Design of Sanitary Landfill for Open Dumping Site Sukawinatan, Palembang

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Abstract. Sukawinatan landfill has been operating since 1994 but still uses an open dumping system. In the absence of good control in the landfill area, it has caused adverse impacts on the environment including landslides of garbage, pollution of water bodies for agricultural water sources and community drinking water sources, and flooding due to blockage of river flow by piles of garbage. This study aims to design a sanitary landfill for open dumping site Sukawinatan in accordance with SNI 19-2454-2002 to avoid negative impacts. In 5 Ha of land for the design, 744.68 m of leachate pipe is needed using HDPE material with a diameter of 300 mm, a 150 mm gas pipe with a length of 1331.5 m equipped with a 1.5 cm perforation hole. In addition, the design also included leachate treatment installations (collection wells, anaerobic ponds, facultative ponds, maturation ponds) with a discharge of 442.26 m^3/hour, monitoring wells (58.88 m^3), drainage channels, and geomembrane layers. The estimated investment cost is IDR 8.5billions and the operational cost is 267 millions/month. This sanitary landfill design can accommodate Palembang city waste for 27 years, until 2049.

Keywords: Sanitary landfill, Open dumping, Leachate, Geomembrane layers, Anaerobic ponds.

1 Introduction

The increasing of the volume of waste in urban areas, including Palembang City, Indonesia, is closely related to the increasing of the number of residents, where every activity always generates waste [1]. Based on data from the Palembang City Environmental Agency (BLH) [2] in 2018, waste generation is 182,500,000 kg/year with an average daily rate of 500 tons/day. According to Law no. 18 of 2008 [3] stipulates that Final Processing Sites (TPA) located in large or metropolitan cities must be planned using sanitary landfill method.

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TPA is a means for processing waste which is the last stage in its management or a place where waste can be isolated safely so it does not cause disturbance to the environment. Sanitary landfill also become an affordable and environmentally acceptable method of solid waste disposal [4][5]. Most of landfills in Indonesia are still operated by open dumping (open system). In an open dumping system, waste is simply thrown away without any continuous processing. In the processing of waste in Palembang City, it is carried out at TPA Sukawinatan and TPA Karyajaya. TPA Sukawinatan has been operating since 1994 and it is still using an open dumping system so far. An open waste processing system like this should no longer be implemented because it endangers the environment and the health of the people around the TPA. TPA Sukawinatan is the biggest TPA in Palembang City, has a land area of 45 Ha and currently less than 10 Ha is still being used.

Based on initial observations and interviews with Sukawinatan TPA officers, it is known that the remaining land area for Sukawinatan TPA has been getting narrower, so that when it is full it will be transferred to Karyajaya TPA. Apart from that, there were several other problems that occurred at the Sukawinatan TPA, including the lack of proper control over the TPA area, landslides of mountains of garbage that hid the yards of houses and agricultural land of local residents, polluted the river "Sedapat" the source of water for residents, and the occurrence of flooding for more than two months due to blockage of the river flow by garbage. If this is allowed to continue, it can potentially lead to wider environmental losses and damage. pollutes water bodies and is hazardous to health. Based on these conditions, this study aims to design a better Sukawinatan TPA installation in accordance with applicable regulations (Indonesian National Standard-SNI 19-2454-2002) so that it can extend the life of the TPA, as well as reduce potential losses and environmental impacts due to TPA activities.

2 Methods

Sukawinatan landfill is an abandoned landfill in Palembang City which is located close to residential areas. Residents around the landfill complained about the frequent landfilling of their land is often piled up due to the avalanche of garbage pushed by workers' heavy equipment and pouring rain. The rubbish collapsed until it covered the flow of the Sedapat River which is right next to the landfill site, resulting in water and rubbish flooding in residents' homes. Moreover, the urgency of selecting Sukawinatan landfill as a research location is due to the remaining landfill land which is only 5 Ha out of a total of 20 Ha. The 5 ha of land consists of vacant land and a leachate processing plant that is no longer operating.

