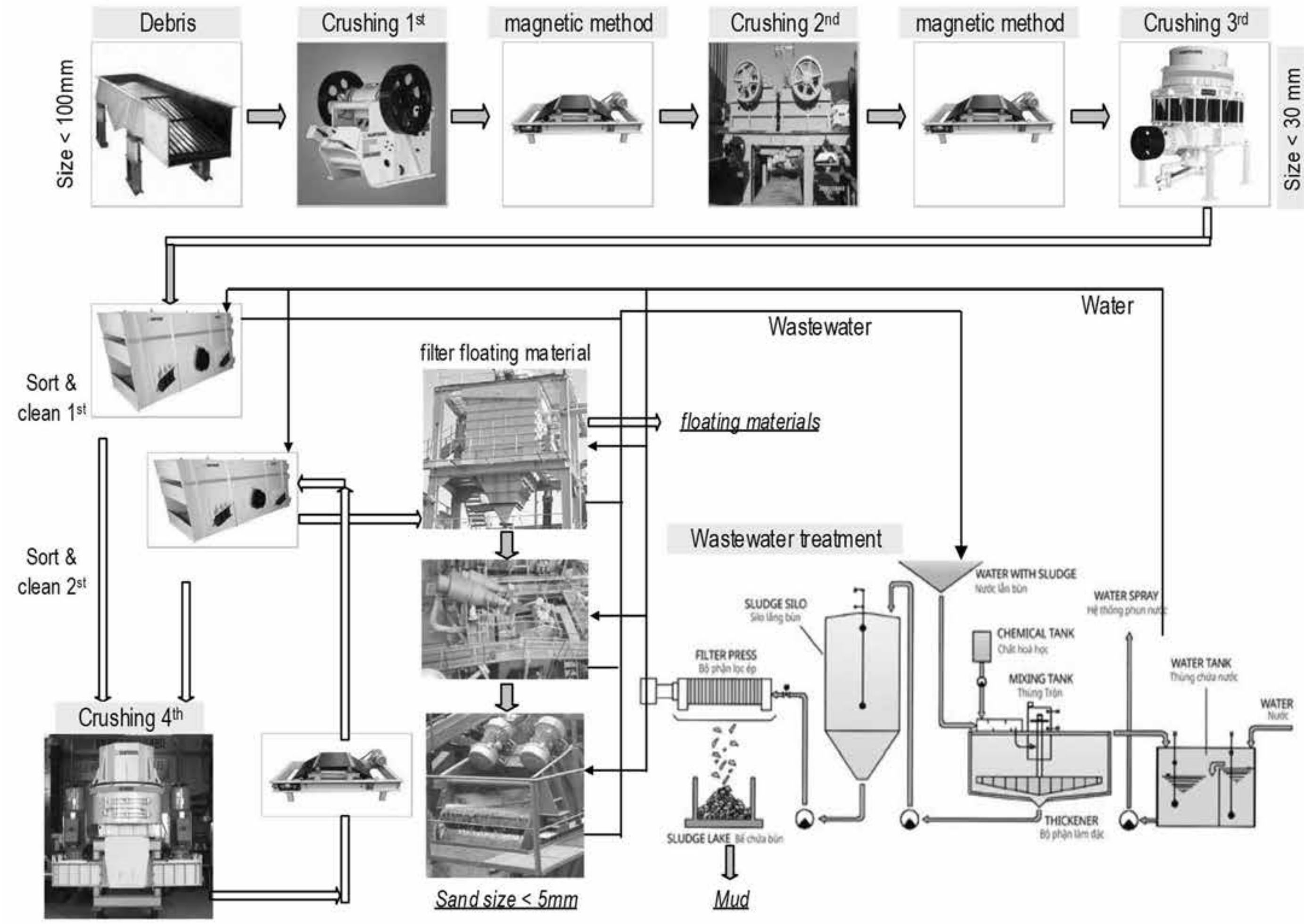


Figure 6. Schematic treatment technology for waste concrete and broken brick

The scheme of treatment technology for waste concrete and broken brick is shown in Figure 6. It is noted that a waste concrete with a size larger than 100 mm needs to be demolished before being input into the treatment process. At first, concrete aggregate, including other impurities such as papers, nylons, and steel, is passed through a conveyor system before transferring to a grinder machine system (1st crushing) to crush debris into smaller size materials (less than 70 mm). After that, a magnetic system is applied to obtain metals (e.g., steel and aluminum pieces) remaining in the crushed waste. Second, the waste component is then put into another grinder machine system (2nd crushing) to crush debris into smaller size materials (less than 50 mm). The magnetic system is again applied to obtain metals. Third, the waste component is put into another grinder machine system (3rd crushing) to crush debris into smaller size materials (less than 30 mm), before automatically sorting and cleaning using a mechanical system. The wastewater is pumped into the water treatment system, as seen in the figure.

