IOP Conference Series: Earth and Environmental Science

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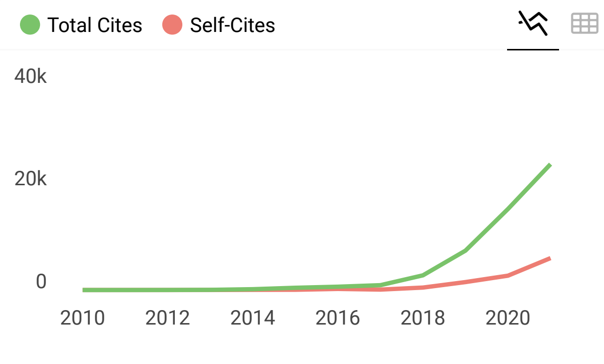

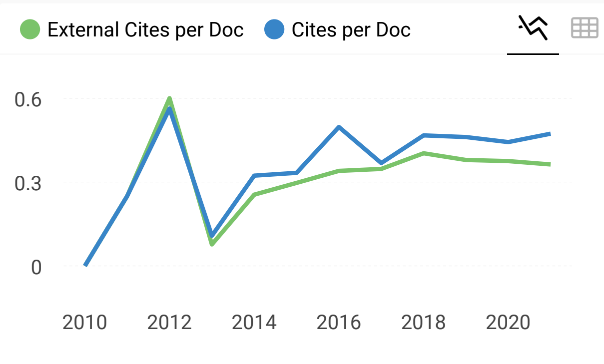

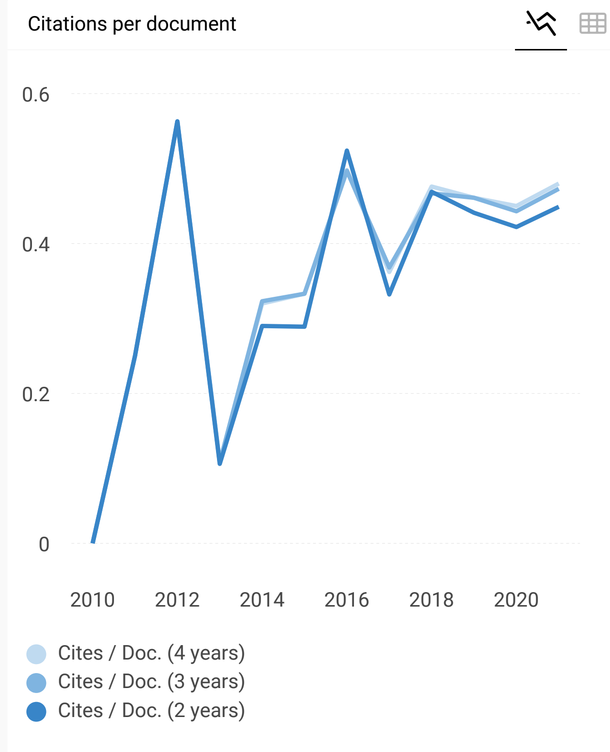

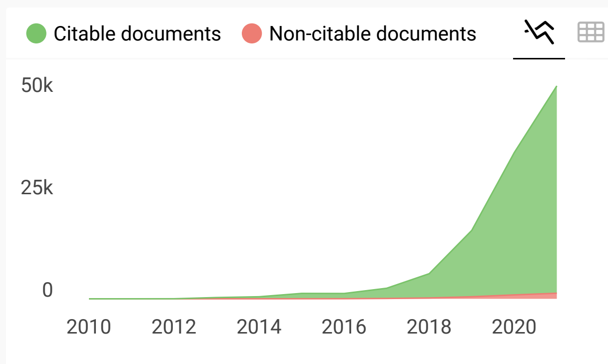

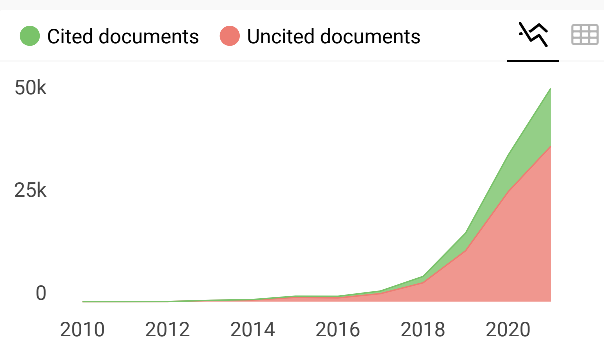

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Sincerelly,
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syaiful

