Evaluation of the Effects of Landfill leachates on Groundwater Quality

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Abstract
This study attempted an evaluation of the effects landfill leachates on groundwater. Samples of groundwater (borehole) were collected from three different locations around the Olusosun landfill in Ojota area of Lagos State, Nigeria, over a period of one week. Physico-chemical and microbiological assessment were carried out on the samples. The results of the analysis showed that pH values range between 5.3 - 7.6, TUR 0.2 - 0.9 FTU, EC 35 - 1890 μScm^{-1}, acidity 6.3 - 11.4 mgl^{-1}, alkalinity 16 - 160mgl^{-1}, total heterotrophic bacteria 1.10 x 10^4 - 2.90 x 10^4 cfu, total coliform 0 - 1.30 x 10^2cfu respectively. Generally 70% of the samples did not conform with Nigeria standard for drinking water quality (NSDWQ) and WHO standard for portable and domestic uses of water. This result indicates that the groundwater sources around the landfill are vulnerable to the effect of the landfill, if not adequately protected. It was concluded that six water samples sources around the Olusosun landfill in Ojota area of Lagos State, Nigeria, are contaminated physically, chemically and microbiologically.

Keywords: Borehole, Chemical groundwater, Microbiological, Physical

Introduction

Water is very essential to the well-being of man, animals and plants. Out of all the earth's essential elements that support life, water is the second most important after air. Amazingly, a mere 3 per cent of the world's water is fresh, not salty. Out of this, 95% of the fresh water is locked up in glacier and ice caps or in the underground aquifer thus leaving 1 per cent that is readily accessible to human kind (Lasisi, 2001). Basically, the total amount of water on earth does not increase or decrease, as the amount on earth now is all that there had been. This is because the water in and around the world endlessly circulates from the oceans to the atmosphere, to the land, into the river and back to the ocean again. Moreover, despite the abundance of fresh water on the earth, many regions are in deep crisis of water shortage due to being polluted by human activities, or the ever increasing demand by industrialization and high population growth.

Life is dependent on water which essentially exists in nature in forms of clouds, rain, snow ice and fog. Chemically, pure water doesn't exist for any appreciably length of time in nature. Even while falling down as rain, water picks up small amount of gases, ion, dust and particulate matters from the atmosphere. As water flows over or through the surface layers of the earth, it dissolves and carries with it or almost everything it touches, including that which is dumped into it by man's activities. These added substances maybe classified as biological, chemical (both inorganic and organic), physical and radiological impurities (FEPA, 1991). They include industrial and commercial solvents, metals and acids, salts, sediments, pesticides, herbicides, plant nutrients, radioactive materials, decaying animals and vegetable, matter as well as living organism such as algae, bacteria and viruses (FEPA, 1991). These impurities give water bad taste, colour, odour, cloudy appearance (turbidity) and cause hardness, corrosiveness, staining or frothing. They may damage growing plants and transmit diseases; however many of these impurities are removed or rendered harmless in municipal drinking water treatment plant.

Landfills have been identified as one of the major threats to groundwater resources (Champman, 1980).Waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation. The dumped solid wastes gradually release its initial interstitial water and some of its decomposition by-products get into water moving th rough the waste deposit. Such liquid containing innumerable organic and inorganic compounds is called 'leachate'. This leachate accumulates at the bottom of the landfill and percolates through the soil. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local user and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years (Saarela, 2003; Abu-Rukah and Kofahi, 2001; Looser et al., 1999; Christensen et al., 1998; De Rosa et al., 1996; Flyhammar, 1995). Many approaches have been used to assess the contamination of underground water. It can be assessed either by the experimental determination of the impurities or their estimation through mathematical modelling (Moo-Young et al., 2004; Hudak, 1998; Stoline et al., 1993; and Butwa et al., 1989) considering the environmental and health implications resulting from the landfill dumps evaluated.

The objectives of this study are to assess the quality of groundwater around landfill sites and to evaluate landfill management option with a view to proffering best probable alternative.

