Environmental and Climate Technologies
2022, vol. 26, no. 1, pp. 129–142
https://doi.org/10.2478/rtuect-2022-0011
https://content.sciendo.com

Automotive Hazardous Waste Management in Automotive Shops of Indonesia's Metropolitan City. Case Study: Bandung City, West Java Province

I Made Wahyu WIDYARSANA[1*], Aurilia Ayuanda MULYADI[2], Suci Ameliya TAMBUNAN[3]

[1–3] *Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Indonesia*

***Abstract* – The number of vehicles in Bandung City continues to increase every year in line with the growth of motorized vehicle repair shops, thereby increasing the generation of hazardous waste from automotive shop activities. Based on Indonesia's Governmental Decree 101 of 2014, vehicle maintenance and repair activities are one of the businesses that produce hazardous waste. This study focused on licensed and unlicensed automotive shops in Bandung City using stratified sampling methods by determining waste generation and composition, evaluating existing management systems, followed by developing management system alternatives. In determining the generation and composition of hazardous waste from automotive shop activities, a sampling of 42 unlicensed automotive shops and 11 unlicensed automotive shops in 3 areas of Bandung City was conducted. Sampling results of hazardous waste generation are 1.83 kg/vehicle/day for motorcycle automotive shops and 6.90 kg/vehicle/day for car automotive shops. The largest composition of hazardous waste produced in licensed shops is used oil with a proportion of 29.60 % and metal scrap component with a proportion of 35.83 % for unlicensed automotive shops. The projection results of hazardous waste generation in 2021 are around 774.26 tonnes/day. If the hazardous waste generated is not properly managed it can pose a risk to human health and the environment. An integrated management system for hazardous waste consists of packaging activity, storage activity, collection, transportation, and recycling activity.**

***Keywords* – automotive shops; hazardous waste generation; management; recycling**

1. INTRODUCTION

1.1. Background

The increase of populations happened annually and would cause an increase in vehicle needs followed by an increase in automotive shop growth. A lot of waste would be generated from automotive shops activities that were usually already contaminated with oils or solvents from the shops activities which would make them hazardous wastes that needed to be managed in the manner conformed to Governmental Decree No. 101 of 2014 concerning Management of Hazardous Wastes. Metal scraps, oil contaminated wastes, used lead-acid batteries, used oil filters and fuel filters are Hazardous Waste Category 1. Used oil, contaminated packaging, and contaminated absorbents are Hazardous Waste Category 2. In Indonesia especially in Bandung City there was not yet a specific regulation concerning hazardous automotive shops wastes. A lot of them were not well managed even though waste from the production and use of vehicles can greatly impact public health as well as

*Corresponding author.
E-mail address: imww.research@gmail.com

©2022 Author(s). This is an open access article licensed under the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0).

environmental conditions [1]. Even the consumers often mix automotive hazardous wastes with domestic wastes. Aside from the absence of specific regulation, an integrated system including proper packaging, storage, collection system, transportation and wastes recycling to manage these wastes is not available.

The application of automotive hazardous waste treatment can be started in big cities in Indonesia first. Big cities in Indonesia have a high level of consumption and means of transportation due to their population which is also more than other cities so that the amount of automotive waste generated will be a lot too. After the progress made in big cities, the system can be continued in cities with less population. The automotive waste management will also be continued with the processing of several components that can provide economic benefits. Where the processing of valuable components in workshop waste will be used as raw materials for further production. Therefore, the processing of workshop waste, especially metal components and used batteries, provides many advantages if carried out properly. To manifest the proper management for hazardous automotive wastes in Bandung City, an integrated system to manage the wastes is needed so all the hazardous wastes produced from automotive shops will be managed efficiently and produced environmentally friendly products which simultaneously boost their economic values.

1.2. Objectives

The objectives of this study are:

1. Identifying hazardous automotive shops waste generations and compositions in automotive shops of Bandung City.
2. Identifying the congeniality rate between automotive shops' hazardous waste management and applied regulations.
3. Determine the projection of hazardous waste generated by automotive shops in Bandung City.
4. Determining hazardous automotive shops waste management strategy covering systems and processing units in reduction, packaging, collection, transportation, and utilization of wastes in Bandung City.
5. Arranging Material Flow Analysis (MFA) for automotive shops in Bandung City.

