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Simulation of Prediction the capacity of Randegan Landfill, Indonesia

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ABSTRACT

The purpose of this research was to make a model of the waste management system in the Randegan landfill without intervention. The modeling results obtained are then used as a simulation model in predicting and describing Randegan landfill conditions. Computing The simulation carried out in this research is based on a quantitative approach using the Powersim Constructor software tools. Research does not ignore the naturalistic paradigm with a qualitative approach through grounded research. The construction of this approach analysis uses constant comparison techniques. The research was carried out at the Randegan waste landfill in Mojokerto city which has a land area of 2.5 ha and has been operating since 1990. Randegan landfill consists of a passive zone and active zone. The passive zone is zone 1 and zone 2 is a zone that cannot receive waste anymore. Active zone is zone 3 which is a zone that still receives new waste entering the landfill. The research method is divided into 2 stages. The first stage is data collection, presentation and analysis. The second stage is carried out dynamic model engineering using powersimcontructor software, stakeholder analysis, problem formulation and making causal loop diagrams. The second stage is carried out to describe the behavior of the model. From several experiments conducted in the research obtained several results, namely the prediction of population growth rate is an average of 1.09% over a period of 30 years. The rate of population growth will increase the volume of waste consisting of inorganic and organic waste. Prediction of the rate of increase in the volume of organic and inorganic waste in the active zone is 167.58%. With limited landfill capacity, the condition in 2018 can no longer accommodate waste. This is because the capacity is smaller than the volume of waste that enters. This condition will also cause the volume of waste that is not accommodated from year to year is also getting bigger. If this is left unchecked, then the predicted volume of unaccounted waste will increase by 901.69% in the next 25 years. Based on simulations carried out using modeling without intervention, it is necessary to have a policy to reduce the burden of accumulating waste volumes in the Randegan landfill.

Key words : *Karst conservation, Bojongmanik, Limestone, Prospect area, Resources.*

Introduction

In line with the increase in population and activities, the amount of waste generated by urban activities increases over time. Population growth and changes in community consumption patterns lead to an increasingly volume, type, and diverse characteristics of waste (Ruslinda Yeni, *et al*., 2012). There is a solid waste problem because there is no professional waste management system planning. The solid waste sector is still not getting priority compared to other fields in urban development. Meanwhile, most urban communities are still not familiar with a good waste management system, still assuming that waste is a social cost, not a cost of profit. In the series of waste management processes, a city needs a place to accommodate and process waste residues, namely the provision of landfill. The mainstay of a city to solve its waste problem is the destruction of waste by landfilling on a landfill (Damanhuri, 2001).

During this time, the pile of waste in the Randegan landfill in Mojokerto city was not followed by the process of reducing waste with technology quickly and not comparable to the limited capacity of waste. So far, there is no waste management using technology specifically in the Randegan landfill. Randegan landfill operates by receiving waste of approximately 265 m3 / day to 300 m3 / day. This volume is predicted to increase due to an increase in the population. Based on this, in the future, one day the Randegan landfill will not be able to compensate for the daily waste generation that enters the landfill and the waste generation that already exists in the Randegan landfill before (anonymous, 2012).

Based on the problems described above, a research was conducted which aimed to (1) make modeling of waste management systems in Randegan landfill (without intervention) (2) simulate modeling designed using the Powersim Constructor application (3) predict and describe the conditions of Randegan landfill during 30 years (2013 to 2043).

Research Method

This research focuses on quantitative approaches using modeling with Powersim Constructor software tools. Research does not ignore the naturalistic paradigm with a qualitative approach through grounded research. The construction of this approach analysis uses the constant comparison technique.

The research was conducted in Randegan landfill located in Randegan, Kedundung village, Magersari sub-district, Mojokerto city as shown on the Figure 1. Randegan landfill has a land area of 2.5 hectares and has been operating since 1990. Randegan landfill consists of a passive zone (zone 1 and zone 2) and active zone (zone 3). The passive zone is a zone that is no longer able to receive waste, while the active zone is a zone that still receives new waste entering the landfill.

The research was carried out for 10 months through the stages of literature study, field survey / observation, data collection (interviews, questionnaires, photos, documents, and archives and data from related agencies), and data compilation, data analysis until journal writing.

This research management includes (1) data collection, presentation and analysis, (2) dynamic model engineering using powersimcontructor software: system analysis (stakeholder analysis, problem formulation and making causal loop diagrams); dynamic model engineering; analysis: description of the output of the model to describe the behavior of the model.