This research begins with the collection of research supporting data such as the topographical map of the city of Palembang, the overall map of the Sukawinatan TPA, data on waste generation in the city of Palembang and its composition, as well as other conditions to support design considerations. The waste generation data is used to find projections of waste generation until 2050 (the age of design) so that it can be used to calculate the capacity of landfill. Then a comparison of alternative landfill designs was carried out using various methods, namely open dumping, controlled landfill and sanitary landfill methods. Determination of the selected design alternative is tested using the Analytical Hierarchy Process (AHP) method, and then detailed design of the selected design alternative is carried out. Parameters for comparison are land area, investment costs, and hygiene.

Research on the evaluation of landfill conditions using various methods has been carried out by many researchers such as research about environmental impacts of open-dumping landfill to lagoon sediments in Nothern Tunisia [6], implication for land degradation of municipal solid waste open dumping in Iran [7], different landfill concept from open dumping to BMP landfill [8], sanitary landfill types and design [9], open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity as waste dumping sites of Islamabad city [10], settlement model of waste soil for dumping area in Malaysia [11], greenhouse gas emission potential of the municipal solid waste disposal sites in Thailand [12], site investigation of open dumping site of municipal solid waste in Faisalabad [13].

The Analytical Hierarchy Process (AHP) method is often used in solving a problem that is not simple and orderly, namely by providing an assessment of several variables based on the subjective perspective of the reviewer and determining the selected variable as a priority in solving the problem [14]. The working steps of the AHP method are: defining the problem and determining the purpose of the problem; structuring complex problem frameworks into hierarchies so that problems can be reviewed in detail and structured; arrange the priority of each problem element in the hierarchy; test the consistency of the comparison between elements. The results will be returned to the experts for consideration if the judgments are inconsistent. Therefore, the AHP method employs the algorithm for calculating the inconsistency rate of a pairwise comparison matrix which is defined as follows [14] [15] [16] [17]:
a. Calculate the weighted sum vector by multiplying the pairwise comparison matrix by the local priority vector
b. Calculate the consistency vector by dividing the elements of the overall priority vector coordinate-wise by those of the local priority vector. That is, each element of the consistency vector is obtained by dividing the corresponding element of the weighted sum vector by that of the local priority vector. The components of the consistency vector are actually λ_{max} estimates.
c. Calculate the largest Eigenvalue of the pairwise comparison matrix (λ_{max}). The average of the elements of the consistency vectors is equal to λ_{max}
d. Calculate the consistency index (CI) by assuming that the pairwise comparison matrix is an m x m matrix, the inconsistency index equals $\frac{\lambda_{max}-m}{m-1}$.
e. Define the consistency ratio (CR) by $\frac{CI}{RI}$, where RI is the random index based on the experts judgment. The results of the pairwise comparisons are acceptable if the CR value is less or equal to 0.1 [18] [19].

3 Results

3.1 Existing Condition of TPA Sukawinatan

TPA Sukawinatan is located in Palembang City with 5 hectares of remaining land out of a total of 20 hectares which was originally used as a landfill. This design was carried out on the remaining 5 hectares of land but still utilized the existing buildings that had existed before. The

5 Ha land consists of vacant land and a leachate treatment plant that is no longer operating (4 ponds).

Palembang City produces 425,390.66 tons of waste per year in 2021 with a composition of wood (1%), paper (10.5%), food waste and leaves (67%), textiles (1%), plastic (7.5%), glass (2.5%), iron and other metals (1%), other waste (8.5%) [20]. If converted into volume units, Palembang City can produce as much as 3552.31 m^3 of waste per year. From waste generation data, a projection of the generation can be simulated to see how many years this design TPA can accommodate Palembang city waste (assuming the average waste reduction/shrinkage is 79.57%: 80% reduction in biodegradable waste, 90% reduction in paper, plastic, textile, glass and metal)) [21]. After the iteration up to 2050, it is known that the design landfill capacity will be full in 2049. This is because the land planned for landfill is in the form of rectangular blocks with a depth of 6 m, length 550 m, width 300 m, and depth 6 m (volume 99 thousand m^3). In 2049, the capacity of waste and soil (density factor 0.3) will reach 96 thousand m^3. Table 1 shows details of iterations of waste generation up to 2050.