2. METHODOLOGY

The methodology used in this study for management of automotive shops wastes are:

1. Literature Study and Preparation Stage.
2. This stage was done for the purpose of determining this study's scope and to help determine the output wanted for this study.
3. Primary and Secondary Data Collection.
4. The primary data consisted of observation results, questionnaires to consumers, and sampling data results. Secondary data were obtained from governmental institution such as (DLHK) Bandung City, (DPM PTSP) Bandung City, Industry trade and service's Bandung City, BPS Bandung City and BPD West Java Province consisting of licensed automotive shops in Bandung City, number of population growth, and number of vehicles growth. The sampling technique used is stratified sampling and the sampling is done in 8 days according to 19–3964–1994 National Standard of Methods for Collecting and Measuring Samples of Waste Generation and Composition of Municipal Waste with the automotive shops distributed equally in 3 areas according to Bandung City Regional Revenue Agencies area of service which

were Kota Bandung I (Pajajaran), Kota Bandung II (Kawaluyaan), and Kota Bandung III (Soekarno – Hatta). The area distribution and sampling locations are shown in Fig. 1.

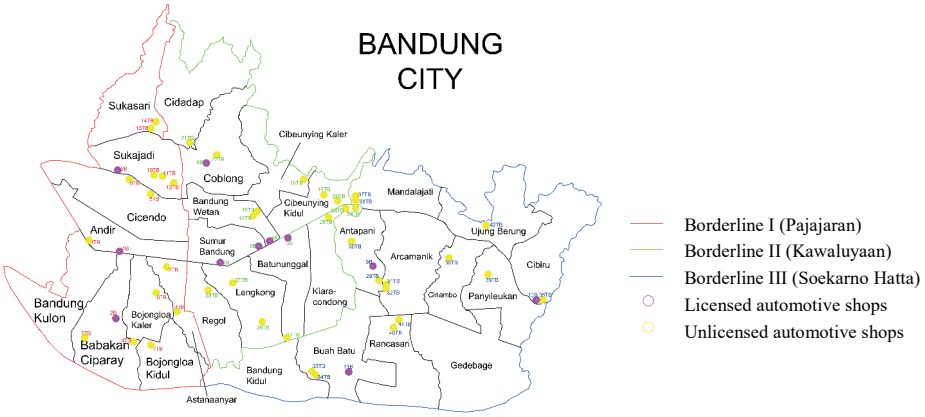


Fig. 1. Classification and sampling locations.

The number of samples is determined by doing a statistics approach. The number of populations for licensed automotive shops is known so the statistical approach would be to use Yamane formula (1967) (1) [2] with 95 % confidence interval and sampling error of 26.29 %. For the unknown number of populations in unlicensed automotive shops, the statistical approach would be to use Cochran formula (1963) (2) [3] with 80 % confidence level and sampling error of 10 %. The total number of samples for automotive shops are 11 samples for licensed shops and 42 samples in unlicensed shops. Those samples would be divided equally to every level.

$$n = \frac{N}{1 + N(e)^2}, \tag{1}$$

where N is population, n – number of samples, and e – level of accuracy.

$$n_0 = \frac{z^2 pq}{e^2}, \tag{2}$$

where:

n_o number of samples;
z critical values based on validity level wanted (z values);
p estimated proportions of attributes in populations;
$q = 1 - p$;
e level of accuracy.

Furthermore, waste generation and components can be calculated using formula (3) and formula (4) [4].

$$Waste\ Generation = \frac{Total\ HW\ in\ automotive\ shops\ (\mathrm{kg})}{Total\ vehicles\ (\mathrm{units/day})} \tag{3}$$

$$\%Components = \frac{Total\,Weight\,of\,1\,component\,(\mathrm{kg})}{Total\,waste\,weight\,(\mathrm{kg})} \cdot 100\% \quad (4)$$

3. RESULT AND ANALYSIS

In this part, all the data obtained will be processed and analyzed resulting in the calculation of total hazardous automotive waste generated, waste generation projection, Material Flow Analysis (MFA), and the integrated management system of hazardous automotive wastes in Bandung City.

According to 1999 US-EPA, hazardous waste generators which in this condition are automotive shops of Bandung City are divided into three categories, according to how much hazardous wastes they generate in a month [5]:

a) Large Quantity Generators (LQGs) generate greater than or equal to 1000 kg of hazardous waste per month;
b) Small Quantity Generators (SQGs) generate more than 100 kg but less than 1000 kg hazardous waste per month;
c) Conditionally – Exempt Small Quantity Generators (CESQGs) generate less than or equal to 100 kg of hazardous waste per month.

3.1. Analysis of Waste Generation and Composition of Hazardous Automotive Shops Waste

Based on automotive shops classification from 1999 US-EPA licensed automotive shops in Bandung City as the object of this study consisted of two shops in small quantity generators group, and nine shops in large quantity generators group. Table 1 showed waste generated in each category and wastes compositions is shown in Fig. 2.