The management of dynamic model engineering includes selection stages on concepts and variables that are consistent and relevant to the engineered model. Cognitive mapping with systems thinking methods is done to develop abstract models of real conditions. Furthermore, a thorough and in-depth assessment of the assumptions and their consistency in the variables and their parameters is based on expert justification. The stages of model construction which includes the developed abstract model are represented in the dynamic model, verification and model validation, structural and functional improvements through simulation. Stages of sensitivity analysis to determine variables that have a significant effect (changes affect the overall model). Variables that are less / no effect in the model are eliminated.

Results and Discussion

The causal circle diagram illustrates the interaction between the components that exist in a system interacting and affecting the system performance that has been made. Population is a very important aspect in urban waste management, because there are many environmental problems caused by population problems. This is in accordance with the opinion of Handono (Handono and Mulyo, 2010). Model Management of Sustainable Waste Management Sites at Cipayung Landfill, Depok City, West Java. Dissertation. Bogor: Post Graduate Program in Bogor Agricultural Institute. which states that in the

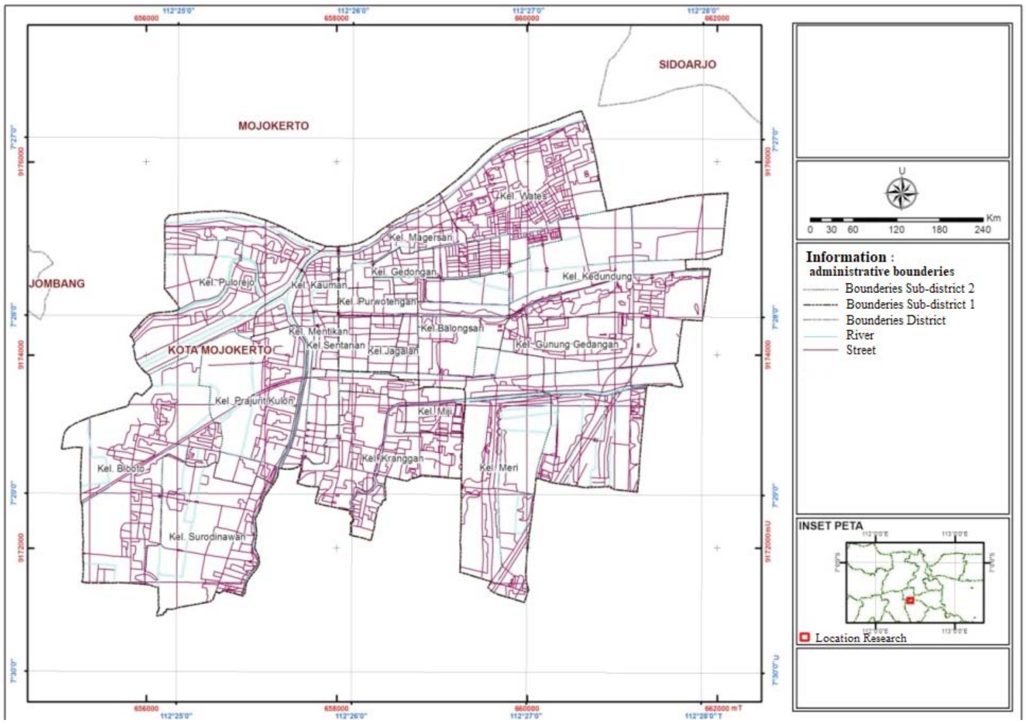

Fig. 1. Map of Research Site of Randegan Landfill City of Mojokerto

system of dynamics of waste management, the main component affecting the amount of residential waste is the population. Other variables that influence causal loop diagrams are organic waste and inorganic waste. Population factors are very important to note because it influences the increase in waste generation (Sasongko and Mulia, 2008).

The increase in the population of Mojokerto City continues to increase from year to year, where the number of residents of Mojokerto is influenced by factors of birth, death, immigration and out-migration. The factors of birth, death, immigration and out-migration affect the total population of the City. With the population increasing from year to year, it increases the volume of garbage generated from household waste/settlements (Hidayatno and Supriatna, 2009).