Materials and Method

Study Location

The study was carried out in Ojota area of Lagos State in Nigeria. The area covers Ikosi Ketu, Oregun industrial estates, the commercial area of Kudirat Abiola way, Ojota residential area and LAWMA dumpsite, known as Olusosun landfill (Bello, 2002). The landfill is located between 6°23'N; 2°42'E and 6°41'N; 3°42'E. It is the largest of all the landfills in Lagos area; it has received more than 50% of the total refuse in Lagos area since 1989. As at the time the dumpsite was created, the area (Ojota) was almost a vacant land (Bello, 2002). The area is however a flourishing commercial central district in Lagos State. The site of the landfill is about 10 km South East of Ikeja Local Government Area (LGA). Ikeja is the capital city of Lagos State. The state is the most flourishing Nigerian commercial arena, with a population of more than 9, 013, 534 and an annual growth rate of 3.2% (NPC, 2006). The landfill is surrounded by some industries, factories, gasoline stations, a motor park, an automobile repair workshop and road network are all sources of waste discharge including the transported waste discharge into the landfill. The wastes deposited in the landfill are predominately solid waste from both domestic and industrial sources.

Data Collection

Three sample points (borehole) were randomly located around the dumpsite and six water samples were collected within a period of one week, from each point a sample was collected in the morning (8am – 10am) and in the evening (4pm – 6pm) this is important since concentration of various parameters may be effected as a function of the dump traffic. Samples were collected in tight capped bottles and later transported to the laboratory under low temperature conditions in ice-box. All analyses were completed within 3 days of sampling.

Study Design

All samples were analysed for the following physico-chemical and microbiological parameters; i.e., colour, pH, turbidity, electrical conductivity, total solids, dissolved solids, acidity, alkalinity, total hardness, calcium, chloride, sulphate, nitrite, nitrate, ammonia, silica, phosphate, iron, copper, manganese, zinc, lead, arsenic, mercury, dissolved oxygen, total heterotrophic bacteria and total coliform. Most of the physico-chemical parameters where determined using spectrophotometer (colorimetric method).

Microbiological Analysis

The media used for the bacteriological analysis of water include nutrient agar (NA), lactose broth (LB), Eosin Methylene blue agar (EMB), and Mac Conkey. All the media used were weighed out and prepared according to the manufacturer's specification, with respect to the given instructions and directions. All the metallic and laboratory glass wares were sterilized by autoclaving at 121oc for 15min; the media used were prepared the previous day by dissolving known quantities in corresponding volume of water according to the manufacturer's specification. The plates were prepared in duplicate and kept in the incubator to check for contamination while uninoculated plates were kept as control. This is in accordance with the works of Anake et al., (2013), Blaustein et al., (2013); Rompré et al., (2002) and Hofstra and Veld (1988).

Results and Discussion

Test Result

Physico-chemical and microbiological characteristics of the water samples depend primarily upon the waste composition and water content in total waste. The characteristics of the water samples collected from the Olusosun landfill site are as presented in Tables 1, 2, 3, 4, and 5 while Table 6 shows the correlation matrix for the various study points.

Table 1: Physical parameters

Samples	Colour	Appearance	Odour	pH @ 20°C	Turbidity (FTU)	Conductivity (μScm⁻1)	Total solids(ppm)	Dissolved solids (ppm)
Well A (morning)	Colourless	Clear	Odourless	7.6	0.2	3.53×10^1	16.40	16.40
Well A (evening)	Colourless	Clear	Odourless	5.3	0.3	3.92×10^1	18.20	18.20
Well B (morning)	Brown	Not clear	Objectionable	7.1	0.9	1.89×10^3	957.0	957.0
Well B (evening)	Brown	Not clear	Objectionable	6.2	0.7	1.86×10^3	938.0	938.0
Well C (morning)	Colourless	Clear	Odourless	5.8	0.3	8.12×10^1	38.10	38.10
Well C (evening)	Colourless	Clear	Odourless	5.4	0.4	7.92×10^1	39.6	39.60

