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*Original Research*

# Solid Waste Generation and Composition at Water Villages in Sabah, Malaysia

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## Abstract

Life in an estuary and at the beach are unique settlement patterns in the history of Malaysia. Sabah is well known for its water village settlements that are built on wooden pillars and which can be found along Sabah coastal water. However, a lot of problems have occurred at the Sabah water villages. Thus, the aim of this study is to measure the solid waste generation and composition in 150 households at select water villages in Sabah, Malaysia. The study was conducted at three major towns in Sabah, namely Kampung Tanjung Batu Laut, Tawau water village, Kampung Tanjung Aru, Kota Kinabalu water village and Kampung Sim-sim, Sandakan water village. Based on the results, the total waste generation is 1519.30 kg and the average solid waste generation rate per household is 0.29 kg/person/day. The main component of solid waste is food waste, which comprises 37% of the total waste generated, followed by plastic waste at 31%, paper waste 14.7%, glass 7.2%, and metal 6.3%. The remainder (3.8%) includes bulky waste, furniture, wood, etc. Although the solid waste generation rate is comparatively low, it will create a negative impact on the environment and public health if proper management of solid waste is not practiced.

**Keywords:** water village, solid waste, solid waste generation, solid waste composition, proper management of solid waste

## Introduction

Solid waste management is a worldwide problem. It is a major challenge throughout the world day by day due to the rise in population and industrialization, as well as our lifestyle changes [1]. Without effective and efficient solid waste management the waste generated from various human activities (from industries, businesses, and households), will result in health hazards and bring a negative impact to the environment. The increase in the world population and industrialization of more cities means increasing the volume of waste, and managing the waste produced by a city becomes more complex [2]. Over the last century, the world has seen an increase in amounts of waste generated and discharged into the environment, which creates environmental consequences. Generally, an increase of waste generated results to the scarcity of land for the sanitary landfill for waste disposal [3].

Sabah is also having problems in managing their solid waste management. The local authority in Sabah does not only need to manage the waste on land but they also have to manage the stranded and floating waste along the coastal area in Sabah. This is due to the water village settlements that were built along the coastal area and cause various problems in solid waste management. Water village settlements have been known as the common tradition settlements along most of the coast, island, and estuaries in Borneo Island state of Sabah. In particularly, the water vil-

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lage existed before the 19th century. It has become the main administrative and economic centre of the maritime government [4]. However, it has deteriorated with widespread waste and litter particular in the water, and framed as a black area and problematic slum due to the attitude of the villagers as shown in Fig. 1.

## Materials and Methods

### Study Area

Sabah, one of the 13 states of Malaysia, is located on the northern portion of Borneo island. It is the second largest state in the country, with a total area of 73,620 km$^2$ and a population of 3,117,045. Sabah, which is surrounded by the South China Sea in the west, the Sulu Sea in the northeast and the Celebes Sea at the east, is often referred as "land below the wind" due to its location at the south of the typhoon-prone region around the Philippines. This study was conducted in three selected water villages in Sabah. There are Kampung Tanjung Batu Laut, Tawau, Kampung Tanjung Aru, Kota Kinabalu, and Kampung Sim-Sim in Sandakan, as shown in Fig. 2. The study areas were selected because the three region areas are the major towns in Sabah and have a high population.

Tawau is located at 117º east longitude and 4º30' in latitude, with a total population of 392,906 people. Tawau Municipal Council is the local authority responsible for administering the 6,243km$^2$ province. Kampung Tanjung Batu Laut was the biggest water village, located about 5 km from the town of Tawau with an area exceeding 300 acres. There are about 6,000 villagers with 800 houses, of which 80% the villagers are Bumiputera [5].

Kota Kinabalu is the capital city of Sabah State, which was declared a city covering 35,070 km$^2$ (136 miless) with a population of 437,500. Kota Kinabalu City Hall is responsible for the administration, which includes the city center, suburbs, rural areas, sea, and islands. 3,000 people live in 240 houses in Kampung Tanjung Aru, Kota Kinabalu water village. Most of the villagers in this area are fishermen, public or private sector workers, retires, and a business owners [6].

