Minimization of household hazardous solid waste (HHSW) with 4R concepts (reduce, reuse, recycle and recovery) in Padang City, Indonesia

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Abstract. Improper management of hazardous waste originating from household activities will potentially pose a threat to health and the environment. Management of hazardous waste includes minimization activities and hazardous waste treatment. This study aims to analyze the existing conditions and potential minimization of Household Hazardous Solid Waste (HHSW) with the 4R concept, namely Reduce, Reuse, Recycle and Recovery in Padang City. HHSW minimization data was obtained through the analysis of questionnaire data distributed to several HHSW generation sources in Padang City, while the minimization potential was obtained from the existing literature review. The minimization of the existing HHSW was 17.4% (2,067 kg/day) from the total HHSW generation in Padang City. This minimization activity consisted of 11.6% reduce activities, 2.2% reuse activities and 3.6% recycle activities. From the calculation and literature study, the potential of minimizing HHSW was 51.2% (6,081 kg/day) which consists of 11.6% reduce potential in the form of large volumes of HHSW packaging purchases, 18.7% reuse potential through the return of product packaging to producers in the Environmental Producer Responsibility (EPR) program, 13.2% recycle potential in the form of oil can recycling, bulbs and cartridges, and 7.7% recovery potential by recovering metal content in batteries and car battery.

1. Introduction
Among various wastes generated from household activities (domestic), there is waste classified as hazardous waste or known as household hazardous solid waste (HHSW). These types of HHSW include used packaging from cleaner products, body care products, cosmetics, paints, lubricant, batteries, and light bulbs that generally contain irritating or other health problems such as metal mercury contained in the battery [1], [2]. Although HHSW is small, it has the characteristics of explosive, flammable, reactive, toxic, infectious, and corrosive, thus endangering the health and environment of water, soil, and air [3]. According to the Government Regulation of the Republic of Indonesia No. 101 of 2014 [4], hazardous materials are substances, energy and/or other components which due to their nature, concentration and/or amount, either directly or indirectly can pollute and/or damage the environment, and/or endanger the health, and the survival of humans and other living things. Burning, dumping or stockpiling HHSW containing heavy metals along with other domestic waste in a residential area or final disposal site can cause health problems for surrounding communities, as happened in China, India, and Ghana. Heavy metals mixed with organic waste for a
certain period of time will experience leaching and produce leachate which contains heavy metals so that it has the potential to contaminate soil or groundwater, which then enters the food chain to plants, animals and finally into the human body [5].

Seeing many impacts caused by hazardous waste, hazardous waste management needs to be done. According to Regulation of Republic of Indonesia Government No. 101 of 2014 [4], hazardous waste management activities include reduction, storage, collection, transportation, utilization, processing and stockpiling. This activity is intended so that the waste produced by each production unit is as little as possible and even cultivated to zero, by striving to use the resources with material management, material substitution, operating activities, and the use of clean technology. If hazardous waste is still produced, it is necessary to utilize hazardous waste which includes reuse, recycle and recovery. The activity of reducing and utilizing hazardous waste is a waste minimization activity.

Padang City is the capital city of West Sumatra Province classified into a big city with a population of 2014 approximately 889,646 inhabitants [6]. Waste management in Padang City is handled by the Environment Agency. However, the management of HHSW has not been carried out. This waste still mixed with other municipal waste both in storage, collection, transportation, and final processing. The results of research on heavy metal content at the last disposal site at Air Dingin Padang showed that the concentrations of Hg, Pb and Cd had exceeded the maximum limits set nationally. That was allegedly due to the contamination of HHSW which was also disposed of with other non-hazardous waste [7].