Table 2: Chemical parameters

Samples	Acidity (mg/L)	Alkalinity (mg/L)	Total hardness (mg/L)	Ca (mg/L)	Cl^-(mg/L)	SO_3(mg/L)	SO_4(mg/L)	NO_2(mg/L)	NO_3(mg/L)
Well A (morning)	6.30	160.0	Negligible	8.0	16.0	Negligible	Negligible	Negligible	0.02
Well A (evening)	11.0	16.0	Negligible	Negligible	32.0	Negligible	0.12	Negligible	0.50
Well B (morning)	7.0	152.0	Negligible	Negligible	264.0	Negligible	1.03	0.40	1.20
Well B (evening)	8.0	136.0	48.0	Negligible	360.0	Negligible	1.21	0.40	3.40
Well C (morning)	9.0	12.0	Negligible	Negligible	264.0	Negligible	Negligible	Negligible	Negligible
Well C (evening)	11.40	12.0	Negligible	Negligible	24.0	Negligible	0.18	Negligible	0.58

Table 3: Chemical parameters

Samples	NH_4 (mg/L)	SiO_2 (mg/L)	PO_4 (mg/L)	Fe (mg/L)	Cu (mg/L)	Mn (mg/L)	Zn (mg/L)	Pb (mg/L)	As (mg/L)
Well A (morning)	0.83	Negligible	0.06	0.38	0.002	0.02	0.41	0.02	Negligible
Well A (evening)	9.0	Negligible	0.65	0.43	0.01	0.01	0.49	Negligible	Negligible
Well B (morning)	1.22	Negligible	0.50	13.91	0.004	0.02	0.59	0.12	Negligible
Well B (evening)	7.10	Negligible	0.91	0.20	0.01	0.02	0.49	0.01	Negligible
Well C (morning)	0.33	Negligible	Negligible	0.67	0.01	0.04	0.61	0.02	Negligible
Well C (evening)	5.08	Negligible	0.54	0.28	0.02	0.04	0.60	0.02	Negligible

Table 4: Chemical parameters

Samples	Hg (mg/L)	DO (mg/L)
Sample A (morning)	Negligible	4.20
Sample A (evening)	Negligible	6.0
Sample B (morning)	Negligible	4.10
Sample B (evening)	Negligible	5.7
Sample C (morning)	Negligible	3.80
Sample C (evening)	Negligible	5.90

Table 5: Microbiological parameters

Samples	Total heterotrophic bacteria (cfu/mL)	Total coliform (cfu/mL)	Isolated microorganism
Sample A (morning)	1.80 X 10^4	1.10 X 10^2	Bacillus *spp* Escherichia coli
Sample A (evening)	1.20 X 10^4	0.00	Bacillus *spp* with endospores
Sample B (morning)	2.90 X 10^4	1.20 X 10^2	Bacillus *spp* Micrococcus *spp* Staphylococcus aureus Escherichia coli
Sample B (evening)	2.10 X 10^4	1.30 X 10^2	Bacillus *spp* with endospores Staphylococcus aureus Escherichia coli
Sample C (morning)	1.20 X 10^4	0.00	Bacillus *spp* with endospores
Sample C (evening)	1.10 X 10^4	0.00	Bacillus *spp* with endospores