Sandakan is located on the northeastern coast of Borneo and has a population of 479,121. Sandakan Municipal Council is responsible under the jurisdiction of the Sandakan District, covering about 2,266 km$^2$ (875 miles$^2$). Kampung Sim-Sim, a water village built on stilts on the coast of Sandakan reachable only by plank walkways, is home to local fishermen who live in neat wooden houses. The water villages are also the site of the original town of Sandakan, which was founded in 1879. It includes about 480 houses and 2,465 people [7].

### Solid Waste Generation and Composition Study

This study focused on household solid waste. Two important aspects are being measured: solid waste generation and composition in selected water villages in Sabah. Solid waste generation is solid waste produced from its source, including waste retained for other purposes, and waste discarded for collection [8]. Solid waste composition is the components of the solid waste. Six categories usually are sufficient for a general solid waste study, namely food waste, plastic, paper, glass, metal, and other waste. The method used for solid waste sampling was based on the method from Malaysian Standards [9]. Samples from 50 houses/premises were taken for solid waste generation and composition study for each water village. 150 household were involved in this study. The samples were selected by randomly choosing houses in a row within the area of study. Then the samples were collected and weighed separately on a daily basis for 7 days a week. Once the waste was collected, the samples were sorted into six categories and recorded. The flow chart of the solid waste sampling activities is shown in Fig. 3.

Fig. 1. Situation at Water Village.


Fig. 2. Location of study area.
Source: www.sabah.gov.my

The solid waste generation rate was calculated using Equation (1) to identify the amount of solid waste produce every day. Separation of solid waste was carried out for finding the percentage composition of solid waste generated by using Equation (2). Waste is separated into the six categories of food waste, paper, plastic, glass, metal, and others. Composition of waste taken is based on the weight of each segregated waste.

$$Waste\ generation\ rate = \frac{Total\ of\ waste\ weight}{No.\ of\ household\ \times 7\ days} \quad (1)$$

$$Waste\ weight\ (\%) = \frac{Weight\ of\ waste\ category}{Total\ amount\ of\ waste} \times 100 \quad (2)$$

## Results and Discussion

### Solid Waste Generation and Composition Study

Total solid waste generation among 150 households studied in three water villages (Kg. Tanjung Batu Laut, Tawau, Kg. Tanjung Aru, Kota Kinabalu, and Kg. Sim-Sim, Sandakan) are shown in Table 1. Based on the results, total solid waste generation per household is 1519.30 kg. Average waste generation per household and per capita waste generation was 0.29 kg/person/day. Kampung Tanjung Batu Laut and Tawau water villages generated the highest waste compared to Kampung Tanjung Aru, Kota Kinabalu and Kg. Sim-Sim, Sandakan. There is a difference in solid waste generation in three study areas. It might be influenced by the difference in socio-economic status in the area where the quantity of solid waste generation is mostly associated with the economic status of a society [10]. Besides that, the solid waste generation varies in different cities depending on the standard of living, life style, social and religious tradition, and the eating habits of the people [11].

Meanwhile, Fig. 4 showed the solid waste composition in three water villages. At 562.20 kg, food waste generation is higher than other types of waste. Plastic waste generated about 471.50 kg, were higher than paper at 222.90 kg. Based on these results, every person generates 0.11 kg of

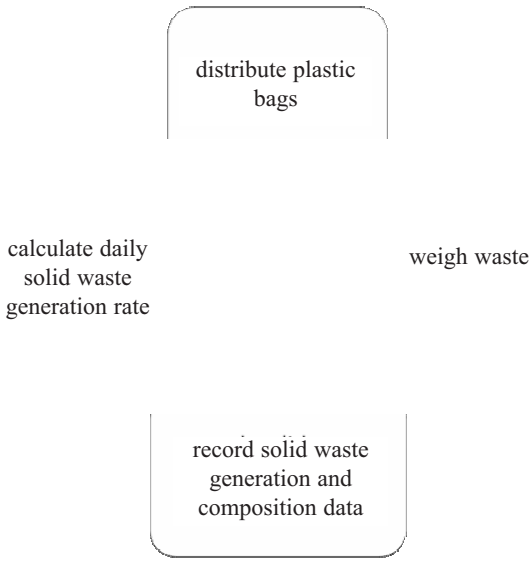


Fig. 3. Flow chart of waste generation and composition study.