From researches that have been conducted in the city of Padang, there was a type of HHSW in waste-producing sources. For domestic (household) sources, the HHSW generation was 3.280 tons/day with 0.041 L/cap/day in volume units or 0.004 kg/cap/day in weight units. The higher the level of community income, the greater the generation of household hazardous generated. The percentage of HHSW in domestic waste was 1.88%. Based on the type of usage, the largest composition of HHSW from domestic sources was 51% body care and 39% cleaning products, which were generally produced from 45% bathrooms and 26.7% bedrooms. Based on the characteristics, HHSW from these households was toxic, carcinogenic, corrosive and flammable by 34% [8]. This HHSW not only results from household activities but also results from activities in commercial sources, institutions, industries and city service facilities. The result of the study of Ruslinda et al. showed the percentage of hazardous waste generation in the total commercial waste in Padang City was 2.58% with an average generation in weight units 0.0022 kg/m²/day or in volume units 0.0727 L/m²/day. HHSW from this commercial source comes from shops, hotels, salons, and workshops. The composition of HHSW was based on the type of use consisting of 47% cleaner products, 20% body care, 14% automotive products, paint and the like 5%, pesticides, 5% insecticides, and herbicides and 9% other products. Based on its characteristics, the composition of HHSW was corrosive 39%, toxic 25%, corrosive and toxic 16%, flammable 10%, toxic and flammable 8% and corrosive and flammable 2% [9].

Based on data from the research results and the composition of HHSW that have been carried out, it is necessary to plan HHSW management systems. In hazardous waste management, the activity that needs to be done first is the minimization of hazardous waste through the concept of 4R (Reduce, Reuse, Recycle, Recovery). By minimizing hazardous waste through the 4R concept, it is expected not only to reduce the number of existing HHSW generation but also to make the presence of HHSW can be delayed and reduce the possibility of mixing HHSW with other waste. The purpose of this study was to study the minimization of HHSW with the 4R concept in Padang City from various waste components in various sources.

2. Material and Method
The study of HHSW minimization with the 4R concept in this study was conducted at each source of HHSW producers including household, commercial, institutional, industrial and city services. This research stage consists of a literature study, data collection, data processing, and analysis. The material
used in this study consisted of questionnaires and scales used to weigh the number of HHSW which were minimized by the 4R concept.

Data collection includes collecting secondary data and primary data. Secondary data needed in this study were general description of Padang City, the number of domestic, commercial, institutional, industrial and city services in the city of Padang which was used as a reference in determining the number of questionnaires obtained from the Central Statistics Agency of Padang, the number of generation and the composition of the Padang City HHSW obtained from research of Ruslinda [10].

Primary data collection was carried out by distributing questionnaires to each source of HHSW producers and interviews with relevant agencies in waste management and the environment in Padang City, namely the Environmental Office of Padang City. The determination of the number of questionnaires was based on SNI 19-3964-1994 concerning the collection and measurement method of municipal solid waste generation and composition. From the calculation results obtained the number of questionnaires distributed as 74 pieces with data reliability value of 93.75%. Details of the number of questionnaires consist of 30 domestic sources, 14 commercial sources, 15 institutional sources, 5 industrial sources, and 10 city service sources. The distribution of questionnaires for domestic sources was based on the level of income of the community, namely High Income (HI), Medium Income (MI), and Low-income (LI), and based on the location of residential houses in the urban area and rural area. For commercial sources, questionnaires were distributed to sources of shops, hotels, restaurants, salons, and workshops, while for institutional sources represent educational facilities, office facilities, and health facilities. The distribution of questionnaires for industrial sources was based on industrial categories, namely large, medium, and small industries. For city service sources, questionnaires were distributed on recreational facilities, beaches, parks, and roads.

Before the distribution of questionnaires, socialization of the types of HHSW was explained to respondents, so that respondents understood the waste they produced was classified as HHSW. Questionnaire data needed to include public knowledge about HHSW, the number of HHSW generated and the minimization of HHSW with the 4R concept that had been conducted by respondents. Then processing and analysis of questionnaire data and interviews. Data processing included the percentage of respondents' knowledge about HHSW, the percentage of HHSW minimization with the 4R concept that had been done by the respondents and the potential of HHSW minimization in Padang City from each source. The analysis of the potential of HHSW's minimization was based on the literature and references to the minimization of HHSW in other cities in Indonesia and abroad that have implemented hazardous waste minimization programs.

