Investigation of Sub-surface Contamination around the Landfill site: A Case Study.

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Abstract. Landfill leachate is a hazardous liquid that poses negative impacts if leaks out into environmental elements such as sub-surface soil and ground water systems. In the current study detailed investigation was conducted on the Municipal solid waste landfill site situated in northern part of Maharashtra, which is a non-Engineered landfill. Ground water samples from nearby well and Tube wells as well as soil samples around the landfill-site were collected to assess the possible impact of leachate percolation on soil and ground water quality. Concentration of various physiochemical parameters and heavy metals (Pb, Cd, Cr, Hg, As) in ground water were determined and compared with Indian Standard for drinking water. The soil samples taken in the vicinity of landfill site at a shallow depth of 1m and 2m using hand auger and were analyses for presence of Heavy Metals and Organic Content. The contaminated soil near landfill was compared with normal soil samples taken at proximity of landfill site. The presence of high organic contents and heavy metals in soil samples indicates that there is appreciable contamination of soil due to leachate migration from landfill site. The result shows that there is a presence of contamination content in ground water table observed in surrounding wells. The study indicated that leachate can damage the soil and ground water properties and can cause greater threat to sub surface environment if further action is not taken.

Keywords: Environmental; Landfill; Leachate.

1 Introduction

Currently the solid waste disposal and management is one of the most important crises tackled by many of the urban and industrial areas in both developed and developing countries which direct the environmental issue in day today life [3]. Leachate is generated due to the percolation of water or precipitation into dumpsites and its permeation through waste as well as by the process of squeezing of the waste due to its own self-weight [5]. Huge amount of solid waste is generated on daily basis and its management is a major issue. Solid waste generation has increased parallel to the development of industrialization, globalization and urbanization [12]. However, today, due to increased land value, inadequate space, and limited nature capacity to handle unwanted emissions and residues pose long-term environmental and human health problems [20]. Unscientific and non-engineering open dumping of waste is commonly prevalent in most developing countries as it is the simplest and most cost-effective method of waste disposal [5]. This practice is also practiced in the developed countries up to a certain extent. Therefore, it desperately needs urgent action to be taken to minimize the associated harmful effects.

2 Study Area

The study Area selected was a solid waste landfill site. The open dumping ground was actually situated in Northern part of Maharashtra. It is a non-engineered landfill. There is no lining at the bottom of the dump yard. The total area occupied by dumping was near about 28 Acres [19]. Daily about 300 Tons of waste was generated was dumped at the site. The height of landfill heap varies from 8m to 10m. The dumping was done at site since last 25 to 30 years. The annual average rainfall is noted to be 533 mm. The region experiences rainfall in the months of June to September. The study aims at addressing current and potential negative environmental impacts due leachate discharge by systematically examining the quality and condition of both soil and water which forms part of the study area and the surrounding environment. Therefore, this research study deals with the soil and water quality issue, thereby providing remedial actions for the study [18]. The proportion of solid waste in the landfill site are identified on the basis of Dry weight of the representative daily solid waste generated and collected from various sectors of the city and finally the average is taken into consideration [19]. The details of solid waste and its categories are shown in table 1.

Table 1. Details of Solid Waste collected from the city

Sr. No	Types of Waste	Percentages (%)
1	Organic Waste	57.3
2	Paper Waste	7.25
3	Plastic Waste	13.25
4	Metal Waste	1.95
5	Glass Waste	2.00
6	Leather & Rubber Waste	2.75
7	Textile Waste	6.25
8	Inert Miscellaneous Waste	9.25

3 Methodology

3.1 Leachate and Groundwater sampling.

The fig. 1 shows the sampling pattern adopted at the landfill site to collect ground water, contaminated soil and leachate samples. The landfill leachate samples were collected which was flowing on the ground surface around waste dumped [10]. The sample collection was carried out both during monsoon (September, 2018) and during summer (April, 2019). The leachate samples were collected both from old waste dumped area as well as one from where the latest dumping is carried out [4, 10].

Fig. 1. Layout of Sampling at Landfill Site.

Table 2. Details of Ground Water Sampling.