TABLE 1. HAZARDOUS WASTE GENERATION IN LICENSED SHOPS

Automotive Shops Type	Shops	Hazardous Waste Generation, kg/day	Hazardous Waste Generation, kg/vehicle/day
Small Quantity	1	15.86	2.20
	2	28.70	13.70
	Average of Hazardous Waste Generation	22.28	7.95
Large Quantity	3	37.42	2.97
	4	47.56	2.64
	5	78.23	7.76
	6	97.92	9.26
	7	1387.77	13.52
	8	137.24	8.48
	9	154.55	8.56
	10	165.45	5.02
	11	187.27	10.72
	Average of Hazardous Waste Generation	254.82	7.66

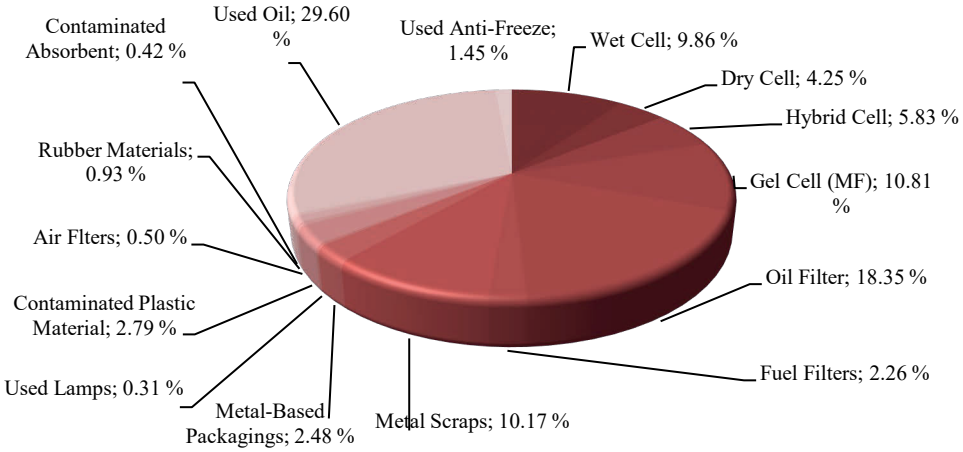


Fig. 2. Waste composition in Bandung City's licensed shops.

Based on the data shown it can be concluded that the average waste generation of small quantity generators in licensed shops is 7.95 kg/vehicle/day and the average waste generation of large quantity generators in licensed shops is 7.66 kg/vehicle/day with the most waste generated in licensed shops was used oil for 29.60 %. Meanwhile, unlicensed automotive shops in Bandung City as the object of this study consisted of 12 shops in the conditionally – exempt small quantity generators group, 39 shops in small quantity generators group, and 1 shop in large quantity generator group. Hazardous waste generated in each category is shown in Table 2, Table 3, and Table 4.

TABLE 2. HAZARDOUS WASTE GENERATION OF CONDITIONALLY EXEMPT SMALL QUANTITY GENERATORS IN UNLICENSED SHOPS

Shops Type	**Shops**	**Waste Generation, kg/vehicle/day**
Conditionally – Exempt Small Quantity	1	0.87
	2	0.56
	3	1.98
	4	1.08
	5	1.91
	6	2.46
	7	0.64
	8	1.84
	9	1.14
	10	1.43
	11	1.17
	12	2.99
Total Average	**1.51 kg/vehicle/day**	

TABLE 3. HAZARDOUS WASTE GENERATION OF SMALL QUANTITY GENERATORS IN UNLICENSED SHOPS

Shop Type	Shops	Waste Generation (kg/vehicle/day)	Shops	Waste Generation, kg/vehicle/day	Shops	Waste Generation, kg/vehicle/day
Small Quantity	13	0.92	23	3.49	33	0.84
	14	5.22	24	0.72	34	4.31
	15	9.69	25	1.15	35	9.24
	16	3.70	26	4.03	36	2.14
	17	3.89	27	1.81	37	6.86
	18	2.64	28	4.26	38	2.58
	19	2.70	29	1.42	39	4.09
	20	1.05	30	0.98	40	7.31
	21	1.28	31	5.39	41	4.26
	22	1.40	32	5.42		
Total Average	3.55 kg/vehicle/day					

TABLE 4. HAZARDOUS WASTE GENERATION OF LARGE QUANTITY GENERATORS IN UNLICENSED SHOPS

Shops Type	Shops	Waste Generation, kg/vehicle/day
Large Quantity	42	4.61
Total Average	**4.61 kg/vehicle/day**	

Based on the data shown it can be concluded that the average waste generation of conditionally exempt small quantity generators in unlicensed shops is 1.51 kg/vehicle/day, the average waste generation of small quantity generators in unlicensed shops is 3.55 kg/vehicle/day, and the average waste generation of large quantity generators in unlicensed shops is 4.61 kg/vehicle/day with the most waste generated in unlicensed shops was metal scraps for 35.83 % followed by 29.72 % of used oil as shown in Fig. 3.