The existing calculation of the minimization of the HHSW in Padang City was done by calculating each of the 4R minimization activities, including reduce, reuse, recycle, and recovery as follows:

- **Reduce** (R1), minimization by reducing concept activities, including purchasing goods in large volumes, thereby reducing the amount of waste produced. The percentage of minimization by reducing concept was obtained by comparing the packaging weight of large volumes with the weight of small volume packaging (sachets), the difference in packaging weight was calculated as a reduction.
- **Reuse** (R2), minimization by reuse activities was carried out by reusing HHSW packaging for the same purposes or different needs without going through physical, chemical, biological and thermal processing. The percentage of minimization by reuse was obtained by calculating the HHSW weight ratio which is reused using the total weight of HHSW.
- **Recycle** (R3), minimization by recycling was done by recycling HHSW through physical, chemical, biological or thermal processing. Percentage of recycling minimization was obtained by calculating the weight ratio of HHSW recycled with the total weight of HHSW.
- **Recovery** (R4), minimization by recovery was carried out by recovering HHSW components with chemical, physical, biological, and thermal processes. Percentage of recovery minimization was obtained by calculating the weight ratio of HHSW which was recovered with the total weight of HHSW.
3. Result and Discussion

3.1. HHSW Knowledge and Socialization

The percentage of knowledge of each source about HHSW was known through the respondent's answer to the questionnaire given. Respondents were considered to know HHSW if they recognize 3 of the 5 HHSW listed in the questionnaire and can define HHSW simply. Institutional sources were sources that have the highest knowledge about HHSW. Of the 15 respondents, those who had knowledge about HHSW were 7 respondents or 47% of the total respondents. Furthermore, industrial facilities amounted to 33%, with commercial facilities at 9% and at domestic facilities at 3%. For urban service sources, respondents did not know HHSW. Figure 1 shows the percentage of people who know about HHSW.

By processing questionnaire data, the average number of the community of the Padang City that knows HHSW was 16%. Some factors that influence a person's knowledge about waste management include education, experience, age, and information sources [11]. In addition, it caused a lack of public knowledge about HHSW in Padang City because the community had never received socialization about HHSW.

![Figure 1. Knowledge of Padang City Community about HHSW](image)

3.2. Existing HHSW Minimization

Waste minimization is a process to reduce waste flow by reducing waste sources, reusing, recycling waste, and reallocating resources [12]. Data on the existing condition of HHSW minimization of Padang City based on the waste component can be seen in Table 1. This data was obtained from the results of questionnaire processing distributed to HHSW sources in Padang City and HHSW generation and composition data from research of Ruslinda et al. The occurrence of the HHSW of Padang City was 11.875 tons/day with HHSW generation unit as 16 g/cap/day. The composition of the HHSW of Padang City was based on the type of use which consists of cleaner products 24%, body maintenance 37%, automotive products 11%, paint and alike 12%, pesticides and insecticides 4% and other products 12% [10]. Based on questionnaire data and HHSW generation and composition data from research of Ruslinda et al. the percentage of HHSW minimization that has been done in Padang City was 17.4% (2,067 kg/day), which consists of 11.6% reduce (1,378 kg/day), reuse 2.2% (262 kg/day) and 3.6% recycle activity (427 kg/day). HHSW recovery activities have never been carried out.

The Reduce activity was generally carried out on waste components that were used as cleaner products such as floor cleaners, toilets, glass, and body treatments such as used packaging, soap, cosmetics and automotive products such as used oil packaging. The reduce activity that was done by avoiding the use and purchase of products that produce large amounts of waste. Waste producers from institutional sources such as education facilities, offices, and health often purchase large volumes of cleaner products with a reduced percentage of 19%. Likewise, with commercial sources such as hotels,
restaurants and salons with a 5% reduce percentage. For domestic sources, high income and medium income people tend to buy products in large volumes, thereby reducing the amount of waste produced when compared to the purchase of products in small volumes (sachets). The percentage of HHSW reduction in the high-income group was 16%, medium-income was 11%, and low-income was only 3%. Low-income people generally buy cleaner and body care products in small volumes (sachets) [8]. Oil packaging reduces only carried out on commercial sources, namely 3% workshop. In urban service sources, minimization by reducing concept was done on chlorine packaging produced from swimming pool facilities. In addition to reducing waste generation, respondents buy large products because of its economical.