Sample No	Water Sample Type	Distance from site Boundary	Depth from G.L
1	Open Well water (OW)	184 m	4.87 m
2	Open Well Water (OW)	322 m	5.48 m
3	Tube Well (TW)	315 m	--
4	Tube Well (TW)	402 m	--
5	Open Well Water (OW)	490 m	6.40 m
6	Open Well Water (OW)	762 m	5.80 m

The Physio-chemical parameters of leachate samples were determined. The 6 No's groundwater sampling locations in the study area are shown in table 2. Water was collected from open wells by drawing buckets tied with ropes, while Tube wells were pumped for 5–15 min before sampling [9, 11]. These samples were collected in pre-cleaned polypropylene containers which was cleaned before storage of samples and kept at room temperature [9]. Water was analyzed for Physio-Chemical Test and Heavy Metals as per table 3.

Table 3. Methodology for Physio-Chemical Test [13].

Sr No	Parameter	Method Adopted	Apparatus /Instruments Used
1	Turbidity	Laboratory Method	Nephelometer Turbidity Meter
2	pH	Electrometric Method	Electronic pH meter
3	Electrical Conductivity	Laboratory Method	conductivity meter
4	Total Hardness	EDTA Titrimetric Method	Laboratory Method
5	Bio-chemical Oxygen Demand (BOD)	D.O. Meter	BOD bottle, Incubators
6	Dissolve Oxygen	Laboratory Method	Digital D.O Meter
7	Chemical Oxygen Demand (COD)	Titration Method	COD reflux apparatus
8	Heavy Metals (As, Cd, Cr, Hg, Pb)	Atomic Absorption Spectrometric Method	Atomic Absorption Spectrometric

3.2 Soil sampling and Analysis.

Soil samples were collected from the dumpsite, by removing the surface debris and subsurface soil dug to a vertical depth of 1m and 2m from ground surface using a manual hand auger [8]. Samples were collected in horizontal direction around the landfill site. As shown in fig. 1, total 9 contaminated soil sampling locations (one at boundary of site and other two at interval of 50 m from site in each direction) were identified in order to determine the horizontal extent of contamination level. Along with these one normal soil sample was collected at distance of near about 520m away from the landfill site. In this way total 19 No's soil samples (at depth of 1m and 2m at each sampling location) were carried to laboratory and analyzed for Chemical analysis such as Organic Content and Heavy metals. These chemical parameters were then compared with normal soil sample at greater distance from the site. The soil sample can be also investigated for the presence of Heavy metals in Atomic Absorption Spectrophometer [8]. Hazardous heavy metals detected are Lead (Pb), Arsenic (As), Cadmium (Cd), Chromium (Cr), and Mercury (Hg). The parameters for analysis were decided by considering the types of solid waste generated and the toxicity of the leachate at the landfill site.

4 Results and Discussion.

4.1 Characteristics of Leachate.

Leachate characteristic were identified by conducting Physio-chemical parameters test on leachate samples collected from the dump site. From the result shown in table 4, it seems that fresh leachate is more polluted than the older one. Leachate was also detected for the presences of Heavy Metals like lead, Cadmium, Chromium, Mercury and Arsenic etc. as these are considered to be hazardous elements in heavy metals. Heavy metals were detected under Atomic Absorption Spectrophotometer [8, 17].

Table 4. Characteristic of Leachate Samples.

Sr No	Parameter	Concentration				Unit
		Monsoon		Summer		
		Sample 1 Old Dump	Sample 2 New Dump	Sample 1 Old Dump	Sample 2 New Dump	
1	Colour	Black	Black	Black	Black	--
2	Odour	Foul smell	Foul smell	Foul smell	Foul smell	--
3	Turbidity	17.7	19.2	15.45	20.02	ppm
4	pH	8.9	9.1	9.22	10.12	--
5	Electrical Conductivity	7291	13212	10873	15442	u/cm
6	Total Hardness	823	729	741	913.12	ppm
7	B.O.D	7560	10500	10255	17522	ppm
8	D. O	0.7	0.6	0.04	0	ppm
9	C.O.D	9530	14050.4	22186	26735.76	ppm
10	Pb	1.92	0.22	3.12	1.91	ppm
11	Cd	0.78	2.47	1.59	2.12	ppm
12	Cr	0.21	0.98	1.02	0.51	ppm
13	Hg	0.52	0.24	1.91	1.02	ppm
14	As	0.12	1.009	1.91	2.61	ppm