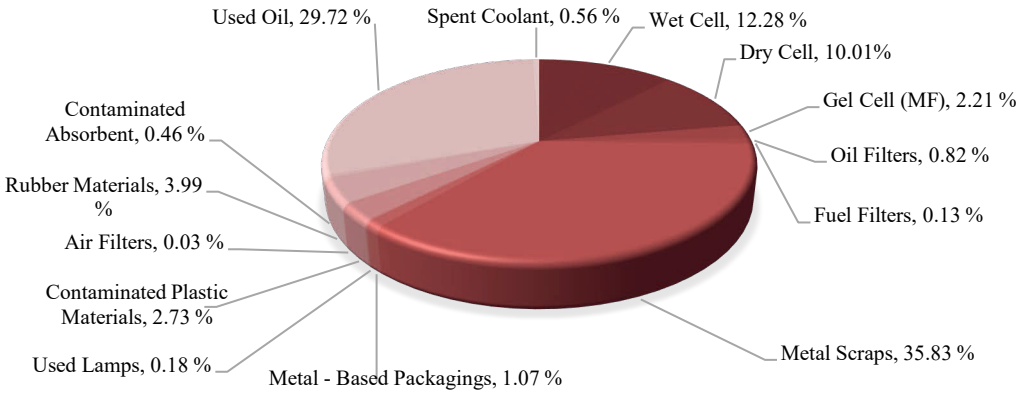


Fig. 3. Waste composition in unlicensed shops.

3.2. Normality and Correlation Test

In determining whether or not the obtained sampling data is normally distributed, a normality test is necessary. Normally distributed data is a bell-shaped and symmetrical data, which means the data is not inclined towards the left or right part of the graph and is considered to be a representative set of data. The normality test used is Shapiro – Wilk method which is efficient to test total samples below 50. IBM SPSS Statistics Version 24 is used to conduct the test, and the everyday data of waste generation is used in this test. This test is used to determine a representative value of waste generation that will eventually be used to project the waste generation in Year 2021 and Year 2040. Normally distributed data is shown to have a significance above 0.05 [6].

After a normality test is conducted, it is known that only car automotive shops are considered to be normally distributed data. As of the motorcycle automotive shops, the test results showed that the data is not normally distributed even after an outlier method is conducted on those data sets. So, the representative value is picked from the average or median value of the data. The waste generation value after the statistical test is shown in Table 5.

TABLE 5. STATISTIC TEST RESULTS

Category	Average/Median Value	Significancy
Car Shops Waste Generation	6.896	0.071
Motorcycle Shops Waste Generation	1.826	0.000

The next step would be to conduct a comparative or correlation test on waste generation data (kg/vehicle/day) to compare the relationship between average waste generated in licensed and unlicensed shops. The null hypothesis (H0) appointed is there is no difference in waste generated average value from licensed and unlicensed automotive shops. The motorcycle and car shops waste generation is joined for the purpose of this test. Based on the normality test conducted, it is known that the joined data is not normally distributed. So the comparative test is done using a non-parametric test with Mann – Whitney method, which the null hypothesis is accepted if the significance or asymp. sig (2-*tailed*) value is less than 0.05. Based on the comparative test using Mann – Whitney method, the significance shown to be 0.00 or less than 0.05, so it can be concluded that there is significant difference between waste generation average value in licensed and unlicensed shops and it could be caused by the difference in service scope, number of vehicles, and the service offered.

3.3. Projection of Hazardous Waste Generation

The waste generation projection is needed to determine the next system development needed to better manage the automotive shops hazardous waste including facilities and the management system affected by the waste generated every year. Historical data on the number of vehicles is obtained from the Central Statistics Agency of Bandung City [7].

Based on the projection result, the waste generated every year is increasing in number simultaneously with the growth of vehicles in Bandung City. The data projected in 2021 is the reference data for Material Flow Analysis (MFA) calculation. The waste generation growth is shown in Fig. 4.

TABLE 6. HAZARDOUS WASTE PROJECTION TO YEAR 2040 IN BANDUNG CITY

Year	Motorcycle shops HW generation, kg/day	Car shops HW generation, kg/day
2020	319 241.35	449 077.66
2021	331 321.07	464 051.15
2022	343 394.82	479 017.23
2023	355 462.60	493 975.91
2024	367 524.42	508 927.20
2025	379 580.27	523 871.11
2026	391 630.18	538 807.64
2027	403 674.14	553 736.79
2028	415 712.16	568 658.59
2029	427 744.24	583 573.02
2030	439 770.40	598 480.11
2031	451 790.63	613 379.86
2032	463 804.95	628 272.27
2033	475 813.36	643 157.36
2034	487 815.86	658 035.12
2035	499 812.46	672 905.57
2036	511 803.17	687 768.72
2037	523 787.98	702 624.57
2038	535 766.92	717 473.13
2039	547 739.98	732 314.40
2040	559 707.17	747 148.40