Reuse activities have been carried out on waste components which were used as body treatments such as shampoo, soap, and cosmetics. This activity was carried out at domestic sources in the form of refilling cosmetic products so that the container or packaging can be re-used. In addition, reuse activities were also carried out by reusing used paint cans and oil cans, which were carried out by domestic sources and workshops. New recycle activities carried out by industrial sources by recycling oil and light bulbs packaging, in collaboration with third parties.

**Table 1. Existing HHSW minimization of Padang City based on waste component**

| Usage type       | HHSW type                                    | HHSW composition kg/day | Existing minimization (kg/day) | Existing minimization (%) |
|------------------|----------------------------------------------|-------------------------|--------------------------------|---------------------------|
| Cleaner product  | Toilet, floor & glass cleaner packaging      | 2,138                   | 18                             | 689 0 0                   | 5.8 0 0                   |
|                  | Cloth cleaner packaging                      | 594                     | 5                              | 48 0 0                    | 0.4 0 0                   |
|                  | Chlorine packaging                           | 95                      | 0.8                            | 95 0 0                    | 0.8 0 0                   |
|                  | Shoe polish                                  | 24                      | 0.2                            | 0 0 0                     | 0 0 0                     |
| Body care        | Shampoo packaging, soap & cosmetics          | 4,038                   | 34                             | 475 48 0                  | 4 0.4 0                   |
|                  | Expired drugs                                | 356                     | 3                              | 0 0 0                     | 0 0 0                     |
| Automotive       | Lubricant packaging                          | 1,188                   | 10                             | 71 214 261                | 0.6 1.8 2.2               |
|                  | Car battery                                  | 118                     | 1                              | 0 0 0                     | 0 0 0                     |
| Paint and alike  | Paint tin can                                | 1,425                   | 12                             | 0 0 0                     | 0 0 0                     |
| Pesticide, Insecticide | Insecticide packaging | 475                     | 4                              | 0 0 0                     | 0 0 0                     |
| Others           | Light bulb                                   | 712                     | 6                              | 0 0 166                   | 0 0 1.4                   |
|                  | Battery                                      | 356                     | 3                              | 0 0 0                     | 0 0 0                     |
|                  | Cartridge                                    | 356                     | 3                              | 0 0 0                     | 0 0 0                     |
| Sub-Total        |                                              | 11,875                  | 100                            | 1,378 262 427             | 11.6 2.2 3.6              |
|                  |                                              |                         |                                | 2067                      | 17.4                      |

Note: R1= Reduce, R2= Reuse, R3=Recycle

**3.3. HHSW Minimization Potential**

Analysis of the minimization potential of each HHSW type was based on the existing literary literature, both from the results of the research and the application of HHSW minimization that has been carried out in several cities — especially in developed countries. For plastic type, HHSW packaging such as toilet cleaner, flooring, glass, detergent, soap, shampoo, and cosmetics packaging,
minimization can be done by reuse of the packaging. Reuse of this plastic packaging can be done by returning the packaging to the manufacturer or factory in the Environmental Producer Responsibility (EPR) program, thereby reducing production for the packaging. In Japan, this has been done for plastic bottle packaging. The amount of EPR depends on the number of products produced, for example from 1000 tons of plastic packaging produced, producers are obliged to reuse 84 tons or 9% with the EPR program. The percentage of EPR is not too large, because the re-collecting plastic waste packaging is more difficult than recycling plastic [13]. Reuse can also be done for packaging in the form of cans such as paint cans and oil cans, which can be used for the same function or different functions.

From the literature, the potential for recycling can be made for oil can components, light bulbs, and cartridges. Oil cans can be recycled into rail pads [14]. The aluminum content in the light bulb can be recycled into scrap metal, while the glass material is recycled into a ceramic material [15]. Potential of minimization for cartridges can be done by separating the parts, the toner can be recycled into materials to make the road surface, and the remaining ink can be used for the printing industry, while the plastic can be recycled again [16]. Minimization by recovery concept can be applied to car batteries, light bulbs, and batteries. Tin metal in a car battery can be recovered through hydrometallurgical methods with an efficiency level of 90% [17]. With the same method, for the battery recovery can be done by 56% consisting of 25.6% Zn content and 30.1% Mn [18]. Neon type light bulbs (CFL) can be recovered by extracting mercury content into thermostat products. For HHSW types in the form of shoe polish packaging, drug packaging and mosquito spraying packages cannot be re-used, based on the existing literature. The Vancouver government on its official website [19] states that shoe polish packaging cannot be used. Expired drug packaging cannot also be used, because it is toxic and will cause danger if minimization is carried out. For insecticide packaging such as mosquito sprayers, it is potentially dangerous because the former cans tend to be pressurized.