Table 6: Parameter Correleation Matrix

	pH	TUR	EC	TS	DS	Acidity	Alkalinity	TH	Ca	Cl^-	SO_3	SO_4	NO_2	NO_3	NH_4	SiO_2	PO_4	Fe	Cu	Mn	Zn	Pb	DO
pH	1																						
TUR	.224	1																					
EC	.339	.950**	1																				
TS	.340	.951**	1.000**	1																			
DS	.340	.951**	1.000**	1.000**	1																		
Acidity	-.949**	-.306	-.470	-.470	-.470	1																	
Alkalinity	.901*	.483	.638	.639	.639	-.903*	1																
TH	-.017	.418	.624	.622	.622	-.184	.358	1															
Ca	.716	-.478	-.328	-.328	-.328	-.583	.515	-.200	1														
Cl	.104	.684	.774	.773	.773	-.377	.306	.640	-.461	1													
SO_3	.537	.657	.549	.551	.551	-.517	.481	-.284	-.081	.314	1												
SO_4	.231	.932**	.986**	.985**	.985**	-.359	.579	.704	-.379	.738	.426	1											
NO_2	.345	.945**	1.000**	1.000**	1.000**	-.476	.648	.632	-.316	.769	.543	.986**	1										
NO_3	.001	.679	.813*	.811	.811	-.167	.416	.939**	-.356	.673	-.030	.887*	.818*	1									
NH_4	-.632	.014	.039	.039	.039	.616	-.309	.425	-.414	-.136	-.467	.187	.049	.457	1								
SiO_2	.715	-.339	-.103	-.104	-.104	-.677	.640	.175	.926**	-.182	-.184	-.132	-.089	-.021	-.296	1							
PO_4	-.348	.560	.571	.571	.571	.300	.075	.651	-.535	.256	-.091	.693	.577	.805	.820*	-.339	1						
Fe	.451	.765	.627	.629	.629	-.418	.450	-.217	-.201	.333	.976**	.527	.619	.076	-.377	-.292	.057	1					
Cu	-.833*	-.132	-.277	-.277	-.277	.866*	-.742	.052	-.572	-.173	-.580	-.156	-.288	.056	.457	-.580	.335	-.422	1				
Mn	-.279	-.179	-.298	-.298	-.298	.270	-.462	-.200	-.200	.068	-.254	-.307	-.316	-.280	-.444	-.254	-.419	-.191	.572	1			
Zn	-.441	.339	.102	.103	.103	.397	-.503	-.253	-.739	.315	.267	.077	.080	-.107	-.222	-.823*	-.044	.364	.516	.679	1		
Pb	.513	.737	.596	.598	.598	-.468	.475	-.241	-.130	.325	.955**	.489	.587	.034	-.501	-.228	-.041	.984**	-.400	-.056	.399	1	
DO	-.643	-.029	-.045	-.045	-.045	.693	-.349	.361	-.361	-.274	-.562	.118	-.038	.398	.943**	-.281	.788	-.428	.645	-.233	-.143	-.507	1

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level.

Discussion

Information on the physico-chemical parameters of the water samples from the six boreholes are shown in Table 1, 2, 3 and 4. The borehole water samples were acidic with a pH range of 5.3 to 7.6 and a mean value of 6.2. The acidic nature of the borehole water could be attributed to the abundance of organic matter in the soil as well as the presence of tiny shale intercalations in the auriferous coastal plain sand (Udom et al., 2002). The pH values are below the minimum desirable limits of 6.5 set by WHO (1993).

The values of total solids (TS) and turbidity were between the range of 16.40 mgl-1 to 957 mgl-1 and 0.2ftu to 0.9ftu respectively; meaning that the water is harmful in its natural state, and not ideal for human consumption. It further indicates the presence of organic and inorganic solids. Conductivity measures the ability of water to conduct an electric current and is used to estimate the amount of dissolved solids. It increases as the amount of dissolved mineral (ions) increases.

The conductivity of the borehole samples varied with values ranging from 35µScm-1 to 1890 µScm-1 with a mean value of 664.15µScm-1. Some of these values are not within WHO's (1993) desirable limit of 250 µScm-1 for drinking water.

Among the nitrogenous compound, ammonia nitrogen (0.33mgl-1 to 7.1mgl-1) had a slightly high concentration, this is probably due to the deamination of amino acids during the decomposition of organic compounds (Crawford and Smith, 1985; Tatsi and

Zouboulis, (2002). Nitrate (NO3) ranged from 0.0000007mgl-1 to 3.4mgl-1 with a mean value of 0.95 mgl-1 and sulphate (SO4) ranged from 0.000005mgl-1 to 1.21mgl-1 with a mean value of 0.42 mgl-1. The relatively low values of NH4, NO3 and SO4 are attributed to the location of boreholes far away from soak away pits and dumpsites; as boreholes do receive domestic and municipal wastes that contain these elements (Adamu and Adekiya, 2010).