From the table 4, it seems that the characteristics of leachate at new dump site are more hazardous as compared to old dump due to presence of active microorganism for decomposition [9]. pH Value for leachate ranges from 8.90 to 9.10 and in summer this values ranges from 9.22 to 10.12 which infers that the it is alkaline in nature [9]. High COD value in the range of 9530 ppm to 26735.76 ppm in leachate samples shows the presence of oxidizable organic materials that had leached from domestic refuse in the landfill site[9]. The leachate generated at the landfill site carries considerable amount of organic matter, percolated through the soil and entered into ground water showing increase in BOD value. Higher Value of Electrical Conductivity indicates the presence of inorganic material in the samples [8]. The concentration of contamination is observed more in summer as compared to monsoon since there is no dilution of precipitation.

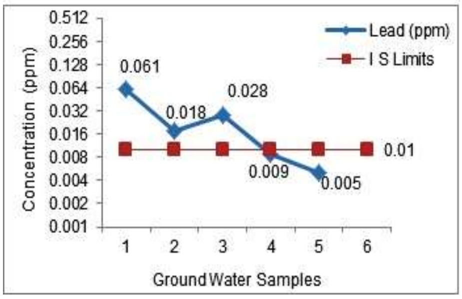
4.2 Characteristics of Ground Water Quality.

Water samples were collected from the existing groundwater sources around the landfill site at varying depth and distances from the boundary of the disposal site and was analyzed for physio-chemical characteristics as well as heavy metals [1].

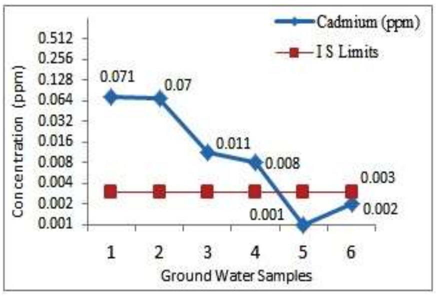
Table 5. Characteristics of Ground water Samples.

Sr. No	Parameter	Concentration in Samples						I.S Limit	Unit
		1	2	3	4	5	6		
1	Colour	Transparent	Transparent	Trans parent	Transparent	Transparent	Transparent	--	--
2	Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Agreeable	---
3	Turbidity	0.2	4.51	1.02	0.2	0.42	0.31	5-10	ppm
4	pH	7.8	7.1	7.3	7.75	6.95	7.9	6.5-8.5	---
5	E.C	1271	1125	1012	987	1008	662	---	u/cm
6	Total Hardness	229	153	163.7	120.01	130.1	112.5	200	ppm
7	B.O.D	0.61	0.38	0.31	0.26	0.41	0.19	---	ppm
8	D.O	4.1	6.5	6.96	7.25	5.21	8.12	---	ppm
9	C.O.D	2.52	2.15	1.96	1.71	2.32	1.32	---	ppm
10	Pb	0.061	0.018	0.028	0.009	0.005	BDL	0.01	ppm
11	Cd	0.071	0.07	0.011	0.008	0.001	0.002	0.003	ppm
12	Cr	0.058	0.09	0.024	0.032	0.003	BDL	0.003	ppm
13	Hg	0.02	0.05	0.015	0.033	0.002	BDL	0.001	ppm
14	As	0.016	1.21	0.01	0.009	0.005	0.001	0.05	ppm

Comparison was made between the observed contamination parameter values with Indian Standards for drinking water. It was found that the pH of the Ground water samples ranged from 6.95 to 7.90. The values of pH were within the prescribed limit of Indian Standards for Drinking water [6, 9]. The Bio-Chemical Oxygen demand (BOD) ranges from 0.19 ppm to 0.61 ppm which state that the Organic content concentration has decreased and not percolated into the ground water. Ground water was also analyzed for the presences of Heavy Metals like lead, Cadmium, Chromium, Mercury and Arsenic etc. The water table is located at 5 m from the ground surface as observed in wells. The rise in water table was observed due to monsoon. The flow of water table was in the direction opposite to highway (evidence from previous local bore observation and technician reports).