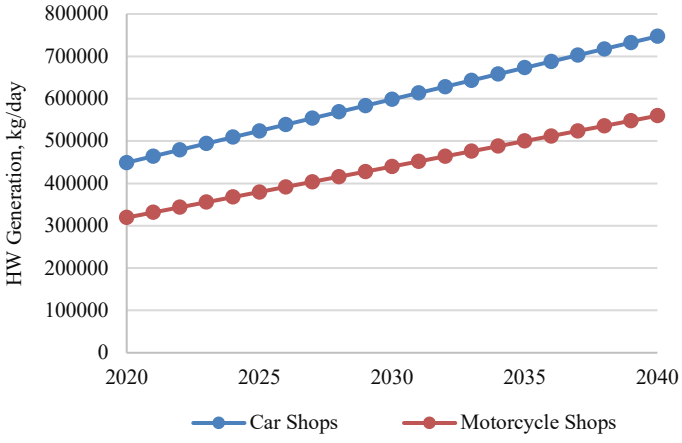


Fig. 4. Hazardous automotive shops waste generation projection in Bandung City.

3.4. Congeniality Rate Analysis between Automotive Shops' Management and Governmental Decree 101 of 2014

Based on observation conducted in automotive shops of Bandung City, the average congeniality rate between licensed shops and applied regulation was 78.67 % based on data in Table 7, which was above 50 %, so it could be categorized as good enough management. However, this value was still quite low considering the danger of hazardous waste in the environment was grave if it was left untreated or wrongly treated. So, an integrated and regulation-based management system was very much necessary. The congeniality rate between the unlicensed automotive shops and applied regulations was really low amounting to only 19.82 %. This value showed that there were still a lot of regulations system disobeyed by unlicensed automotive shops. Some evaluation from licensed automotive shops that will be taken into consideration while determining hazardous waste management system are, (1) not keeping records of the amount of hazardous waste nor the records about waste identification; (2) not pasting labels and symbols of hazardous waste in waste packaging; (3) not preparing and reporting the management activities report to government.

TABLE 7. CONGENIALITY RATE IN AUTOMOTIVE SHOPS MANAGEMENT TO APPLIED REGULATIONS

Hazardous Waste Management	Average Percentage
Licensed Shops	78.67 %
Unlicensed Shops	19.82 %

3.5. Automotive Shops Hazardous Waste Management System Strategy

The end-of-life vehicle management is such a crucial issue to deal with the actors like governments, producers, treatment facilities and users. Due to regulations and new legislation, it is becoming even more important both environmentally and economically [8]. The existing condition showed that the management system for hazardous waste in general is still not well integrated. The packaging of wastes including symbols and labels is still not well done. Based on the observation, it is known that 45.24 % of automotive shops still store their hazardous wastes outside of the shops area where they were exposed to sun and rain. Based on Governmental Decree Number 12 of 2020 concerning Hazardous Waste Storage, the storage of wastes has to have enough protection from sun and rain exposure. Moreover, there are 18.18 % of automotive shops that don't have hazardous waste temporary storage.

The alternatives proposed for an integrated automotive shops management include collection activity, packaging activity, and waste transporting activity. The alternatives proposed for waste collection is to provide collection points spread in 4 areas of Bandung City (North Bandung, West Bandung, East Bandung, South Bandung). These collection points are provided by TPS 3R around the area and the additional 2 areas in North Bandung that don't have TPS 3R. Fig. 5 shows the spread of collection points in Bandung City.

The alternatives for packaging and transporting activity as a support facility will be chosen by weighting the criteria of both activities. Based on Governmental Decree Number 12 of 2020 about Hazardous Waste Storage, the package advised for solid hazardous wastes is cubic yard container and jumbo bag. Steel drum and IBC tank are the package advised for liquid hazardous waste. These waste packaging had to have appropriate symbols and labels to the waste contained there. The symbols given are toxic, flammable liquid, and flammable solid completed with labels corresponding to the waste characteristics contained inside.