Household waste/ settlements are dominated by organic waste sourced from leftovers, vegetables and road waste (leaves) (Sasongko and Mulia, 2008). Whereas inorganic waste consists of plastic, metal, paper and glass waste. Increasing the volume of organic and inorganic waste produced by the population has resulted in increasing waste generation in polling stations in Mojokerto City. The source of waste in urban polling stations mostly originated from residential waste (Hidayatno and Supriatna, 2009).

Increasing waste generation results in increased volumes of garbage in Mojokerto TPS, resulting in increased volumes of waste (organic and inorganic) at the Randegan landfill (Handono and Mulyo, 2010). The large volume of waste in the landfill will increase the land needs for waste management in the landfill from year to year. With the increase in the need for management land, it results in reduced land availability in the landfill (Handono and Mulyo, 2010). Uncontrolled accumulation of waste resulted in the place in the future not being utilized properly. As a result, the limited amount of land in urban areas will be increasingly limited or thinning (Sasongko and Mulia, 2008).

Waste Management Model without Intervention, it is assumed that there is no handling at the Randegan Landfill. There is no effort to reduce waste accumulation, for example by landfill mining, scavenger participation, or composting. TPA runs naturally with no intervention from anywhere (except natural waste reduction factors).

Some of the assumptions of the Waste Management Model without Intervention are as shown on Table 1.

Table 1. Assumption of Waste Management Model without Intervention

No	Assumption	Value
1	Volume of garbage per person/day	0.0016963 kg/day
2	New Waste Density	165 kg/m³
3	Reduction factor /Natural shrinkage of waste	28% /year
4	Area of Active Zone (Zone 3)	5.726,809 m²
5	Compacting factor	3,2
6	Initial Volume of TPA Waste Zone (Zone 3)	46.387,15 m³
7	Maximum TPA plan height	15 m
8	Waste fraction that enters the landfill	80%
9	Initial population	136.373 Persons
10	Immigration Faction	0.022
11	Emigration Faction	0.019
12	Birth fraction	0.0142
13	Fraction of death	0.0077
14	One year	365 days

Dynamic system approach (Forrester, 1968), flow diagram is used as a tool in writing equations. The flow chart of the "Waste Management Model without Intervention" is presented in the following Figure 3 (Muhammadi *et al.*, 2001).

Based on the simulation results of the Waste Management Model without intervention, it shows that the population of Mojokerto continues to increase, from 136,373 people (in 2013) to 181,099 in the final year of the simulation (2043) as shown on Figure 3.

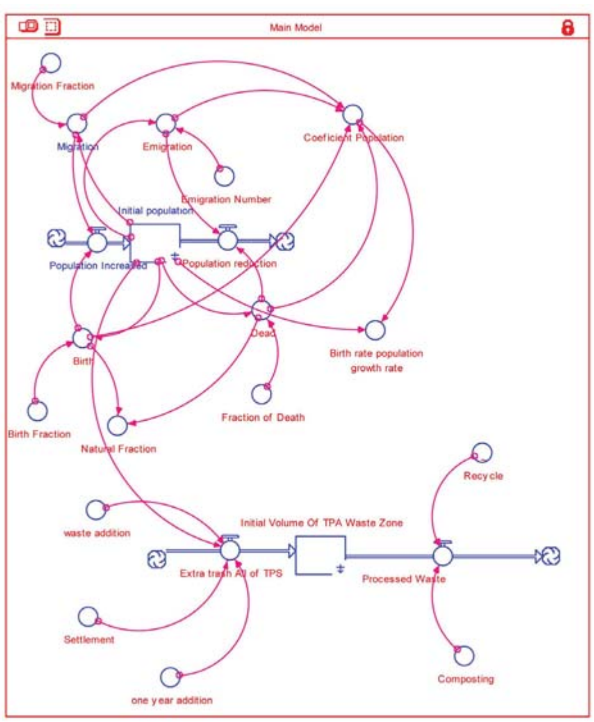

Fig. 2. Flow Chart of the Waste Management Model without Intervention

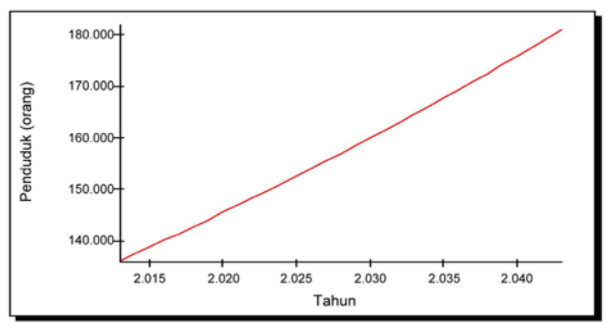

Fig. 3. Graph of Increased Dynamics of the population of the City of Mojokerto

The development of the city of Mojokerto is quite rapid resulting in a special attraction for the surrounding rural population, so that in droves migrated to the city of Mojokerto, and resulted in the population of "The City of Mojokerto" increasing. The increase of population will eventually increase the volume of waste as well. Simulation graph of increasing waste until 2043 as shown on Figure 4.