After sorting and cleaning materials for the first time, the coarse solid waste is put into a grinder machine system (4th crushing) to crush debris into smaller size materials (commonly less than 20 mm). The remaining metal in the waste composition is separated using the magnetic system. The continuous process is performed until eliminating all metals in waste compositions. Finally, the waste composition is put into a filter system to obtain floating materials (e.g., small foams). The rest of the waste component (sinking materials) is screened using a vibrating machine in order to classify into three groups, including the size of smaller 20 mm, 10 mm, and 5 mm.

In the treatment process, recycling materials can be obtained automatically using crushing and sieving systems. It helps to facilitate the production of waste concrete, and it also reduces most of the hard-to-treat waste in cities.

4.2 Treatment technology for wood

It is known that there are many waste woods coming from construction activities and demolition of construction. A part of the waste wood can be reused as a need of homeowners. Most of most waste woods are treated for recycling activities such as making walls, wood pulp, plywood, or even fuel. The treatment and recycling of waste wood are commonly handled by enterprises that come from a waste recycling area.

Figure 7 shows the wood recycling process with several steps. First, inputting waste woods need to be cut into relatively small sizes according to the processing equipment sizes. It is noted that metals from waste wood should be eliminated before feeding into a crushing system. The woods are chopped into smaller sizes of wood pieces. The first sieve layer passes the standard chips, small chips, and dust, and the long chips are kept to be chopped again. The second layer of the sieve keeps the standard chips, and the unsatisfactory chips and dust are transferred to the furnace (boiler). Using standard wood chips, compressive and hydraulic jacking systems are utilized to form basic poly wood sheets (i.e., step 1). The poly wood sheets are then heated and treated to make the final products, as seen in the figure.

It is noted that when waste woods consist of metals (e.g., steel nails), the magnetic separation method should be applied to eliminate them from the wood chips.

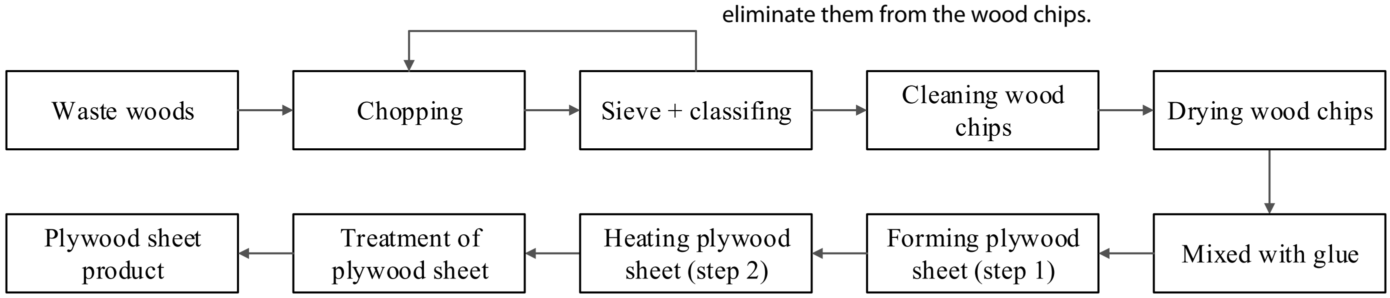


Figure 7. Schematic treatment technology for waste wood

4.3 Treatment technology for gypsum

Figure 8 shows the scheme of treatment technology for waste gypsum. At first, recycled gypsum is first passed through specialized crushing and screening equipment, and it is preliminarily sorted by manual method to separate certain metals, plastics, and other debris. Second, the remaining materials are then loaded into a large conveyor belt to separate non-ferrous metals and ferrous metals using an electromagnet system. Third, the non-ferrous materials are moved to the closed processing area where waste papers are separated from waste gypsum. Four, the separated gypsum is then shipped to specialized manufacturers to form new drywall products. Lastly, the waste paper is treated before being recycled for various applications (e.g., toilet paper).