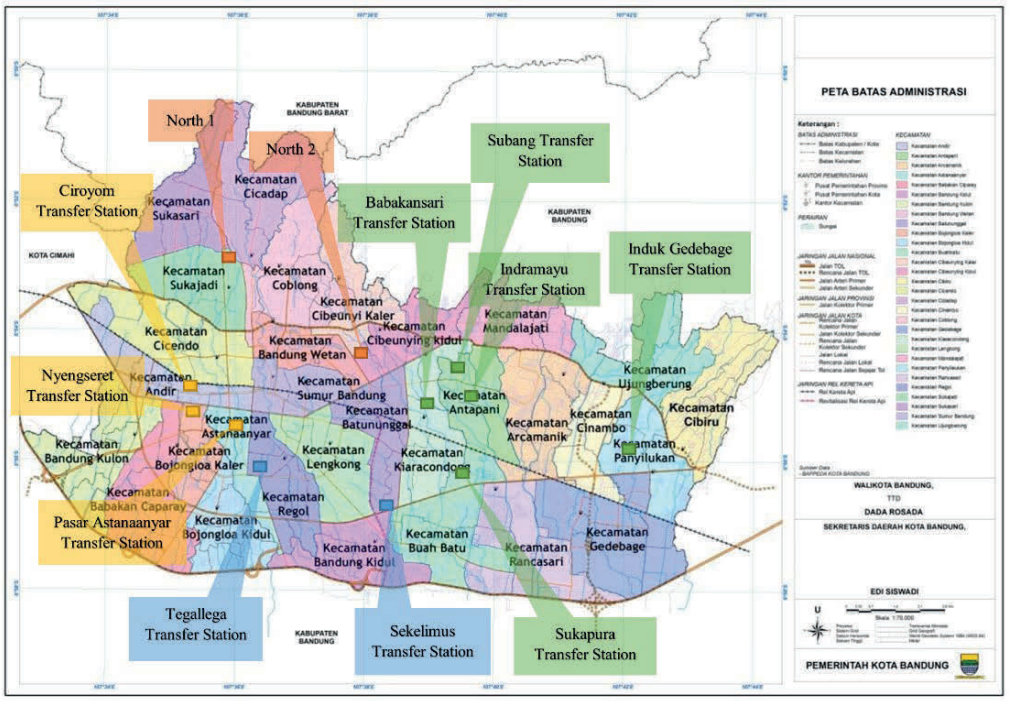


Fig. 5. Automotive shops' hazardous waste collection system [9].

TABLE 8. HAZARDOUS WASTE CHARACTERISTICS [10]

No	Hazardous waste	Characteristics of hazardous waste
1	Used coolant	Toxic
2	Used lamps	Toxic
3	Used oil	Flammable liquid
4	Contaminated absorbents	Flammable solid
5	Used lead-acid battery, contaminated metal scraps, and metal-based packaging	Toxic
6	Oil filters and fuel filters	Toxic and flammable solid

Based on Governmental Decree Number 4 of 2020 about Hazardous Wastes Transportation, the proper vehicle to transport the wastes has to be a four – wheeled or more vehicle, including the company information, and pasted with appropriate symbols and labels. The recommended transportation vehicle for waste category 1 is a closed vehicle like truck box and wing box truck.

The alternatives are chosen using the Simple Additive Weighting (SAW) method. The criteria used for the weighting consideration is chosen by priority [11]. The ranks of each alternative is chosen with the rank scale from 1 to 4. The higher the scale, the more the criteria meets the need [12]. The value 1 means very low, 2 is low, 3 is high, and 4 is very high. The criteria used for the weighting consideration is shown in Table 6.

TABLE 9. ALTERNATIVES WEIGHTING CRITERIA

Criteria	Criteria Information	Criteria, weight	Criteria, %
C1	Procurement Fee	8	8
C2	Operational Fee	11	11
C3	Operation and Maintenance Convenience	11	11
C4	Environmental Damage Potential	13	13
C5	Influence on Human Health	11	11
C6	Lifetime	11	11
C7	Land Requirements	11	11
C8	Suitability to Hazardous Wastes Characteristics	13	13
C9	Operator Readiness	11	11

Based on the weighting done on every alternative proposed with Simple Additive Weighting, the chosen alternatives have the maximum value. The chosen alternatives for solid hazardous waste packaging activities is a cubic yard container with maximum value of 0.96 and also 0.96 for liquid hazardous waste packaging using steel drum. The chosen alternatives for transportation vehicles are wing box trucks with maximum value of 0.96. After the collection is done, the next process is to recycle waste with feasible economic value such as metal scraps, metal – based packaging, oil filters, fuel filters, used lead – acid battery, used rubber material, contaminated plastic materials, used oil, and spent coolant. Battery cells recycled with cupola furnaces and used spare parts went through thermal process before combined with scrap metals recycling then shredded with scrap metal shredder, sorted with magnetic drum and eddy current separator, melted with electric arc furnace followed by solidification and distribution. This process has a very high recovery rate around 96 % [13]. Recycled used oil produces base oil products [14], recycled plastic materials produce plastic pellets [15], recycled used radiator liquid produces pure glycol [16], recycled rubber materials produce carbon black, and steel wire and synthetic oil [17]. An integrated hazardous waste management system, starting from packaging, storage, collection and transportation activities is shown in Fig. 6.