Based on the literature review above, the potential of HHSW minimization was calculated in Padang City for each waste component. In the existing condition, the community has minimized by reducing activities by 11.6% (1,378 kg/day) with the effort to purchase cleaner and care products in large volumes. Although most respondents carried out this activity with a reason to save costs, there were also some respondents who had realized their activities were one of the efforts to minimize waste. It was estimated that this reduction activity has a potential of 11.6% according to existing conditions. HHSW minimization with the concept of reuse can be increased from the existing condition which was only 2.2% (262 kg/day) to 18.7% (2,221 kg/day). The activities that can be carried out were the reuse of HHSW packaging, especially for cleaner, body care, and oil packaging components. This reuse activity can be increased through the Environmental Producer Responsibility (EPR) program, as has been done in Japan, with a potential level of 9% [13]. The industry as a product producer must be responsible for the reuse of waste produced [20]. In addition, the community as a waste producer is asked to participate in collecting HHSW packaging in the form of cleaner and body care products to the collecting points that have been provided, to be transported to the industrial producers. In its implementation, the EPR program can work with the waste bank or waste processing facility (abbreviated as TPS3R and TPST in Indonesian) which already exists in Padang City. The community saves the waste from the HHSW packaging cleaner products and body care to the waste bank, and then the waste bank will resell this waste to a third party, namely the producer. Waste banks, TPS-3R and TPST can act as collection points [7].

The potential of HHSW minimization with recycle activities can be increased from the existing condition which was only 3.6% (427 kg/day) to 13.2% (1,568 kg/day), by recycling the oil packaging that can be used as rail pads, glass on the light bulbs is made into ceramic material, and in the cartridge, the toner is recycled into materials to make the road surface, the remaining ink is used for the printing industry, while the plastic is recycled. The HHSW types including car batteries, light bulbs, and batteries have the potential to be minimized by recovery activities. The lead can be recovered from 90% of the car battery, from 56% recovered Zn and Mn batteries and from the light bulbs the mercury content is recovered. By the calculations, the potential for recovery of the three
types of HHSW was 7.7% (914 kg/day). From the description above, the potential for HHSW minimization by the 4R concept in Padang City was 51.2% (6,081 kg/day). This high potency will certainly affect the management planning of HHSW in Padang City. Until now, there is no specific management for HHSW in Padang City because the City Government is still focusing on municipal solid waste management (non-hazardous waste) with the 3R concept through the construction of 3R waste processing facilities (TPS-3R) and waste banks. By this study, it is expected that the Padang City Government will begin to develop the planning the HHSW management system by considering the concept of waste minimization so it can reduce the processing, transportation, and final processing costs of HHSW. Table 2 shows the potential for minimizing HHSW in Padang City.