Table 1. Total solid waste generation in three water villages.

| Water Villages | Total solid waste generation daily (kg) | Average solid waste generation (kg/person/day) |
|---|---|---|
| **Kg. Tanjung Batu Laut** | **607.70** | **0.35** |
| Kg. Tanjung Aru | 443.60 | 0.25 |
| Kg. Sim-Sim | 468.00 | 0.27 |
| **Total** | **1519.30** | **0.29** |

food waste per day and food waste contributes nearly 37% of the total waste generated in the study area.

As illustrated in Fig. 4, food waste is always the main component in waste generation. Meanwhile, plastic waste is also prevalent in water village area at 31% of the total, while paper waste generated is about 14.7%, glass 7.2%, and metal 6.3%. However, other waste generated (3.8%) includes bulky waste, furniture, wood, etc. The overall socio-economic conditions in the area is also very much responsible for the high percentage of waste component. Furthermore, this study revealed that the percentage of recyclables like paper, glass, and metal were high in all locations.

A study by Visvanathan also found that food waste dominated over the major portion of the waste generated in most developing countries in Asia such as China, India, Sri Lanka, and Thailand [12]. Moreover, Malaysian solid waste contains a very high concentration of organic waste and consequently has high moisture content [13]. However, the data shows that there has been a change in solid waste composition. The quantity of plastic wastes also has increased. Shekdar also reported that the proportion of plastics and paper is high, which is influenced by economic status [10].

A change in solid waste generation and composition caused by demographic factors such as family size, income level, economic growth, and lifestyle has a strong influence on solid waste generation and composition [14]. Meanwhile, the factors that affect solid waste generation of the households are household size and income levels [15], meanwhile other factors of socio-economic characteristics include education and age. Solid waste generation and composition is also influenced by the economic sector's growing population and economy, whose solid waste generation is increasing [11]. However, family size and income are the most significant factors affecting quantity of solid waste from household consumption [16].

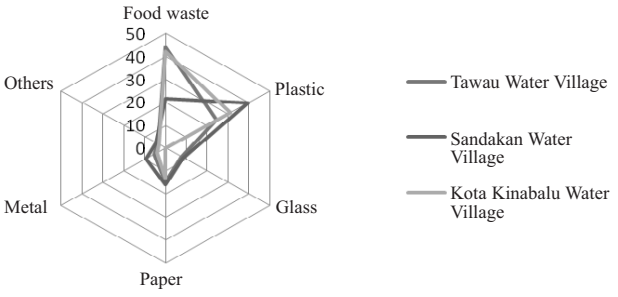


Fig. 4. Solid waste composition in Sabah water villages.

Table 2. Solid waste generation and composition at Tawau water village.

| Type of waste | Total solid waste generation daily (kg) | Solid waste composition (%) | Average solid waste generation (kg/persons/day) |
|---|---|---|---|
| **Food waste** | **268.20** | **44.10** | **0.15** |
| Plastic | 148.60 | 24.50 | 0.09 |
| Glass | 46.20 | 7.60 | 0.03 |
| Paper | 88.50 | 14.60 | 0.05 |
| Metal | 33.80 | 5.60 | 0.02 |
| Other | 22.40 | 3.70 | 0.01 |
| **Total** | **607.70** | **100.00** | **0.35** |

## Solid Waste Generation and Composition in Tawau Water Village

Table 2 shows the total waste generation daily at Kg. Tanjung Batu Laut, Tawau with 50 households being selected and a total of 248 family members. Total solid waste generation daily was 607.70 kg, of which food waste generation (268.20 kg) is the highest. Meanwhile, plastic waste generated about 148.60 kg, paper 88.50 kg, 46.20kg glass, 33.80 kg metal, and 22.40 kg other waste generated daily in Tawau water village. Based on these results, every person generates 0.15 kg of food waste per day and food waste contributes nearly 44.1% of the total waste generated in the study area. Average waste generation per household and per capita waste generation in Tawau water village was 0.35 kg/person/day, respectively.