Chloride is an ion that may be associated with individual septic disposal system (ISDSS) and is present in all natural waters, usually in relatively small amounts. High concentration of chloride in water is known to cause no health hazard (Obiefuna and Sheriff, 2011). The value of chloride in this study was a bit high and ranged from 16mgl-1 to 360mgl-1 with a mean value of 160 mgl-1, which is below the maximum allowable concentration of 250mg/l (WHO, 1993).

However, the total hardness of the water samples ranged from 0.000005 and 48 mgl-1 with a mean value of 8.0 mgl-1, and is below WHO 500 mgl-1 acceptable limit, meaning the water is soft and foamy. This indicates that the boreholes are not corrosive and would not cause mutations as such.

The level of Fe (0.2mgl-1 to 13.91mgl-1) in the water samples indicates that Fe and steel scrap are also dumped in the landfill. The dark brown color of the water sample B (Table 1) which has the highest content of Fe; this could be attributed to the oxidation of ferrous to ferric form and the formation of ferric hydroxide colloids and complexes with fulvic/ humic substance (Chu, et. al., 1994).

The presence of Zn (0.41mgl-1 to 0.61mgl-1) in the water samples shows that the landfill receives waste from batteries and fluorescent lamps. The presence of Pb (0.000001mgl-1 to 0.12mgl-1) in the water samples indicates the disposal of Pb batteries, chemicals for photograph processing, Pb-based paints and pipes at the landfill site (Moturi et al., 2004; Mor et al., 2005).

Comparatively, the physico-chemical concentration of parameter obtained across the ground water samples varied spatially and significantly due to variation in the location of boreholes and human activities. The borehole for sample C (Table 1- 5) had the least concentration as such, was most potable for consumption. Bacteriologically, the six samples have heterotrophic bacteria and isolated organism indicating the presence of contamination. Coliform are a family of bacteria common in soil, plant and animal. One can come in contact with these bacteria by eating or drinking (ingesting) soils on plants and in rivers.

The presence of coliform in water indicates the possibility, but not the certainty that disease organisms may also be present in the water. Total or fecal coliform bacteria can be found in water contaminated by human and animal waste. The presence of heterotrophic bacteria, total coliform and isolated organism implies an imminent health risk. However, bacteriological speaking, water from the six samples were not within WHO (1993) recommended guideline standard for drinking water. The guideline requires that water intended for drinking should not contain any pathogen or micro-organisms indicative of fecal contamination. Thus, the entire borehole water samples examined had trace of heterotrophic bacteria, total coliform and isolated organism. The borehole used for the study may be assumed to be properly constructed with no cracks to give way to any form of contamination from runoff. In conclusion, the bacteriological quality of the sample boreholes is not ideal and unsuitable for drinking and domestic purpose.

Correlation analysis is a preliminary descriptive technique to estimate the degree of association among the variables involved. The purpose of the correlation analysis is to measure the intensity of association observed between two variables. Such association is likely to lead to reasoning about causal relationship between the variables. Correlation matrix between various parameters is shown in Table 6. Most of the parameters were found to bear statistically significant correlation with each other indicating close association of these parameter with each other.