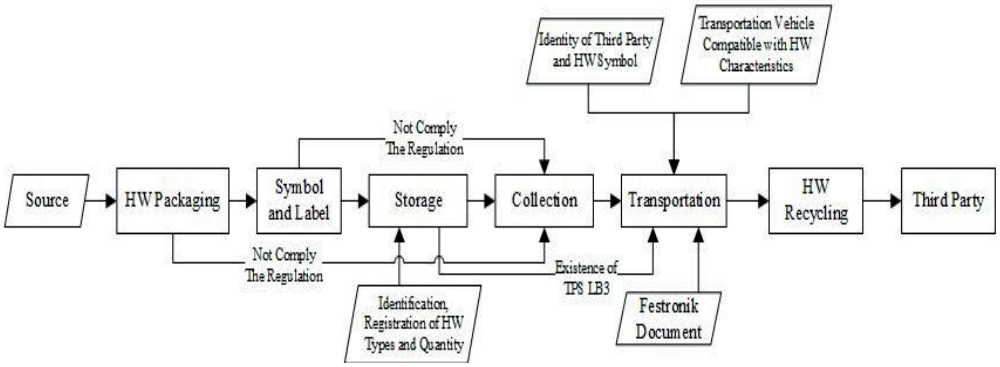


Fig. 6. Integrated management system of automotive shops hazardous waste in Bandung City.

3.6. Material Flow Analysis (MFA)

The waste flow in this analysis is based on consumer behaviour towards their automotive waste that they took home and wastes that were sent home to the consumers according to

automotive shops' data. In this calculation, the waste generation for liquid hazardous waste will be converted to mass units. Waste generation value used as a multiplier factor is the normally distributed data tested with IBM SPSS Version 24. The material flow analysis of hazardous automotive waste in Bandung City year 2021 is shown in Fig. 7. Based on the material flow shown it is known that only 5.07 % of hazardous waste were recycled. 6.26 % wastes were dumped to the environment while 6.10 % were dumped and mixed together with domestic wastes. An integrated management system is one of the solutions to solve the problems in hazardous waste management in automotive shops.

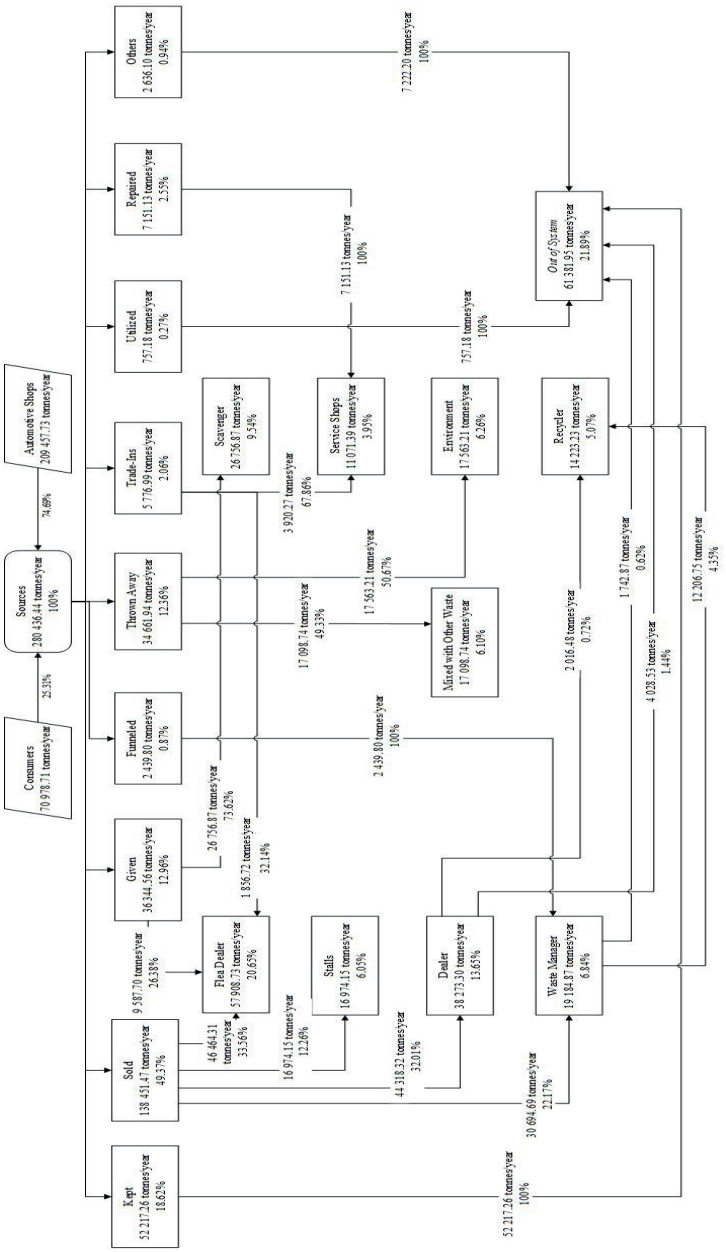


Fig. 7. *Material Flow Analysis* of hazardous automotive waste in Bandung City Year 2021.