Table 1. Calculation of the Usage Age of the landfill

Year	Solid Waste Generation (m^3)	Reduction (%)	Reduction Volume (m^3)	Solid Waste Generation after Reduction (m^3)	Waste Dispossed to Landfill (m^3)
2023	904998.453	79.57	720107,2691	184891,184	271499,5359
2024	950067.376	79.57	755968,6111	194098,7649	285020,2128
2025	997380.731	79.57	793615,848	203764,8834	299214,2194
2026	1047050.292	79.57	833137,9172	213912,3746	314115,0875
2027	1099193.396	79.57	874628,1855	224565,2109	329758,0189
2028	1153933.227	79.57	918184,6691	235748,5584	346179,9682
2029	1211399.102	79.57	963910,2656	247488,8366	363419,7307
2030	1271726.778	79.57	1011912,997	259813,7806	381518,0333
2031	1335058.771	79.57	1062306,264	272752,5069	400517,6313
2032	1401544.698	79.57	1115209,116	286335,5818	420463,4093
2033	1471341.624	79.57	1170746,53	300595,0937	441402,4871
2034	1544614.437	79.57	1229049,707	315564,7294	463384,331
2035	1621536.236	79.57	1290256,383	331279,8529	486460,8707
2036	1702288.740	79.57	1354511,151	347777,5896	510686,622
2037	1787062.719	79.57	1421965,806	365096,9136	536118,8158
2038	1876058.443	79.57	1492779,703	383278,7399	562817,5328

2039	1969486.153	79.57	1567120,132	402366,0211	590845,846
2040	2067566.564	79.57	1645162,715	422403,849	620269,9691
2041	2170531.379	79.57	1727091,818	443439,5606	651159,4136
2042	2278623.841	79.57	1813100,99	465522,8508	683587,1524
2043	2392099.308	79.57	1903393,42	488705,8887	717629,7925
2044	2511225.854	79.57	1998182,412	513043,442	753367,7562
2045	2636284.902	79.57	2097691,896	538593,0054	790885,4705
2046	2767571.890	79.57	2202156,953	565414,9371	830271,5669
2047	2905396.970	79.57	2311824,369	593572,6009	871619,0909
2048	3050085.739	79.57	2426953,222	623132,5165	915025,7217
2049	3202980.009	79.57	2547815,493	654164,5158	960594,0026
2050	3361438.613	79.57	2674696,704	686741,9087	1008431,584

3.2 Selection of Design Alternatives with the AHP Method

Furthermore, a comparison of design alternatives between open dumping method, controlled landfill, and sanitary landfill was carried out. In terms of hygiene, the parameter is the number of fly eggs that may be formed due to compaction (soil cover) of the waste and overburden. In controlled landfill and open dumping it is predicted that there will be 900 fly eggs due to compaction of waste and soil once a week for controlled landfill and no compaction for open dumping [23]. Sanitary landfill have no potential to produce fly eggs because it is compacted every day. For land area parameters, sanitary landfill (alternative 1) requires approximately 50,070 m^2 of land, controlled landfill of 40,035 m^2 of land, and open dumping of 200 thousand m^2 of land. The difference in land area is found in the anaerobic pond section which is not available in the controlled landfill. Whereas in the open dumping method, waste compaction is not carried out so that a waste room that is much wider than the other two methods is needed [23].

For investment costs, sanitary landfills require funds that are not much different from controlled landfills, namely 8,456,879 IDR for sanitary landfills and 8,251,357 IDR for controlled landfills. Meanwhile, open dumping requires an investment cost of IDR 2,760,512. The selection of design alternatives is carried out using the Analytical Hierarchy Process (AHP) method through a comparison of the selected criteria and predetermined priority scales.

In assessing the weight of the criteria between hygiene, land area, and investment costs, as well as the normalized weighting of the criteria, a CR value of 0.006 is obtained, the weight for hygiene vs. Alternatives and normalized hygiene vs criterions CR 0.000, weight fot land area vs alternatives and normalized land area vs criterions CR 0.000, weight for investment costs vs alternatives and normalized investment costs against criterions CR 0.000. All of the four CR values are less than 0.1, which means the weighting value is acceptable. Based on the AHP calculation at that stage [24], the highest weight value was obtained for the sanitary landfill alternative.