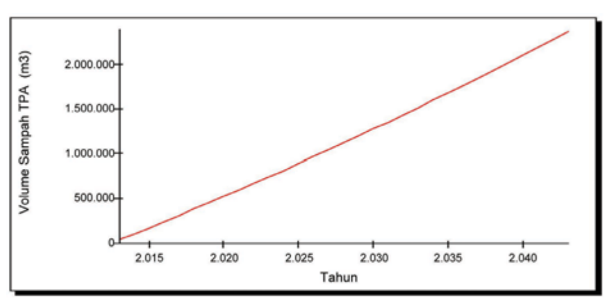

Fig. 4. Dynamics of Waste Volume Graph at Randegan Landfill

The result of Population Dynamics Simulation, Organic Waste Volume, Inorganic Waste Volume and Waste Volume in Landfill as shown on Table 2

Based on the Table 2, the increase in the population of Mojokerto City from year to year increases the volume of waste consisting of inorganic and organic waste. The volume of organic waste at the beginning of the simulation year (in 2013) amounted to 30,898 m menjadi increased to 1,584,249 m^3 (in 2043), while the volume of inorganic waste at the beginning of the simulation year (2013) was 15,488 m^3 increased to 794,146 m^3. Increasing the volume of waste both organic and inorganic waste will continue along with the increase in population (Sasongko and Mulia, 2008).

The volume of waste generation is also strongly influenced by the income of the population. The greater the income of the population in an area, the more likely the waste is produced, while the smaller the income of the population, the less likely the waste is produced (Cointreau and Sandra, 1982). In addition, the level of population growth also greatly affects the volume of urban waste which is the result of consumption of the population (Surjandari *et al.*, 2009).

Income and economic growth have an impact on the composition of the waste produced. High-income communities will consume more packaged products, resulting in a higher percentage of inorganic materials in the form of waste with a composition of metal, plastic, glass and textiles. Whereas for middle and low income people produce more organic waste (Ogwueleka, 2009).

The increment of organic and inorganic waste

Table 2. Population Dynamics Simulation Results, Organic Waste Volume, Inorganic Waste Volume and Waste Volume in TPA

Time	Population	Volume of Organic Waste (m^3)	Inorganic Waste Volume (m^3)	Landfill Waste Volume (m^3)
2013	136,373.00	30,898.48	15,488.67	46,387.15
2014	137,668.54	75,892.35	38,043.02	113,935.37
2015	138,976.39	121,313.66	60,811.64	182,125.30
2016	140,296.67	167,166.47	83,796.56	250,963.03
2017	141,629.49	213,454.89	106,999.83	320,454.72
2018	142,974.97	260,183.04	130,423.54	390,606.58
2019	144,333.23	307,355.12	154,069.77	461,424.89
2020	145,704.40	354,975.32	177,940.64	532,915.97
2021	147,088.59	403,047.92	202,038.29	605,086.21
2022	148,485.93	451,577.21	226,364.86	677,942.07
2023	149,896.55	500,567.53	250,922.53	751,490.06
2024	151,320.56	550,023.25	275,713.50	825,736.76
2025	152,758.11	599,948.81	300,739.99	900,688.80
2026	154,209.31	650,348.66	326,004.23	976,352.89
2027	155,674.30	701,227.30	351,508.48	1,052,735.78
2028	157,153.21	752,589.30	377,255.02	1,129,844.31
2029	158,646.16	804,439.23	403,246.15	1,207,685.37
2030	160,153.30	856,781.73	429,484.19	1,286,265.93
2031	161,674.76	909,621.49	455,971.50	1,365,593.00
2032	163,210.67	962,963.23	482,710.44	1,445,673.67
2033	164,761.17	1,016,811.72	509,703.40	1,526,515.11
2034	166,326.40	1,071,171.76	536,952.79	1,608,124.55
2035	167,906.50	1,126,048.23	564,461.05	1,690,509.27
2036	169,501.61	1,181,446.02	592,230.63	1,773,676.65
2037	171,111.88	1,237,370.09	620,264.03	1,857,634.12
2038	172,737.44	1,293,825.44	648,563.75	1,942,389.19
2039	174,378.44	1,350,817.11	677,132.31	2,027,949.43
2040	176,035.04	1,408,350.21	705,972.28	2,114,322.49
2041	177,707.37	1,466,429.87	735,086.22	2,201,516.10
2042	179,395.59	1,525,061.29	764,476.75	2,289,538.04
2043	181,099.85	1,584,429.70	794,146.49	2,378,396.19