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Planning of Waste Management using Zero Waste Approach at SMAN 14 Bandung, Indonesia

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Planning of Waste Management using Zero Waste Approach at SMAN 14 Bandung, Indonesia

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Abstract. SMAN 14 is one of the educational institutions that still adhere to waste management with a liner system, namely waste generated and disposed of in the final disposal site. In addition, SMAN 14 Bandung is a school with the title of an independent Adiwiyata School with environmental insight, but this school has not paid attention to managing its waste. This study aims to plan waste management with zero-waste approach so that the amount of waste sent to landfills is zero. Calculation of zero waste index (ZWI) was performed for a school scale wherein the results of ZWI were used for evaluation and as a basis for the future planning of solid waste management. Sampling measurements were carried out using the load count analysis method. The waste generated is 37,544 kg/day. With a composition of 13.12% organic, 60.42% plastic, 20.957% paper, 0.36 % metal, and a mixture of 5.14% with a zero-waste index of 0.80, the substitution of material savings of 30.09 kg, the substitution of energy 953.94 MJ, greenhouse effect reduction 26.89 Kg/CO2e, and water-saving -232.02 L. Furthermore, through this planning, the estimation of cost reduction was as much as Rp. 23,315 a day.

1. Introduction

According to Law [1] on Waste Management, waste is the residue of daily human activities and/or natural processes in solid form. Garbage is one of the things that cannot be separated from daily human activities that come from household or domestic and non-domestic activities originating from trade, offices, industry, institutions, including schools in it.

Schools are educational institutions that produce various types of waste, both household and other types of waste. Environmental problems in the school environment can be reduced by implementing the Adiwiyata Program. The Adiwiyata Program is an effort to improve the environment, especially in the school, which aims to create an environmentally sound school [2]. One of the schools in Bandung that has a vision of implementing environmentally-friendly schools is SMAN 14 Bandung. However, the waste management system in that school still uses a linear system. Namely, waste generated, and all of it is sent to the final disposal site. A waste disposal system like this not only takes up space and produces pollution, and in turn, it also requires a large number of transportation costs. Therefore, there is a need to minimize waste in the school context, and the waste transported to the final disposal site approaches 0 or known as zero waste, so that the costs required to transport the waste are efficient.

Zero Waste (ZW) can be implemented by reducing waste generation following the existing field conditions and referencing regulations or standards set by the government. Waste reduction activities include limiting waste generation, recycling waste and/or, reusing waste known as 3R (Reduce, Reuse, and Recycle). The 3R principle is related to the concept of ZW, which can be interpreted as an effort to design a cycle of a resource that includes processes to maximize recycling, minimize waste, and streamline consumption or at least can be recycled so that the impact of disposal can be reduced by nature [3]. The Circular economy aims to extend the life of waste into something useful to be reused as an alternative raw material or recycled by new products [8]. In line with the ZW concept aforementioned, circular economy refers to the 3R concept, namely reduction, reuse, and recycling [4].

An index is an essential tool to measure environmental performances [5] [6]. Zero waste index (ZWI) is a tool to measure the potentiality of virgin materials to be offset by zero waste management systems [3]. A few studies have been done to apply the ZWI in city and country scales [7][8][9]. Also, an application of ZWI was carried out at the university scale [10]. However, there is no-example of ZWI use on a smaller scale, such as at a school. Furthermore, ZWI has not yet been conducted as a basis not only for evaluation but also for planning waste management. Therefore, the contribution of the study is twofold. The first is to provide an application of ZWI for a school scale, and the latter, for the first time, was used as a basis for the future planning of waste management.

Guided by the advantages of implementing ZWI [3], the improvement of the waste management system can be measured through an evaluation so that it can continue to be improved. This study will discuss the improvement of school-scale waste management with the principle of zero waste based on a circular economy using ZWI: (i) energy that can be saved, (ii) reduction of greenhouse gases (GHG), (iii) saving the amount of water, and (iv) to calculate the reduction in costs incurred through the application of the principle of 3R. Through these efforts, recommendations will be given to manage household-type (domestic) waste at SMPN 14 Bandung so that the waste transported to the landfill can be reduced to as little as possible.