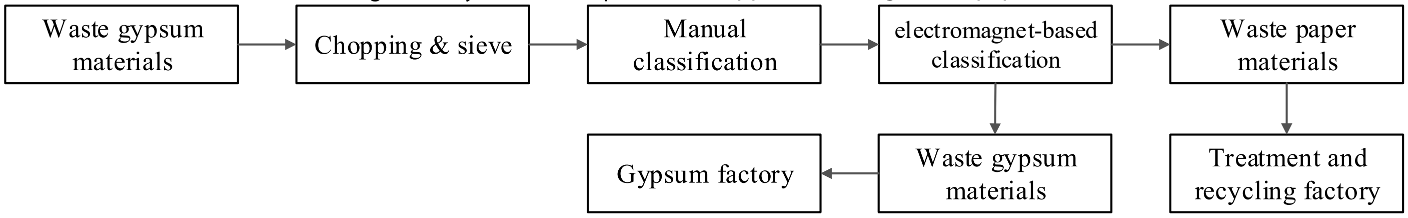


Figure 8. Schematic treatment technology for waste gypsum

4.4 Treatment technology for construction sludge

Figure 9 shows the scheme of treatment technology for construction sludge. A centrifugal sludge press machine is often used to treat construction sludge. First, the machine is moved to construction sites. Secondly, a specialized polymer is added to the sludge to coagulate suspended colloidal materials, flocculate suspended solids, and precipitate dissolved materials to separate them from water. Then, waste sludge is fed into the machine through a pressure vessel. Third, through valve and inlet pipes, dry sludge particles flow into the cage through the accelerator fan. Under the action of centrifugal force, most sludge is gradually separated from wastewater, and the remaining sludge in wastewater is also collected using the filtering system at the bottom of the rotating cage.

At the same time, the wastewater is poured into the container, and the treated sludge is moved from the small hopper to the larger hopper by rotating the shaft automatically. In the small hopper, the precipitated substances are pushed out using the screw. Meanwhile, the sludge enters the large hopper, it creates new sediment layers, and they are retained using the filter devices. The sediment layer, after being precipitated, is pushed out to make it dry. Finally, the dry sediment is pressed using the screw system placed at the end of the large water tank. After that, the sludge is pushed out of the machine.

As seen in Figure 9, the outputs of the treatment process are wastewater and dry sludge. So far, the wastewater from the centrifugal sludge machine needs to be filtered using the pressure method because the color wastewater is not satisfied the standard of current wastewater criteria. After that, the treated wastewater can discharge into the general collecting system of wastewater to move to the water treatment factory. Moreover, dry sludge can be mixed with other materials to be used for the backfill of construction sites.

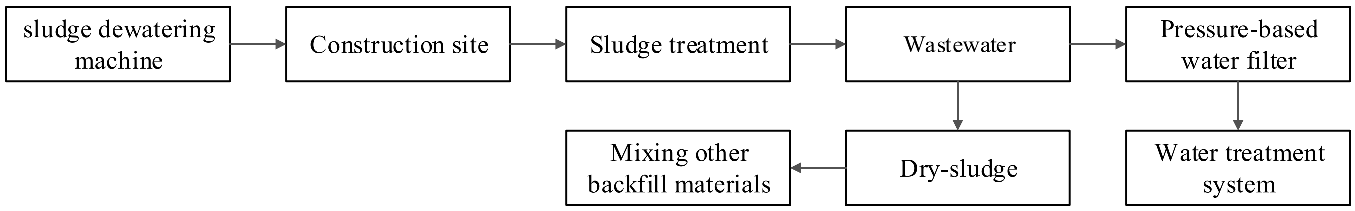


Figure 9. Schematic treatment technology for construction sludge

4.5 Treatment technology for waste metals

After separating metal materials from CSW components, metals are transferred to specialized recycling units in accordance with regulations. It is noted that the steel scrap and other metal materials can be directly reused, or they can be put into a furnace to make other recycled metal materials. It is estimated that about 90% of steel and 70% of aluminum are reused or recycled. It reveals the demand for the recycling of these materials.