4. CONCLUSION

The average value of hazardous waste generation in small quantity licensed shops is 7.95 kg/vehicle/day and 7.66 kg/vehicle/day for large quantity licensed shops with the most waste generated in licensed shops is used oil for 29.60 %. As for the average value of hazardous waste generation in conditionally – exempt small quantity unlicensed shops is 1.51 kg/vehicle/day, 3.55 kg/vehicle/day for small quantity unlicensed shops and 4.61 kg/vehicle/day for large quantity unlicensed shops with the most waste generated in unlicensed shops is metal scraps for 35.83 %. The projection of hazardous waste produced in car shops in 2020 is 464 051.15 kg/day and 331 321.07 kg/day in motorcycle shops. The congeniality rate between licensed automotive shops and Governmental Decree Number 101 of 2014 was 78.67 % and 19.82 % for unlicensed automotive shops. The integrated system to manage automotive shops hazardous waste consisted of twelve collection points spread across Bandung City. In those collection points, the chosen alternatives for packaging are cubic yard containers for solid hazardous waste and steel drums for liquid hazardous waste. The alternative chosen as a transportation vehicle is a wing box truck. Total waste generation used for this Material Flow Analysis calculation came from metal components waste, used lead – acid battery, non-metal components waste, and used oil from Year 2021 for 280 436.44 tonnes/year. Based on the material flow shown it is known that there were a lot of automotive shops' hazardous wastes still unaccounted for and did not comply with the regulations used. Some wastes are also still dumped to the environment and mixed with other domestic wastes. The recycling percentage is also very small with only 5.07 % wastes go to formal recyclers. Therefore, a more specific regulation and a better and integrated management system are needed to ensure proper automotive waste management as discussed in this research.

REFERENCES

[1] Giacomin H., Unno, M., Eichbauer, K., Atkins, C. Automotive wastes. *Water Environment Research* 2019:91(10):1223–1228. https://doi.org/10.1002/wer.1217
[2] Yamane T. Statistics: An Introductory Analysis. 2nd Edition. New York: Harper and Row, 1967.
[3] Johnson D., Shoulders C. Beyond Magic Words and Symbols: Rethinking Common Practices in Quantitative Research. *Journal of Agriculture Education* 2019:60(3):291–303. https://doi.org/10.5032/jae.2019.03291
[4] National Standardization Agency of Indonesia. Sampling Methods for Collection and Measurement of Municipal Waste Generation and Composition. 1994.
[5] United States Environmental Protection Agency. RCRA in Focus Vehicle Maintenance. United States of America, 1999.
[6] Gravetter F. J., Wallnau L. B. Statistics for the Behavioral Sciences. 9th Edition. USA: Jon-David Hague, 2013.
[7] Bandung City Central Bureau of Statistics. Bandung City in Numbers [Online]. [Accessed 21.09.2020]. Available: https://bandungkota.bps.go.id/
[8] Karagoz S., Aydin N., Simic V. End-of-life vehicle management: a comprehensive review. *Journal of Material Cycles and Waste Management* 2020:22(2):416–442. https://doi.org/10.1007/s10163-019-00945-y
[9] Bandung City Regional Development Planning Agency, 2013.
[10] CalPoly Pomona. Automotive Waste Requirements [Online]. [Accessed 21.09.2020]. Available: https://www.cpp.edu/ehs/portals/environmental/automotive-waste.shtml
[11] Ibrahim A., Surya R. A. The Implementation of Simple Additive Weighting (SAW) Method in Decision Support System for the Best School Selection in Jambi. *Journal of Physics* 2019:1338(1). https://doi.org/10.1088/1742-6596/1338/1/012054
[12] Haswan, F. Application of Simple Additive Weighting Method to Determine Outstanding School Principals. *SinkrOn* 2019:3(2):186. https://doi.org/10.33395/sinkron.v3i2.10082
[13] UNIFE – The Europian Rail Industry. Rail Vehicles Recycling. Belgium, 2014.
[14] Nandyojati K. The Design of Separation Process of Heavy Fractions in Used Lubricating Oil with Vacuum Distillation and Thin Film Evaporator. Sepuluh Nopember Institute of Technology, 2017.
[15] Chandara, Hin, Sunjoto, Sarto. Plastic Recycling in Indonesia by Converting Plastic Waste (PET, HDPE, LDPE, and PP) Into Plastic Pellets. National Polytechnic Institute of Cambodia, 2015.

[16] Sequoia Global. Coolants or Antifreeze Recycling. [Online]. [Accessed 21.09.2020]. Available: https://www.sequoia-global.com/coolant-recycling/

[17] Rowhani A., Rainey T. J. Scrap Tyre Management Pathways and Their Use as a Fuel-A Review. Basel: Multidisciplinary Digital *Energies* 2016:9(11):888. https://doi.org/10.3390/en9110888