3.3 Detail Design of Sanitary Landfill

The layout of the sanitary landfill design can be seen in Figure 1 and the front look of the landfill Sukawinatan Palembang in **Figure 2**. The landfill consists of the stockpilling area (1), monitoring well (2), pump house (3), anaerobic pool (4), facultative pool (5); maturation pool (6), gas processing installation (7), haevy equipment parking area (8), guardhouse (9), parking lot (10), office (11), toilet (12), laboratory (13), composting house (14), waste processing building (15).

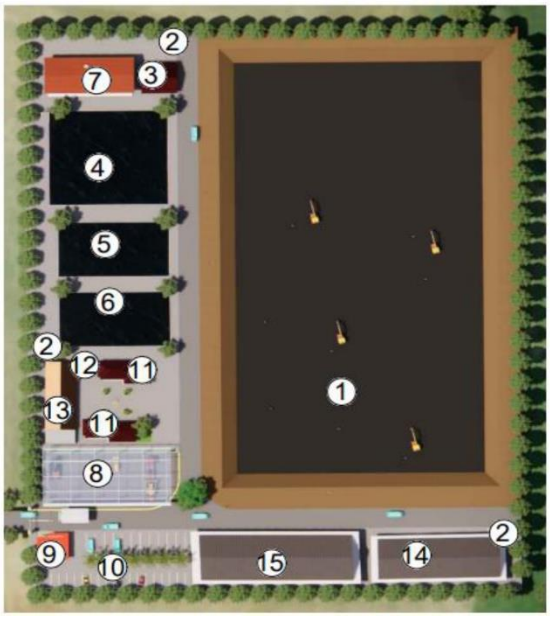

Fig. 1 Layout of Sukawinatan Landfill

Fig. 2 The Frontlook of Sukawinatan Sanitary Landfill

Main Building

Based on the guidelines in the Book of Procedures for Planning and Development of landfill (2018) [25], [26], [27], there are 3 main buildings with the following criteria:

1) Gate: has a height ranging from 4.2 to 5 meters; the width of the door at the main door or entrance can be passed by trucks (two-ways); there is placement in the form of PUPR (Minister For Public Works and Human Settlements) and Regency/City logos in accordance with the development area; the design used in constructing the landfill is should contain the characteristics of the Regency/City.

2) The Guard Post: is a building that functions as a monitor in weighing the mass of waste from the entry of garbage trucks carrying waste from serviced areas as well as a landfill security control center. In planning the construction of a guard post, the following criteria must be considered: the guard post must be able to accommodate at least 1 guard operator and one security guard (optional); building area for the construction of an inter-prone post 4 - 9 m^2; guard posts can be built merge with the gate or can be built separately, if there is construction of a guard post that is merge with the gate, then it needs to be built with the characteristics of that area. During the construction process, qualified material construction must meet K175 for concrete , quality of U24 type and 12 size for steel reinforcement.

3) The office: was built as a supporting facility that functioned as the center of landfill waste management activities. The office being built needs to pay attention to the following criteria: able to accommodate from 3 to 5 operators; the area of land for office

construction is attempted to be ± 75 m^2; has other supporting rooms such as warehouses, toilets and places of worship.

Leachate Collection System

Based on the Regulation of the Minister of Public Works (2013) and other sources [27], [28], there are two channels in the leachate collection channel, namely the secondary collection channel and the primary collection channel. It is necessary to have criteria that must be considered for planning a leachate distribution system, including:

1) Criteria for secondary collection channels: installed in an elongated position in the middle of the block/zone of stockpiling; minimum slope of 2% consisting of a series of PVC pipes; the bottom of the collecting duct must be made of a waterproof coating.

2) Criteria for primary collection channels: use PVC/HDPE pipes directed to pipes with a diameter of 300 mm. In the pipe that goes to the non-perforated leachate collection tank, the primary channel is connected to the downstream part of the secondary channel by a control tank whose purpose is as a ventilation combined with a vertical gas collecting channel. The design criteria for pipe dimensions are 15-20 cm (the diameter makes it easier to clean)

3) Leachate drainage: Leachate drainage is carried out very optimally using the gravity method with a flow rate of 0.6-3 m/sec. The channel or pipe (d/D) has a maximum water depth of 80%, where d is the height of the water and D is the diameter of the pipe.

4) Calculation of leachate discharge: carried out using the assumption of rainfall where the rain concentrated at 4 hours is 90% (van Breen method), so the peak factor becomes 5.4. It is assumed that as much as 20-30% of rainwater that falls will become leachate. It is also assumed that in 1 month there will be rain for 20 days based on daily or annual precipitation data for the last 5 years.