## Solid Waste Generation and Composition in Kota Kinabalu Water Village

Total solid waste generation and composition in Kg. Tanjung Aru, Kota Kinabalu is shown in Table 3. We selected 50 households with total number 256 people. Kg. Tanjung Aru, Kota Kinabalu water village generated about

Table 3. Solid waste generation and composition at Kota Kinabalu water village.

| Type of waste | Total solid waste generation daily (kg) | Solid waste composition (%) | Average solid waste generation (kg/persons/day) |
|---|---|---|---|
| **Food waste** | **191.60** | **42.20** | **0.11** |
| Plastic | 138.30 | 31.20 | 0.08 |
| Glass | 22.90 | 5.00 | 0.01 |
| Paper | 58.90 | 13.00 | 0.03 |
| Metal | 18.10 | 4.00 | 0.01 |
| Other | 13.80 | 3.00 | 0.01 |
| **Total** | **443.60** | **100** | **0.25** |

Table 4. Solid waste generation and composition at Sandakan water village.

| Type of waste | Total solid waste generation daily (kg) | Solid waste composition (%) | Average solid waste generation (kg/persons/day) |
|---|---|---|---|
| Food waste | 102.40 | 21.60 | 0.06 |
| **Plastic** | **184.60** | **39.40** | **0.11** |
| Glass | 39.70 | 8.40 | 0.02 |
| Paper | 75.50 | 15.90 | 0.04 |
| Metal | 43.60 | 9.20 | 0.02 |
| Other | 22.20 | 4.70 | 0.01 |
| **Total** | **468.00** | **100.00** | **0.27** |

443.60 kg of waste. Food waste generation is 191.60 kg, greater than other types of waste, whereas plastic waste generation was lower at 148.30 kg. Meanwhile, paper waste generated, 58.9 kg, was higher than glass, 22.9kg. Another type of waste is metal, which is 18.10 kg, and other waste, 13.80 kg. Food waste contributed nearly 42.2% of the total waste generated in the study area. Average waste generation per household and per capita waste generation in Kota Kinabalu water village were 0.25 kg/person/day.

## Solid Waste Generation and Composition in Sandakan Water Village

However, there is a difference in solid waste generation and composition in Kg. Sim-Sim, Sandakan water village. Based on the results of Table 4, the total daily solid waste generation among 50 select households and 250 total number of household members is 468.0 kg. Plastic waste generation, 184.60 kg, was higher than other types of waste, whereas food waste generation was lower at 102.40 kg. Meanwhile, paper generated was 75.50 kg, higher than glass (39.70 kg), metal (43.60 kg), and other waste (22.20 kg) generated daily. Based on these results, every person generates 0.11 kg of plastic per day, and plastic contributes nearly 39.4% of the total waste generated in the study area. This shows that residents in Kg. Sim-Sim, Sandakan water village generate more plastic waste. Average waste generation per household per capita waste generation in Kg. Sim-Sim, Sandakan water village was 0.27 kg/person/day.

## Relationship between Family Size and Income Level and Solid Waste Generation

Table 5 shows the relationship between family sizes with the solid waste generation in Sabah water villages. Based on the results, there is a significant positive correlation ($p = 0.00$, $p < 0.01$) at 0.01 probability level. This is obviously due to the reason that increasing household numbers leads to increasing resource consumption, resulting in an increase in solid waste generation. Due to the probability value of Pearson correlation ($r=0.292$), it is more than the determined alpha value ($\alpha/2 = 0.025$). Therefore, from the finding it can be concluded that there is significant relationship between family size and solid waste generation. Based on the results, this study revealed that family size can influence solid waste generation.

Table 5. Relationship between family size and solid waste generation.

| | | Family size |
|---|---|---|
| Solid waste generation | Pearson Correlation | 0.292* |
| | Sig. (2-tailed) | 0.000 |
| | N | 150 |

*Correlation is significant at the 0.01 level (2-tailed).