(a)



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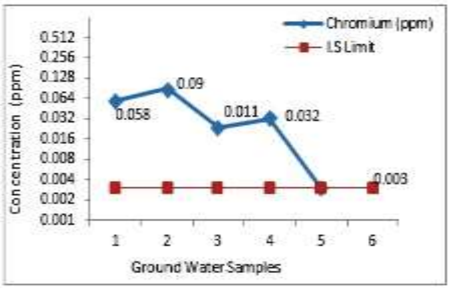

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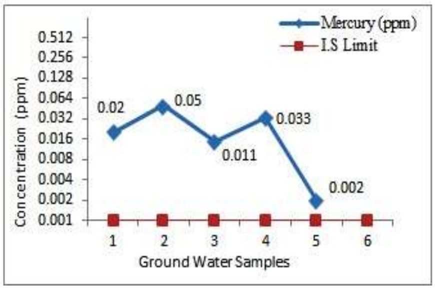

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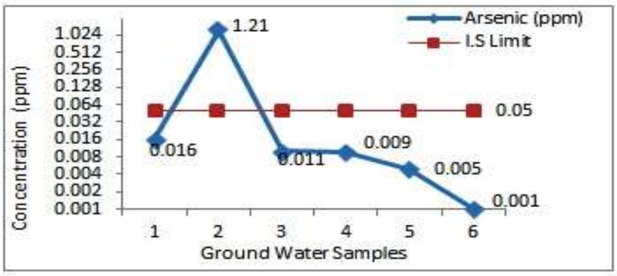

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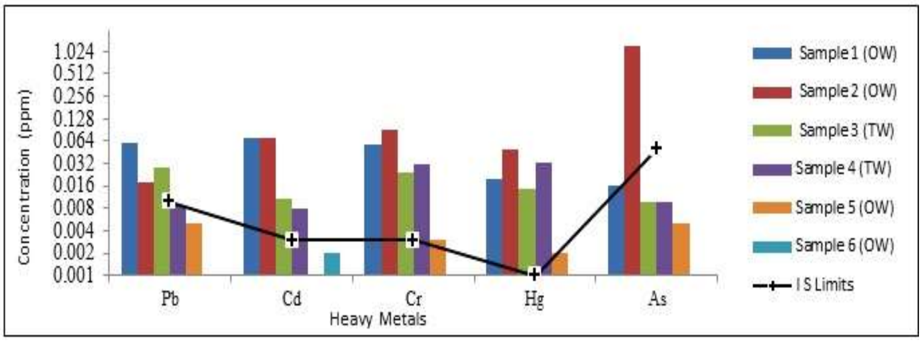


Fig. 2. Comparison of Heavy Metals in Ground Water Samples with Drinking Water Standards. [(a) Lead (b) Cadmium (c) Chromium (d) Mercury (e) Arsenic].

As per obtain results in table 5, the tube well water samples have shown less contamination concentration as compared to samples collected from open well water at higher depth. The Ground water contamination parameters seems to be reducing beyond 500 m landfill site as observed from samples 5 and 6, the contamination parameters are with the permissible limit stated by Indian standards for Drinking water [6]. From the observed parameters of ground water, it can be concluded that the contamination flume is transported in the direction opposite to the highway. This may have followed the ground water flow path.

4.3 Chemical Analysis of soil.

4.3.1. Organic Content in soil samples.

The organic content in the soil samples were determined in laboratory in order to obtain the decomposable content present in subsurface soil. The temperature maintained for the analysis was 105^0 C-110^0 C in oven and muffle furnace at 400^0 C for 24 hours. From the values in the table 6, the Maximum organic contamination in the range of 2.12% to 7.31 % has been observed in sample 2, 3, 5, 6 and 7 i.e. in the direction opposite to highway .This infers that the soil at the boundary of the dump site has high organic content due to the seepage of leachate when compared to the control sample.

Table 6. Presences of Organic Content in (%) present in Soil samples.