5) Leachate container: must be acid-resistant and watertight with dimensions according to the calculated leachate discharge. It is estimated that the leachate discharge can be generated as much as 21.42 m^3/day taking into account the rainfall of 1,307 m/year, an infiltration rate of 60%, and a landfill cell area of 10,000 m^2. The landfill design in this study used leachate pipes with a diameter of 300 mm.

Gas Handling System

There are several design criteria, namely the material of the pipe casing is made of PVC or HDPE with a diameter of 100-150 mm, with drilled holes diameter of 50-100 cm and perforations with a diameter of 8-12 mm with a vertical distance of 25-50 m. The installation of gas piping in this landfill consists of 3 series, namely horizontal ventilation which functions to catch the flow of gas in from one cell or layer of waste, vertical ventilation which directs and flows the gas formed upwards, final ventilation which is built when the final pile has been formed (can be connected to gas burner/gas collector for further utilization) [25], [26], [27]. In this study, the design of landfill gas pipelines uses PVC material with a diameter of 150 mm.

Leachate Treatment System Installation

The design criteria are carried out referring to the Regulation of the Minister of Public Works No. 3 of 2013 [27] which regulates the function of the installation, leachate depth, BOD removal (percentage of BOD that can be removed), detention time (days), organic load (kg/ha.day), pH, and the physical material of the processing building (stone/soil pair permeability) [25], [26], [27], [29]. In this study an alternative treatment was designed using 1 unit of anaerobic pond which functions as influent stabilization, sedimentation allowance, and removal of high-value BOD, COD and TSS levels, 1 facultative pond for BOD, COD and TSS removal as well as a semi facultative pond. anaerobic - aerobic which can also be known as a transitional pond to an aerobic pond and 1 maturation pond or commonly known as an aerobic pond which functions as a removal of pathogenic microorganisms and nutrients. Wetland ponds or biological ponds (which function as nutrient, BOD, COD, and TSS parameter removal) was not used because the detention time used in anaerobic ponds is long enough, so the function of all ponds used to produce effluent from the leachate installation comply with applicable quality standards.

A collecting well volume of 0.195 m^3 and an excavation volume of 0.507 m^3 are required with a leachate discharge of 21.42 m^3/day,. The aerobic pool is designed with an area of 238.19 m^2 with the consideration that it can set aside 1000 mg/L BOD. The detention time in the anaerobic pond was 45 days. The design pool volume is 127,296 m^3 with a surface area of 63.64 m^2 for facultative ponds. The facultative pond is designed to remove 1500 mg/L BOD with a detention time of 6 days. Meanwhile, the maturation pond was designed to remove 375 mg/L BOD with a detention time of 7 days, having a volume of 147.56 m^3 (surface area of 147.56 m^2).

Monitoring Well

The planning of a Sanitary Landfill is necessary to construct monitoring wells in order to monitor the quality of groundwater in certain aquifers (whether there is water contamination by leachate or not). This is regulated in Law no. 18 of 2008 concerning waste management [30] and in the Minister of Energy and Mineral Resources regulation number 31 of 2018 [31]. There are several criteria or conditions that can be used, including (a) there are at least 3 monitoring wells, (b) the position follows the direction of groundwater flow with a minimum distance of 10-20 meters (1 upstream and 2 downstream), (c) a minimum depth of 20 m and an area of a minimum area of 1m, (d) concrete construction material with a thickness of 15 cm and a diameter of 100 cm, (d) around the surface of the well, a layer of gravel (20 m thick) is made and a concrete cover plate is provided, (e) the well must be shallow so that the groundwater table is stable at the change of seasons, (f) there is adequate road access and equipment. In this study, 3 monitoring wells were built with a depth of 25 m and a diameter of 1 m, resulting in a volume of 9.62 m^3 for each well.

Landfill Base Layer

The excavation cover area is 2593 m^2 with the consideration that there are 12 excavation segments with an area of 216.09 m^2 each [25], [26], [27]. Based on this, 10 rolls of geomembrane material from the base layer and from the landfill are needed (1 roll = 275 m^2).