Table 6. Relationship income level with solid waste generation.

| | | Family size |
|---|---|---|
| Solid waste generation | Pearson Correlation | 0.067 |
| | Sig. (2-tailed) | 0.415 |
| | N | 150 |

In addition, household size is the most significant factor affecting the quantity of solid waste from household consumption [17]. As in the Ghorbani study, family size is an important determinant in household waste production [18]. While Jones states that the quantities of waste generated generally depend on the number of households, larger households tend to generate larger quantities of waste compared to smaller households [19].

Table 6 shows results of the relationship between income levels with solid waste generation. It shows that the correlation coefficient of income level is not significant ($p=0.415$, $p>0.05$) at 5% probability level of confidence. Based on the results, it shows that there is no relationship between income level and solid waste generation. This is due to the fact that higher income didn't influence the solid waste generation in household consumption. Due to the probability value, Pearson correlation is $r=0.067$. Therefore, from the finding it shows that there is no significant relationship between income levels with solid waste generation.

Many research findings point out that generally solid waste generation increases as income rises. However, we also note that when household income increases, waste generation decreases. This is because of their attitude in implementing the 3R concept in their daily life, which reduces waste, and reuses and recycles waste. Duminda and Prasansa also revealed that family income is negatively related if a family applies the reuse concept to shopping bags [20]. Moreover, it might be due to recycling activities, which have been on the rise [21]. Respondents in the study area might sell bottles/paper/metal items to the recycle shop

Table 7. Comparison of solid waste composition in three water villages.

| | | Mean Square | Sig. |
|---|---|---|---|
| Food waste | Between groups | 105.693 | 0.000 |
| | Within groups total | 3.195 | |
| Plastic | Between groups | 0.835 | 0.622 |
| | Within groups total | 1.753 | |
| Glass | Between groups | 5.425 | 0.044 |
| | Within groups total | 1.651 | |
| Paper | Between groups | 1.010 | 0.636 |
| | Within groups total | 2.225 | |
| Metal | Between groups | 1.341 | 0.032 |
| | Within groups total | 0.371 | |
| Others | Between groups | 0.079 | 0.592 |
| | Within groups total | 0.150 | |

and earn income. Besides that, it might because of the increasing level of awareness of responsibility and active participation among respondents in supporting and implementing good municipal solid waste management practices.

### Comparing Solid Waste Composition in Three Selected Water Villages

Table 7 the shows the comparison of solid waste composition in the three select study areas. Due to the probability value of ANOVA, there is significant difference between solid waste compositions in Sabah water villages at 5% probability level.

According to Table 7, there is significant difference of food, glass, and metal waste composition in Kg. Tanjung Batu Laut, Tawau, Kg. Tanjung Aru, Kota Kinabalu, and Kg. Sim-Sim, Sandakan which is food waste ($p=0.00$, $p<0.05$), while glass ($p=0.44$, $p<0.05$) and metal ($p=0.032$, $p<0.05$) are at 5% probability level. The finding show that solid waste composition is different in the three water villages.

Meanwhile, there is no significant difference between solid waste composition in plastic, paper and other waste. The significant value of plastic is ($p=0.622$, $p>0.05$), paper ($p=0.636$, $p>0.05$), and other waste ($p=0.592$). It can be concluded that there is no difference of solid waste composition (plastic, paper, and other) in the three water villages (Kg. Tanjung Batu Laut, Tawau, Kg. Tanjung Aru, Kota Kinabalu, and Kg. Sim-Sim, Sandakan).

## Conclusion

In conclusion, solid waste generation in Sabah water villages amounted 1519.3 kg, and the average of solid waste generation per household was 0.29 kg/person/day. In the solid waste composition study, food waste formed the largest fraction of the MSW at 37%, followed by plastic 31%, paper 14.7%, glass 7.2%, and metal 6.3%. However, another 4% of solid waste generated includes other waste. Therefore, for further study the researcher can add other water villages in each district and add up other districts in Sabah to see the issue widely. Furthermore, the actual data of solid waste generation and waste composition in Sabah can be acquired.