2. Method

This research was conducted in February 2020.Using the load count analysis method sampling measurements were carried out during workdays for eight days referring to SNI 19-3964-1994 [11]. SMAN 14 Bandung has 1130 students and staff work [12]. The generation measurement is carried out at the temporary disposal site, wherein each transported waste is based on the means of transportation and the source of the waste generation to measure the weight and volume of waste from each source. The implementation of this method is as follows [11].

$$Q = \frac{\text{Average weight (kg)}}{\text{Number of students,teachers and employees (p)}} \quad (1)$$

The reference used to calculate the composition of waste is the Implementation of Waste Infrastructure and Facilities in Handling Household Waste and Waste Similar to Household Waste [13]. The Waste calculation can use the following formula.

$$PC = \frac{PL}{PT} \text{x } 100 \quad (2)$$

where PC is the percentage of each category, PL is the amount of category presented in kg, and PT is the total weight of the sample in kg.

ZWI is used to compare different waste management systems in different cities and provide a broader picture of the potential demand for raw materials, energy, carbon pollution and water in a city [3]. In this study, ZWI was performed to evaluate the waste management of an educational institution.

$$ZWI = \frac{\sum_1^n WMS_i * SF_i}{\sum_1^n GWS} \quad (3)$$

WMS is the amount of waste managed by system (i.e., i =1, 2, 3…n), and n is the amount of waste avoided, recycled, treated, etcetera. SFi is the substitution factor for different waste management systems based on their virgin material replacement efficiency as presented in Table 1, while GWS is the Total amount of waste generated (tonnes/kg of all waste streams).

Table 1. SFi of the resource for the zero waste index. [3]

Waste management systems	Waste category	Virgin material substitution efficiency (tonnes)	Energy substitution efficiency (GJLHV tonne^{-1})	GHG emissions reduction (CO2e tonne^{-1})	Water saving (kL tonne $^{-1}$)
Recycling	Paper	0.84–1.00	6.33–10.76	0.60–3.20	2.91
	Glass	0.90–1.00	6.07–6.85	0.18–0.62	2.30
	Metal	0.79–0.96	36.09–191.42	1.40–17.8	5.97–181.77
	Plastic	0.90–0.97	38.81–64.08	0.95–1.88	–11.37
	Mixed	0.25–0.45	5.00–15.0	1.15	2.0–10
Composting	Organic	0.60–0.65	0.18–0.47	0.25–0.75	0.44
Incineration	Mixed MW	0.00	0.972–2.995b	0.12–0.55	0.00
Landfill	Mixed MW	0.00	0.00–0.84	–0.42 to 1.2	0.00

3. Results and discussion

3.1. Waste generation and category

The waste management system of SMAN 14 Bandung, namely the storage stage, is divided into 2, namely organic and inorganic. The transportation is carried out every day at 15.00 WIB using a closed cart. The waste is stored in the temporary disposal to be transported to the city landfill. The waste that has been managed in this school is cardboard waste by selling to third parties.

The amount of waste generated by SMAN 14 Bandung daily was around 0.033 kg/p (using Eq. 1). That was significantly higher, than in SNI-04-1993-03 [9], wherein the waste generated by schools usually ranging from 0.010 to 0.020 kg/p. So paid attention is needed to minimize the waste generated and transported to the final disposal site.

Figure 1 presents the solid waste category in SMAN 14 Bandung. It was observed that the average weight of waste generated in SMAN 14 Bandung was 37,544 kg/day, and there were five different categories of waste. Using Eq. 2, the average weight for each category: organic (13.12%), paper (20.97%), plastic (60.42%), metal waste (0.36%) and mixed (5.14%), respectively.