Waste Processing Flow in Landfill

The steps in which waste enters from the landfill entrance to leachate processing can be seen in Figure 3. First, the garbage truck heads to the weighbridge to record incoming waste generation data then heads to the landfill to be compacted and filled. The leachate produced will flow to the leachate processing pond while the gas produced will go to the gas installation pipe.

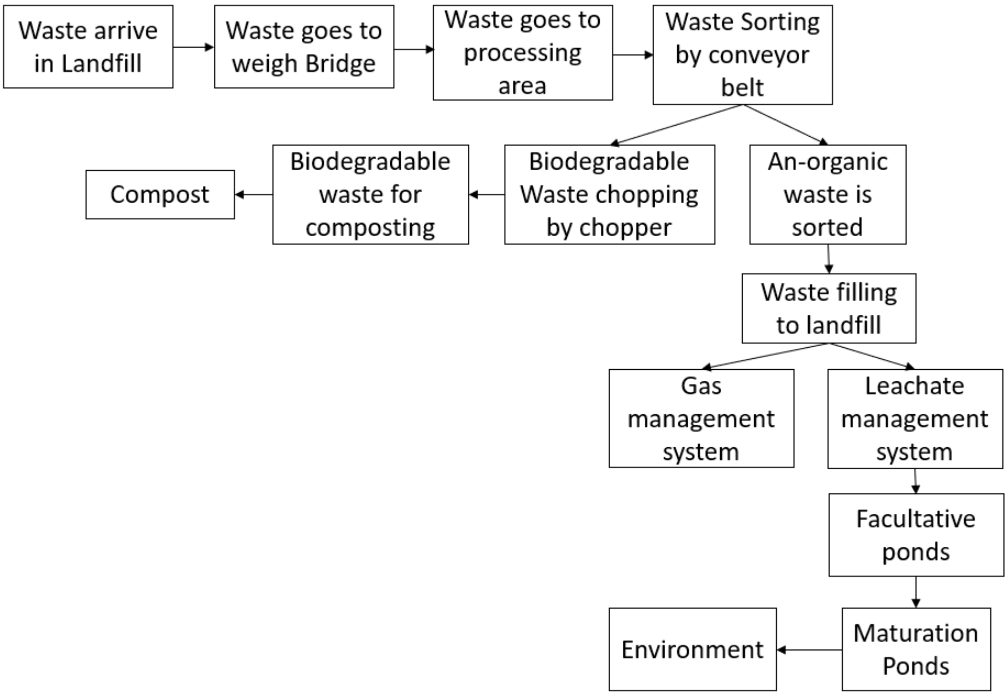

Fig. 3 Steps of Waste Flow in Landfill Sukawinatan Design

Budget Plan

The construction of the leachate pipe and gas pipeline required a cost of 230 million rupiah and 272 million rupiah respectively. Meanwhile for leachate treatment ponds, it costs 32 million rupiah to construct collecting wells, 363 million rupiah for anaerobic ponds, 66 million rupiah for facultative ponds, 231 million rupiah for maturation ponds. In addition, the costs required for monitoring wells, drainage channels, geomembranes, road pavements amounted to 54 million rupiah, 26 million rupiah, 1.8 billion rupiah and 1.9 billion rupiah respectively. At the beginning of the design, it required the purchase of heavy landfill equipment such as a compactor (912 million rupiah), a power shovel (22.5 million rupiah), and the cost of a digger. If all are added up, an investment cost of 8.6 billion rupiah is obtained. For the needs of operational costs such as employee salaries, electricity bills for water and office needs, a fee of 268 million rupiah per month is required.

Conclusions

- The design of the sanitary landfill in this study used guidelines from the Book on Procedures for Planning and Development of Waste Final Processing Sites (TPA), 2018 and Regulation of the Minister of Public Works No. 3 of 2013. With a lifespan of 27 years in the future, the Sukawinatan landfill which was previously full and must be transferred to the new landfill, can extend its useful life and prevent the new landfill from being used.

- The sanitary landfill method designed in this study is not only for landfill, but also complete with supporting facilities such as gates, guard posts, weigh stations, offices, laboratories, parking lots and toilets, leachate collection systems, gas treatment systems, processing plants. leachate (anaerobic, facultative and maturation ponds), drainage system, and monitoring wells.

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