will increase the volume of waste at the Randegan landfill, namely at the beginning of the simulation year (2013) of 46,387 m^3 increased to 2,378,396 m^3. The problem of the high volume of urban waste is influenced by the high purchasing power of urban communities and the high level of population growth (Hidayatno and Supriatna, 2009). The increment of volume of waste will also increasing heavy of waste. From the results of simulation calculations at the beginning of the simulation year (2013), amounting to 7,653,879 kg increased to 392,435,371 kg (2043) as shown on Figure 5.

Before calculating the volume of waste that is not accommodated, the calculation of post reduction waste must be calculated, because the volume of waste in the Randegan landfill is affected by the factor of natural waste reduction worth 28% per year. Waste in the landfill must undergo a reduction process. The process of degradation or decomposition of waste material in landfills is a process where the waste in the landfill area has been degraded with an average shrinkage of 28% per year (Krook and Joakim, 2012). The simulation results in these conditions are shown on Table 3.

Based on the simulation results as shown on Figure 6, it shows that the volume of waste in landfill (post reduction) at the beginning of the simulation year (2013) was 33,398 m^3, increasing to 1,712,445

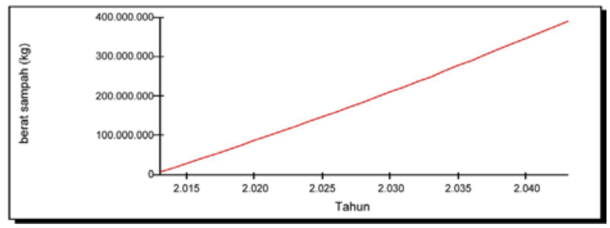

Fig. 5. Graph the dynamics of increase heavy of Landfill

Table 3. Dynamics of Waste Volume in Post-Reduction

Time	Population	Landfill Waste Volume (m^3)	Post-Reduction Waste Volume (m^3)
2013	136,373.00	46,387.15	33,398.75
2014	137,668.54	113,935.37	82,033.47
2015	138,976.39	182,125.30	131,130.21
2016	140,296.67	250,963.03	180,693.38
2017	141,629.49	320,454.72	230,727.40
2018	142,974.97	390,606.58	281,236.74
2019	144,333.23	461,424.89	332,225.92
2020	145,704.40	532,915.97	383,699.49
2021	147,088.59	605,086.21	435,662.07
2022	148,485.93	677,942.07	488,118.29
2023	149,896.55	751,490.06	541,072.84
2024	151,320.56	825,736.76	594,530.47
2025	152,758.11	900,688.80	648,495.94
2026	154,209.31	976,352.89	702,974.08
2027	155,674.30	1,052,735.78	757,969.76
2028	157,153.21	1,129,844.31	813,487.90
2029	158,646.16	1,207,685.37	869,533.47
2030	160,153.30	1,286,265.93	926,111.47
2031	161,674.76	1,365,593.00	983,226.96
2032	163,210.67	1,445,673.67	1,040,885.04
2033	164,761.17	1,526,515.11	1,099,090.88
2034	166,326.40	1,608,124.55	1,157,849.67
2035	167,906.50	1,690,509.27	1,217,166.68
2036	169,501.61	1,773,676.65	1,277,047.19
2037	171,111.88	1,857,634.12	1,337,496.57
2038	172,737.44	1,942,389.19	1,398,520.22
2039	174,378.44	2,027,949.43	1,460,123.59
2040	176,035.04	2,114,322.49	1,522,312.19
2041	177,707.37	2,201,516.10	1,585,091.59
2042	179,395.59	2,289,538.04	1,648,467.39
2043	181,099.85	2,378,396.19	1,712,445.26

m³. This happened because the waste generation produced by urban communities fluctuated dynamically with time due to population growth and the amount of waste produced by each resident per day (Handono and Mulyo, 2010).