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## References

1. SINGH R.P., P. SINGH S., ARAUJO A. S. F., HAKIMI IBRAHIM M., SULAIMAN O. Management of urban solid waste: Vermicomposting a Sustainable Option. Resources, Conserv. Recycling, **55**, (7), 719, **2011**.
2. TAHIR M.M. Waste Management and Society: A Case Study of Public Participation in Waste Management Kota Kinabalu City. Health and Environment Journal, **2**, (2), **2011**.
3. AGAMUTHU P. Solid Waste: Principles and Management, Institute of Biological Sciences, University of Malaya **2001**.
4. AMALUDDIN BAKERI, MOHAMMAD RADUAN MOHD ARIFF. Pembongkaran Petempatan Kampung Air Di Pulau Borneo: Kajian Kes Kota Kinabalu, Sabah (Demolishment of Water Village Squatters In The Island of Borneo), JATI, **9**, 1-18, **2004**.
5. TAWAU MUNICIPAL COUNCIL http://www.mpt.gov.my Accessed on August 5, **2013**.
6. KOTA KINABALU CITY HALL http:// www.dbkk.gov.my Accessed on August 5, **2013**.
7. SANDAKAN MUNICIPAL COUNCIL http;//www.mps.gov.my Accessed on August 5, **2013**.
8. TCHOBANOGLOUS G.H., THEISEN S.A. Integrated Solid Waste Management: Engineering Principles and Management Issues. Mcgraw Hill International Editions, Civil Engineering Series 6, Mcgraw Hill Inc., Singapore, **1993**.
9. MALAYSIAN STANDARD. Guidelines for Sampling of Household Solid Waste Composition and Characterisation Analysis. Department of Standards Malaysia, **2012**.
10. SHEKDAR A.V. Sustainable Solid Waste Management: An Integrated Approach for Asian Countries. Waste Management **29**, 1438, **2009**.
11. VIRARAGHAVAN T., POKHREL D. Municipal Solid Waste Management in Nepal; Practices and Challenges. Waste Manage. **25**, 555, **2005**.
12. VISVANATHAN C. Solid Waste Management in Asian Perspectives, Asian Institute of Technology, Bangkok, 1-7, **2006**.
13. LATIFAH ABD MANAF, MOHD ARMI ABU SAMAH, NUR ILYANA MOHD ZUKKI. Municipal Solid Waste management in Malaysia: Practices and Challenges, Waste Manage. **29**, 2902, **2009**.

14. ZHU D., ASNANI P.U., ZURBRUGG C., ANAPOLSKY S., MANI S. Improving Municipal Solid Waste Management in India. World Bank, Washington, 1-8, **2008**.
15. AFROZ R., MUHAMMAD MEHEDI M. Using A Contingent Valuation Approach for Improved Solid Waste Management Facility: Evidence From Kuala Lumpur Malaysia Waste Management, pp. 800-808, **2011**.
16. SIVAKUMAR K., SUGIRTHARAN M. Impact of Family Income and Size on Per Capita Solid Waste Generation: A Case Study In Manmunai North Divisional Secretariat Division of Batticaloa J. Sci. Univ. Kelaniya, **5**, 13, **2010**.
17. RICHARDSON R.A., HAVLICEK J. JR. Economic Analysis of Composition of Household Solid Wastes. J. Environ. Econ. Manag. **5**, 103, **1978**.
18. GHORBANI N., WATSON P.J., HARGIS M.B. Integrative Self-Knowledge Scale: Correlations and Incremental Validity of A Cross-Cultural Measure Developed in Iran and United States. J. Psychol., **142**, (4), 395, **2008**.
19. JONES P.D., LISTER D.H., LI Q. Urbanization Effects in Large-Scale Temperature Records With an Emphasis on China, J. Geophys. Res, 113, **2008**.
20. DUMINDA K., PRASANSA K. The Problem of Solid Waste: A Case Study of The Maharagama Local Authority. Journal of National Science Foundation, **33**, (1), 51, **2005**.
21. HASSAN BASRI, IWAN BUDHIARTA, CHAMHURI SIWAR, Current Status of Municipal Solid Waste Generation in Malaysia, International Journal on Advanced Science Engineering Information Technology, **2012**.
22. SABAH MAP http://www.sabah.gov.my Accessed on December 20, **2013**.