4.6 Recycling of waste paper, cartons, and nylon

After preliminarily sorting using manual and machine to collect paper, cartons, and nylon, the materials are packed into separated blocks, and the packages are transferred to a competent unit for the next recycling work.

5. CONCLUDING REMARKS

Ho Chi Minh City has about 1500 tons of CSW (data in 2017, nearly 5 times the amount of MSW being treated at Hoa Phu waste treatment complex of Vinh Long province is about 350 tons/day at now), the treatment CSW is an urgent problem for this city.

In this study, the methods for treatment and recycling of construction solid waste were investigated. First, construction solid waste in HCM city, including source, amount, and composition, was briefly described. Second, the two ways of classification for treatment and recycling of construction solid waste were presented to illustrate the advantages. Last, the treatment technologies for construction solid waste components were presented.

For the study, the following concluding remarks can be drawn. First, the proposed technique is promising to be used for treating CSW to minimize environmental impacts. Second, the treatment technology for concrete debris can produce sand and coarse aggregate from CSW with less manual work. Third, depending on the equipment, the reused material after demolition has heterogeneous properties, porosity, and lower strength than natural aggregates. There should be general regulations guiding and recommending the use of recycled materials from the government or professional associations.

REFERENCES

1. Nations, U. (2019) World Population Prospects 2019: Highlights.

2. Ding, Y., Zhao, J., Liu, J.-W., Zhou, J., Cheng, L., Zhao, J., *et al.* (2021), "A review of China's municipal solid waste (MSW) and comparison with international regions: Management and technologies in treatment and resource utilization," *Journal of Cleaner Production*, vol. 293.

3. Alam, O., and Qiao, X. (2020), "An in-depth review on municipal solid waste management, treatment and disposal in Bangladesh," *Sustainable Cities and Society*, vol. 52.

4. Kaza, S., Yao, L., Bhada-Tata, P., and Van Woerden, F. (2018), *What a waste 2.0: a global snapshot of solid waste management to 2050.* World Bank Publications.

5. Kassim, S.M., and Ali, M.J.H.I. (2006), "Solid waste collection by the private sector: Households' perspective-Findings from a study in Dar es Salaam city, Tanzania," vol. 30(4), pp. 769-780.

6. Damghani, A.M., Savarypour, G., Zand, E., and Deihimfard, R.J.W.M. (2008), "Municipal solid waste management in Tehran: Current practices, opportunities and challenges," vol. 28(5), pp. 929-934.

7. Prajapati, K.K., Yadav, M., Singh, R.M., Parikh, P., Pareek, N., and Vivekanand, V. (2021), "An overview of municipal solid waste management in Jaipur city, India - Current status, challenges and recommendations," *Renewable and Sustainable Energy Reviews*, vol. 152.

8. Madon, I., Drev, D., and Likar, J. (2019), "Long-term risk assessments comparing environmental performance of different types of sanitary landfills," *Waste Manag*, vol. 96, pp. 96-107.

9. Moberg, Å., Finnveden, G., Johansson, J., and Lind, P. (2005), "Life cycle assessment of energy from solid waste-part 2: landfilling compared to other treatment methods," *Journal of Cleaner Production*, vol. 13(3), pp. 231-240.

10. Qu, S., Guan, D., Ma, Z., and Yi, X. (2019), "A study on the optimal path of methane emissions reductions in a municipal solid waste landfill treatment based on the IPCC-SD model," *Journal of Cleaner Production*, vol. 222, pp. 252-266.

11. Jain, P., Powell, J.T., Smith, J.L., Townsend, T.G., Tolaymat, T.J.E.S., and Technology (2014), "Life-cycle inventory and impact evaluation of mining municipal solid waste landfills," vol. 48(5), pp. 2920-2927.

12. Qiu, J., Lu, F., Zhang, H., Liu, W., Chen, J., Deng, Y., *et al.* (2020), "UPLC Orbitrap MS/MS-based fingerprints of dissolved organic matter in waste leachate driven by waste age," *J Hazard Mater*, vol. 383, pp. 121205.

13. Chen, W., Gu, Z., Ran, G., and Li, Q. (2021), "Application of membrane separation technology in the treatment of leachate in China: A review," *Waste Manag*, vol. 121, pp. 127-140.