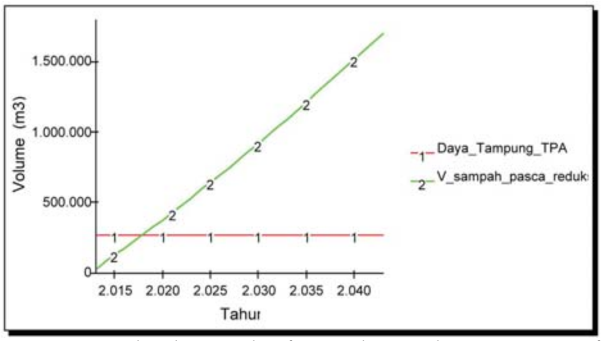

Fig. 6. Graphs the result of Simulation the Dynamics of Volume the Waste and the capacity (without intervention)

Based on the graph as shown on Figure 7, post-reduction waste volume has increased the maximum landfill capacity (zone 3) of 274,886 m³. With limited landfill capacity, it causes conditions in

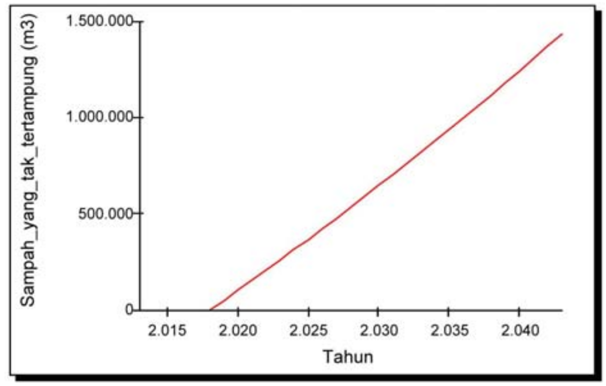

Fig. 7. Graph of waste remaining that is not accommodated at the Randegan landfill

Table 4. Dynamics of Waste that is not accommodated

Time	Post-reduction Waste Volume (m³)	Landfill Capacity (m³)	Waste is not accommodated (m³)
2013	33,398.75	274,886.83	-
2014	82,033.47	274,886.83	-
2015	131,130.21	274,886.83	-
2016	180,693.38	274,886.83	-
2017	230,727.40	274,886.83	-
2018	281,236.74	274,886.83	6,349.91
2019	332,225.92	274,886.83	57,339.09
2020	383,699.49	274,886.83	108,812.66
2021	435,662.07	274,886.83	160,775.24
2022	488,118.29	274,886.83	213,231.46
2023	541,072.84	274,886.83	266,186.01
2024	594,530.47	274,886.83	319,643.63
2025	648,495.94	274,886.83	373,609.10
2026	702,974.08	274,886.83	428,087.25
2027	757,969.76	274,886.83	483,082.93
2028	813,487.90	274,886.83	538,601.07
2029	869,533.47	274,886.83	594,646.64
2030	926,111.47	274,886.83	651,224.64
2031	983,226.96	274,886.83	708,340.12
2032	1,040,885.04	274,886.83	765,998.21
2033	1,099,090.88	274,886.83	824,204.05
2034	1,157,849.67	274,886.83	882,962.84
2035	1,217,166.68	274,886.83	942,279.84
2036	1,277,047.19	274,886.83	1,002,160.36
2037	1,337,496.57	274,886.83	1,062,609.74
2038	1,398,520.22	274,886.83	1,123,633.38
2039	1,460,123.59	274,886.83	1,185,236.76
2040	1,522,312.19	274,886.83	1,247,425.36
2041	1,585,091.59	274,886.83	1,310,204.76
2042	1,648,467.39	274,886.83	1,373,580.56
2043	1,712,445.26	274,886.83	1,437,558.43

2018, the landfill cannot accommodate garbage anymore, due to the capacity of <volume of waste entering. This condition causes greater volume of inaccessible waste, starting in 2018 the remaining unused waste of 6,349 m^3 increases to 1,437,558 m^3 as shown on Table 4.

Graph of the simulation the remaining waste that is not accommodated at the Randegan landfill as shown on Figure 7.