Table 2. HHSW minimization potential of Padang City

| Type of usage | HHSW types                     | HHSW composition (%) | Minim potential (kg/day) | Minim potential (%) |
|---------------|--------------------------------|----------------------|--------------------------|---------------------|
|               |                                | Kg/day               | R1   | R2   | R3   | R4   | R1 | R2 | R3 | R4 |
| Cleaner       | Toilet, floor and glass cleaner packaging | 2,138 18 | 689 190 | 0 0 5.8 | 1.6 0 0 |
| Product       | Clothes cleaning packaging     | 594 5        | 48 48 0 0 | 0.4 0.4 0 0 |
|               | Chlorine wrap                  | 95 0.8       | 95 0 0 0 | 0.8 0 0 0 |
|               | Shoe polish                    | 24 0.2       | 0 0 0 0 | 0 0 0 0 |
| Body care     | Shampoo, soap & cosmetics       | 4,038 34     | 475 356 0 0 | 4 3 0 0 |
|               | Expired drugs                  | 356 3        | 0 0 0 0 | 0 0 0 0 |
| Automotive    | Lubricant packaging            | 1,188 10     | 71 214 903 0 | 0.6 1.8 7.6 0 |
|               | Car battery                    | 118 1         | 0 0 0 71 | 0 0 0 0.6 |
| Paint and alike| Paint can                      | 1,425 12     | 0 1,413 0 0 | 0 11.9 0 0 |
| Pesticide, Insecticide | Insecticide packaging | 475 4         | 0 0 0 0 | 0 0 0 0 |
| Others        | Light bulb                     | 712 6        | 0 0 190 665 | 0 0 1.6 5.6 |
|               | Battery                        | 356 3        | 0 0 0 178 | 0 0 0 1.5 |
|               | Cartridge                      | 356 3        | 0 0 475 0 | 0 0 0 4 0 |
| Sub-Total     |                                | 11,875 100   | 1,378 2,221 1,568 914 | 11.6 18.7 13.2 7.7 |
| Total         |                                | 6,081       | 51.2 |

Note: R1= Reduce, R2= Reuse, R3=Recycle, R4=Recovery

4. Conclusion

Although knowledge of HHSW is still low, the people of Padang City have already minimized HHSW by 17.4% without realizing by reduce, reuse and recycle activities. From the results of calculations and literature studies, the HHSW minimization has the potential to be increased to 51.2% by reducing activities through minimizing waste generation by purchasing large volumes of products, reusing packaging for cleaner products and body care through the Environmental Producer Responsibility (EPR) program, recycling cans oil, light bulbs and cartridge and recovering content in battery components and car batteries. By minimization of the HHSW through the 4R concept, it is expected not only to reduce the quantity of waste generation but also to delay the existence of the HHSW and to reduce the possibility of the HHSW mixed with other waste.
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References
[1] Harry JE 2010 J. Chem. Health and Saf. 17 12
[2] Rim-Rukeh A 2016 International Journal of Environmental Science and Toxicology. 4 146
[3] Iswanto, Sudarmadji S and Wahyuni ET 2016 Jurnal Manusia dan Lingkungan. 23 179
[4] Republic of Indonesia Government Regulation No. 101/2014 2014
[5] Kiddee P, Naidu R, and Wong MH 2013 J. Waste Manage. 33 1237
[6] Central Bureau of Statistics Indonesia. 2016. Padang City in Number 2015.
[7] Raharjo S, Bachtiair VS, Ruslinda Y, Rizki ID, Matsumoto T, Rachman I and Abdulhadi D 2017 ARPN Journal of Engineering and Applied Sciences. 12 5692
[8] Ruslinda Y and Yustisia D 2013 Jurnal Lingkungan Tropis. 7 21
[9] Ruslinda Y, Raharjo S, Dewilda Y and Fimeylia S 2017 Proceeding of Civil Engineering Conference 2nd, Udayana University, Denpasar, Bali, Indonesia
[10] Ruslinda Y, Raharjo S and Dewilda Y 2017 Study of Hazardous Solid Waste Management System in Padang City as an Effort in Energy Conservation Final Report Padang
[11] McCoy CV, Naquin M, Massawe E, Gillan W, Haynes C, Cormier C, Zannis M 2017 Athens Journal of Health. 4 131
[12] Franchetti, MJ 2009 Solid Waste Analysis and Minimization: A System Approach. McGraw Hill, New York.
[13] Yamashita, M, and Matsumoto, S 2014 International Journal of Environmental Protection and Policy. 2 132
[14] Shipley, D 2000 Development of Reprocessing Option and Market For Used Oil Container: Final Report. Asosiation Inc and The Australian Institute of Petroleum
[15] https://earth911.com/
[16] https://planetark.com/
[17] Yoheeswaran, E and Govindaradjane, S 2013 Eng. J. 65 70
[18] Chen WS, Liao CT, and Lin KY 2015 J. Environ. 107 167
[19] http://ns.vancouver.ca
[20] Nahman A 2010 Resour. Conserv. Recycl. 54 155