Sr No	Depth below G.L.	Soil Samples									
		1	2	3	4	5	6	7	8	9	10
1	1 M	0.78	3.24	7.31	2.12	4.37	5.89	6.89	2.34	2.69	2.13
2	2 M	---	1.87	4.55	1.67	3.47	2.62	4.01	1.57	2.15	1.16

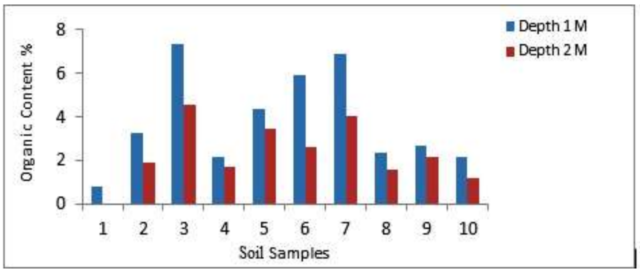


Fig. 3. Organic Content in soil Samples at varying depth.

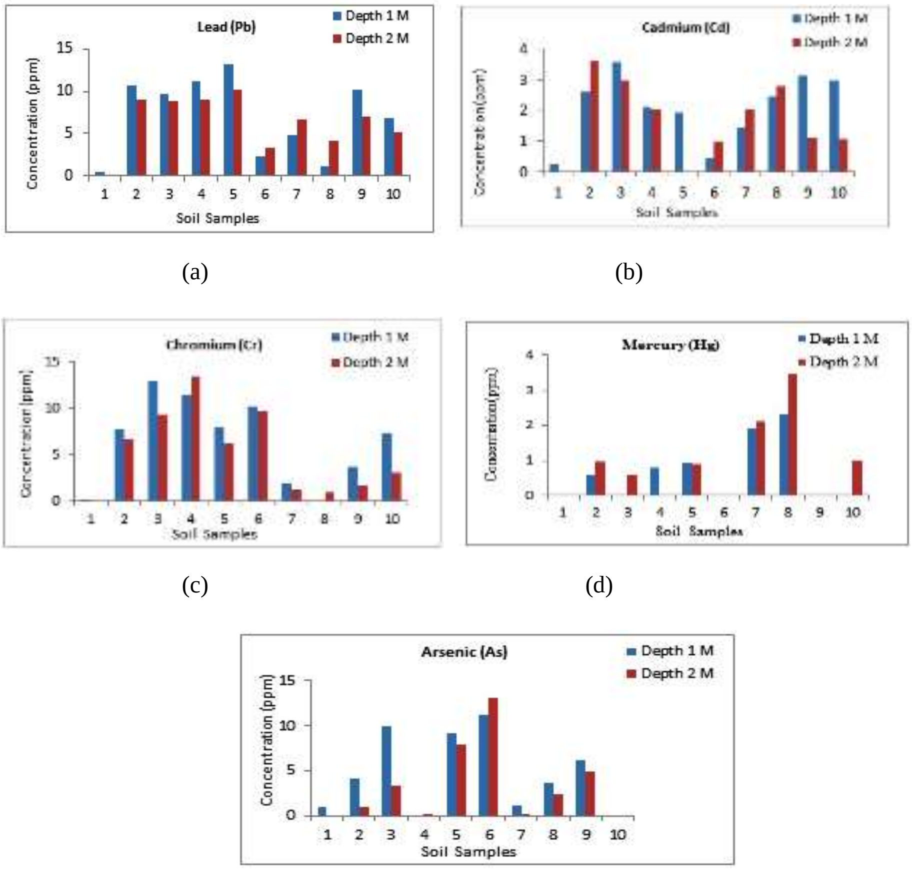
4.3.2 Heavy Metal Contaminations.

Contamination of heavy metals in the environment is of major concern because of their toxicity and threat to human life and the environment [2]. Many investigators have conducted researches on heavy metal contamination in soils. Heavy metals were detected under Atomic Absorption Spectrophotometer [8, 16]. Heavy Metals are deposited in soil due to municipal waste containing refused batteries, paint products; metallic items phosphate fertilizers, presence in sewage sludge and waste water percolation etc. [20]. The heavy metal concentration present in normal soil sample is due to the geological formation of the soil strata. There is no Indian standard available to indicate the presences of heavy metals in particular soil sample. Therefore many researchers have tried to compare the contaminated soil at the landfill side with the normal soil samples available at particular distance away from the landfill site.

Table 7. Heavy Metal Concentration in Soil samples.