Based on the above conditions (waste management in landfill without intervention), shows that the Randegan landfill is no longer able to accommodate waste starting in 2018. In this regard, a policy is needed to reduce the accumulation/ volume of waste at the Randegan landfill. The volume of waste that goes into landfill is increasing from year to year, causing the accumulation of waste is also getting bigger (Surjandari *et al*., 2009). Landfill conditions will get worse if the handling of waste in the landfill is not controlled by means of illegal buildup that will threaten the environment both around the landfill and the city (Surjandari *et al.,* 2009).

Conclusion

Based on the results and discussion of the research "the Waste Management System model in the Randegan Landfill of Mojokerto City (without intervention)" has been done, it was concluded that:

1. Based on the simulation results of the Waste Management Model without intervention, it shows that the population of Mojokerto continues to increase, from 136,373 people (in 2013) to 181,099 in the final year of the simulation (2043). The average percentage of increase is equal to 1.09% for 30 years. The increasing number of residents of Mojokerto City from year to year increases the volume of waste consisting of inorganic and organic waste. The volume of organic waste at the beginning of the simulation year (in 2013) amounted to 30,898 m increased to 1,584,249 m^3 (in 2043), while the volume of inorganic waste at the beginning of the simulation year (2013) was 15,488 m^3 increased to 794,146 m^3. The average percentage of increase is equal to 167, 58% for 30 years.
2. Post-reduction waste volume has increased the maximum capacity of Landfill (zone 3) of 274,886 m^3. With limited landfill capacity, it causes conditions in 2018, the landfill cannot accommodate waste anymore, due to the capacity of <volume of waste entering. This condition causes greater volume of inaccessible waste, starting in 2018 the remaining unused waste of 6,349 m^3 increases to 1,437,558 m^3. The average percentage of increase is equal to 901,69% for 25 years.
3. Waste management in Landfill (without intervention) shows that the Randegan landfill is no longer able to accommodate waste starting in 2018. In this regard, a policy is needed to reduce the accumulation/volume of waste at the Randegan landfill.

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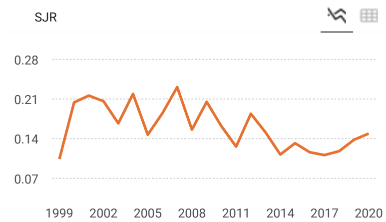

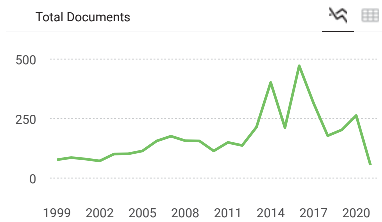

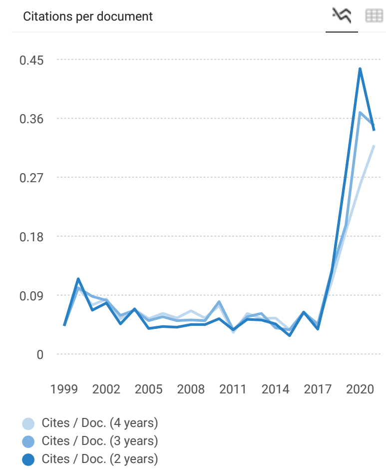

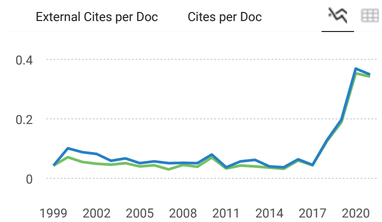

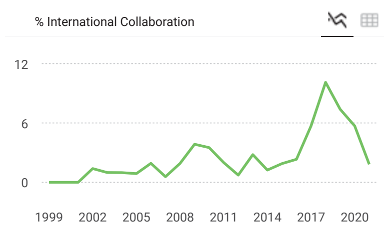

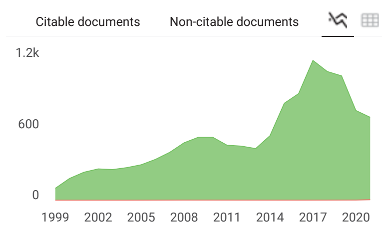

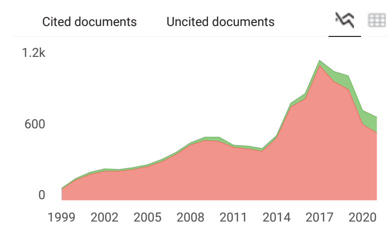

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