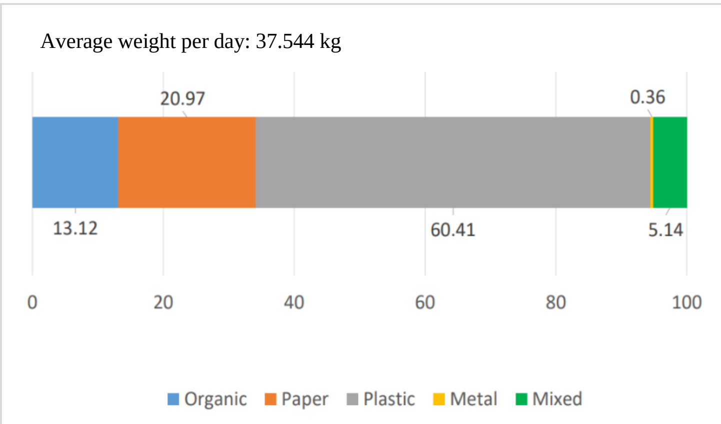

Figure 1. Solid waste category in SMAN 14 Bandung.

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3.2. ZWI in SMAN 14 Bandung

Scenario 1 is based on the existing condition, wherein SMAN 14 Bandung managed the waste generation by collecting and selling a 1.050 kg/day paper for Rp. 1,000/kg. Using Eq. 3, the ZWI was 0.028, as presented in column 8 of Table 2. This indicates that only about 2.8% of 37.544 kg/day waste generated was recovered. Under scenario 1, energy substitution and water-saving have been saved 7.913 MJ of energy and 3.638 L of water, respectively. In addition, for GHG emissions reduction, scenario 1 produced 14.494 kg/CO2e a day.

Table 2. Potential ZWI under scenario 1.

Waste management systems	Waste category	Total waste managed (Kg)	Potential total virgin material substituted (Kg)	Total energy substituted (MJ)	Total GHG emissions reduction (Kg/CO_2e)	Total Water saving (L)	ZWI
	Paper	1.250	1.050	7.913	0.750	3,638	
Recycle	Metal	0.000	0.000	0.000	0.000	0.000	
	Plastic	0.000	0.000	0.000	0.000	0.000	0.028
Compos	Organic	0.000	0.000	0.000	0.000	0.000	
Landfill	Mixed	36.294	0.000	0.000	-15.244	0.000	
Total		37.544	1.050	7.913	-14.494	3.638	

Scenario 2 refers to a study conducted at UII Yogyakarta in 2017 in implementing the zero-waste program. They received 26% of ZWI by recycling 90% plastic waste, 85% paper waste, and 60% organic, as presented in Table 3. Considering SMA and Campus have the same waste characteristics, the program on the UII campus will be feasible to be implemented. Under this scenario, the resulting ZWI of SMAN 14 Bandung was 0.687. This means that about 68.70% of 37,544 waste produced daily can be recovered from the waste management system. The potential of materials substituted as much as 25.735 kg/day, replacing the energy needs of 836.144 MJ/day, and reducing GHG emissions will be as much as 21.215 Kg/CO2e. However, water saving cannot be done at SMAN 14 since plastic uses a lot of fresh water to process its raw materials. However, for paper and organic waste, water savings can be made, namely 19.233 L for paper and 1.301 L for organic waste, respectively.

Table 3. Potential ZWI under scenario 2.

Waste management systems	Waste category	Total waste managed (Kg)	Potential total virgin material substituted (kg)	Total energy substituted (MJ)	Total GHG emissions reduction (Kg/CO_2e)	Total Water saving (L)	ZWI
	Paper	6.688	5.618	42.335	4.013	19.,233	
Recycle	Metal	0.000	0.000	0.000	0.000	0.000	
	Plastic	20.414	18.373	792.277	19.394	-232.110	0.687
Composting	Organic	2.957	1.774	0.532	0.739	1,301	
Landfill	Mixed	7.485	0.000	0.000	-3.069	0.000	
Total		37.544	25.735	836.144	21.215	-211.344	

Scenario 3 assumes all categories of waste are recycled and composted except for residual waste. With a recycling percentage of 81.73%, composting 13.12%, and landfilling 5.14%, it is observed that SMAN 14 Bandung produces 37.544 kg of waste per day as presented in Table 4, of which more than

50 percent of the waste generated is plastic waste that can be handled by recycling which has a reasonably high selling value. In addition to the ideal scenario 3, this is the selected scenario from the three planned scenarios. The ZWI value for SMAN 14 Bandung is 0.801. That means about 80.10% of resources can be recovered from the amount of waste generated from the waste management system, leading to replace natural materials are 30.088 kg per day. The waste management system at SMAN 14 Bandung can potentially replace the energy needs of 935.940 MJ per day. The substituted GHG emissions are 26.882 (kg/CO2e), but water-saving cannot be implemented because the more significant waste produced is plastic waste, so it requires much water in the manufacturing process. The water used in SMAN 14 Bandung is 232.019 L per day.