Sr No	Heavy Metals	Depth below G.L.	Soil Samples									
			1	2	3	4	5	6	7	8	9	10
1	Pb	1 M	0.4	10.7	9.7	11.13	13.2	2.31	4.7	1.12	10.1	6.75
		2 M	--	8.9	8.8	8.92	10.1	3.22	6.6	4.12	7.02	5.21
2	Cd	1 M	0.2	2.5	3.5	2.12	1.92	0.41	1.4	2.45	3.12	2.96
		2 M	--	3.6	2.9	2.04	0.01	0.98	2.0	2.79	1.09	1.07
3	Cr	1 M	0.1	7.7	12.	11.3	7.91	10.12	1.9	BDL	3.61	7.32
		2 M	---	6.6	9.3	13.3	6.12	9.72	1.0	0.84	1.62	2.97
4	Hg	1 M	0.1	0.5	0.5	0.8	0.92	BDL	1.9	2.31	0.01	BDL
		2 M	---	0.9	0.5	BDL	0.89	BDL	2.1	3.49	BDL	1.05
5	As	1 M	0.9	4.2	10	BDL	9.1	11.19	1.1	3.64	6.1	BDL
		2 M	---	0.9	3.2	0.05	7.85	13.12	0.1	2.36	4.92	BDL

*BDL = Below Detection Level. All values in ppm.



(a) (b)

(c) (d)

(e)

Fig. 4. Heavy Metal Concentration in soil Samples at varying depth. [(a) Lead (b) Cadmium (c) Chromium (d) Mercury (e) Arsenic].

From the analysis of the heavy metals detected at study site, it seems that the elements are presents in the following sequences (Pb > Cr > Cd > As > Hg) with varying depth [8].

4.4 Geotechnical Aspect of soil.

The index properties of the soil samples are analyze to identify the profile and characteristic of the contaminated soil and also that of normal soil sample [3, 14]. From the results shown in the table 8, it seems that the characteristics of the contaminated and uncontaminated soil are nearly comparable and not much difference was found. Also the contaminated soil in the vicinity of the landfill is more permeable than the normal or uncontaminated soil. This may be due to permeation of leachate through the soil mass [14].

Table 8. Geotechnical aspect of soil samples.

Sr No	Properties of soil	Normal Soil	Contaminated Soil			
		1	2	3	4	5
1	Specific Gravity	2.64	2.56	2.52	2.54	2.59
2	Cu	1.69	0.92	1	0.781	1.14
3	Cc	18.80	13.33	17.50	12.83	17.75
4	Coarse Sand (%)	14.8	19.04	21.86	18.48	15.02
	Med Sand (%)	28.82	39.52	35.62	39.20	38.02
	Fine Sand (%)	39.754	25.84	29.12	27.66	31.53
	Silt and Clay (%)	16.40	15.60	13.40	14.80	15.42
5	W_L (%)	28	22	20	23	24.50
6	Soil Classification	SW	SP	SW	SP	SW
7	K in cm/s	0.0038	0.00371	0.00475	0.00397	0.00410

5 CONCLUSION.

The Solid Waste dumping site is observed to be Non-engineered. The characteristics of leachate from new dumping area show more contamination than the old dumped leachate. Leachate in monsoon has comparatively less contamination potentials but more amount due to the effect of dilution, whereas the leachate observed in summer has more contamination potential but in less quantity. The physio-chemical and heavy metals contamination parameters of Ground water exceeds beyond the permissible Standards of Drinking Water. Hence it is not useful for potable and domestic purpose and may cause public health problems [10, 15]. It will be recommended to treat water before use for domestic purpose. The groundwater quality improves with the increase in depth and distance of the well from the pollution source. Particularly beyond 500 m of the Radius of the Landfill site, the ground water quality meets the permissible limits for domestic uses. The soil at site was contaminated for organic content varies from 2.12% to 7.31%. Heavy metals present in soil (Pb > Cr > Cd > As > Hg) with varying depth and Ground water contents heavy metals as (Cd > Cr > Pb > Hg > As). There is a need to determine the remediation measures for the contamination based on the present scenario. It is recommended to apply Electro Kinetic technique for remediating the contaminated land around landfill site [11].

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