Table 4. Potential ZWI under scenario 3.

Waste management systems	Waste category	Potential total virgin material substituted (kg)	Total energy substituted (MJ)	Total GHG emissions reduction (Kg/CO2e)	Total Water saving (L)	ZWI
Recycling	Paper	6.609	49.805	4.721	22.896	0.801
	Metal	0.108	4.940	0.192	0.817	
	Plastic	20.414	880.308	21.548	-257.900	
Composting	Organic	2.957	0.887	1.232	2.168	
Landfill	Mixed	0.000	0.000	-0.810	0.000	
Total		30.088	935.940	26.882	-232.019	

3.3. Cost reduction

For achieving the 80% ZWI, several programs are planned to reduce the generation of waste transported to landfills: (i) organic waste can be composted by Takakura composting, (ii) while plastic waste can be reduced by bringing each other's drink bottles, and carrying bags for shopping from home, it can also be sold to a waste bank, (iii) paper waste can be reduced by computing programs starting with school administration and giving assignments via email, (iv) metal waste can be sold to a waste bank. It is assumed that the reduction program can reduce waste by 30%, and 70% is sold to third parties.

Estimated costs incurred and entered from the zero-waste program at SMAN 14 Bandung can be seen in Table 5. Under Scenario 3, there will be a cost reduction of as much as Rp. 23,315 a day.

Table 5. Estimated costs incurred and entered from the zero-waste program.

Activities	Unit	Amount	Unit cost (Rp.)	Price (Rp.)
Credit				
Book paper	Kg/day	2.102	1,400	2,942
Cardboard book	Kg/day	0.875	1,000	875
Packing carton	Kg/day	2.531	800	2,025
Plastic bottles	Kg/day	10.831	4,200	45,491
Plastic cup	Kg/day	3.040	3,800	11,553
Plastic packing	Kg/day	2.006	550	1,104
Aluminium	Kg/day	0.096	1,500	144
Organic	Kg/day	4.928	-	-
Water gallon sales	L/day	95	1,000	95,000
Total credit				**159,133**
Debit				

Activities	Unit	Amount	Unit cost (Rp.)	Price (Rp.)
Waste retribution	day	1	26,667	26,667
Garbage collector salary	day	1	8,333	8,333
Office salary	day	1	75,500	75,500
Garbage transportation	Kg/day	1.929	165	318
Purchase of refill gallons	pieces	5	5,000	25,000
Total debit				**135,818**
Balance				**23,315**

4. Conclusion

This paper presents how the 3R principle is implemented at a small-specific educational institution as an initial reference for "grounding" the zero-waste approach. Through the application of ZWI, it was found that it can be used as a basis for evaluation and can be used for planning of waste management, leading to cost reduction of school waste management in the future.

The waste generation of SMAN 14 Bandung from daily activities was 37.544 kg/day with 13.12% organic waste, 60.420% plastic, 20.957% paper, 0.360% metal, and 5.140% residual waste. The results of this study, under the best scenario with a zero-waste index of 0.801, also indicates that there will be daily substitution of material savings of 30.088 kg, the substitution of energy 953.940 MJ, greenhouse effect reduction of 26.882 Kg/CO2e, the estimation of cost reduction was as much as Rp. 23,315 a day. However, waste management at SMAN 14 Bandung cannot be done to save water as it still consumes 232.019 l/day of water.

For future works, in line with another tool performance, ZWI calculation can be involved as an additional indicator to evaluate Aditwiyata Program. This study also charts pathways in implementing zero waste management in a bigger picture. If this planning of school waste management runs successfully, in turn it will shift "collect-transport-disposal" to an approach that aims to reduce waste generation from the source (or known as up-the-pipe approach), which then results in the reduction of the burden of overall solid waste management cost for West Java Province.

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