In the study pH has a strong significance negative correlation with Acidity (r = -0.949) and Cu (r = 0.833) and also a strong significance positive correlation with Alkalinity (r = 0.901), SiO2 (r = 0.715) and Ca (r = 0.716). This shows that pH influences both acidity and alkalinity greatly; similarly, so also it is with Cu and SiO2. A significance positive correlation was found between Turbidity and EC (r = 0.950), TS (r = 0.951), DS (r = 0.951), SO42- (r = 0.932), NO2- (r = 0.945), Fe (r = 0.765) and Pb (r = 0.737). This indicates that an increase or decrease in turbidity will exhibit an increase or decrease in EC, TS, DS, SO42-, NO2-, Fe and Pb. Electrical conductivity has a significance high positive correlation between TS (r = 1.000), DS (1.000), SO42- (r = 0.932), Cl- (r = 0.774), NO2- (r = 1.000) and NO3- (r=0.813). This shows that an increase or decrease in EC will exhibit an increase or decrease in TS, DS, SO42-, Cl-, NO2- and NO3-. A significance positive correlation was found between Total Solids and DS (r = 1.000), Cl- (r = 0.773), SO42- (r = 0.985), NO2- (r = 1.000) and NO3- (r = 0.811). This show that an increase or decrease in TS will exhibit an increase or decrease in DS, Cl-, SO42-, NO2- and NO3-. A significance positive correlation was found between Dissolved Solids and Cl- (r = 0.773), SO42- (r = 0.985), NO2- (r = 1.000) and NO3- (r =0.811). This show that an increase or decrease in TS will exhibit an increase or decrease in Cl-, SO42-, NO2- and NO3-. Acidity has a significant negative correlaation with Alkalinity (r = -0.903), this shows that an increase or decrease in acidity will exhibit a decrease or inrease in alkalinity. Acidity also has a positive significance with Cu (r = 0.866) this means an increase or decrease in acidity will exhibit an increase or decrease in Cu. A significance of negative correlation was found between Alkalinity and Cu (r = -0.742), this means a decrease or increase in alkalinity will exhibit an increase or decrease in Cu. Total hardness was found to have significance of positive correlation between SO4- (r = 0.704) and NO3- (r = 0.939), this means an increase or decrease in total hardness will exhibit an increase or decrease in SO4- and NO3-. Calcium showed a significance of positive correlation between SiO2 (r = 0.926) and a significance of negative correlation with Zn (r = -0.739). Significance of positive correlation was detected between Chloride, SO4- (r = 0.738) and NO2- (r = 0.769). Sulphite showed a significance of positive correlation between Fe (r = 0.976) and Pb (r = 0.955) also Sulphate showed a significance of positive correlation between NO2- (r = 0.986) and NO3- (r = 0.887). Nitrite and Nitrate showed significance of positive correlation with NO3- (r = 0.818) and PO43- (r = 0.805) respectively. Ammonia showed significance of positive correlation with PO43- (r = 0.820) and DO (r = 0.943), this means that an increase or decrease in Ammonia will exhibit an increase or decrease in both PO43- and Dissolved oxygen. A significance of positive correlations were found in phospahate and iron with DO (r = 0.788) and Pb (r = 0.984) respectively. Silica showed a significance of negatiive correlation with Zn (r = -0.823). Finally, it can be concluded that the correlation studies of the water quality parameters have great significance in the study of water resources. This result agrees with the results obtained by Jhamnani and Singh (2009); Onwughara et al., (2010) and Jothivenkatachalam et al., (2010). This established further the indications of the possibility that the landfill site poses an immediate health risk.

Conclusions

The study has shown that the six water samples sources around the Olusosun landfill in Ojota area of Lagos State, Nigeria, are contaminated physically, chemically and microbiologically. As there is no natural or other possible reason for high concentration of these pollutants, it can be concluded that leachate has significant impact on groundwater quality near the area of Olusosun landfill site. Although, the concentrations of few contaminants do not exceed drinking water standard even then the ground water quality represent a significant threat to public health.

From the groundwater samples analysed it is clearly evident that the leachate generated from the landfill site is affecting the groundwater quality in the adjacent areas through percolation in the subsoil. Therefore, some remedial measures are required to prevent further contamination. This can be achieved by the management of the leachate generated within the landfill. Leachate management can be achieved through effective control of leachate generation, its treatment and subsequent recycling throughout the waste.

Engineered landfill sites should be generally provided with impermeable liner and drainage system at the base of the landfill, which will not allow leachate to percolate into subsoil. All the leachate accumulated at the base of the landfill can be collected for recycling or treatment. This collected leachate can be distributed throughout the waste by means of spraying the leachate across the landfill surface. Some of the water may be lost through evaporation and therefore leading to reduction in the volume of the leachate for ultimate treatment. Techno-economic feasibility studies should be carried out for choosing the options for a landfill site. Retrofitting techniques for the existing old landfill like Olusosun landfill, would be cumbersome and expensive, therefore remedial measures should be considered by taking this into account. Olusosun landfill site is non-engineered landfill; it does not have any bottom liner or any leachate collection and treatment system. Therefore, all the leachate generated finds its paths into the surrounding environment. In view of this, the following specific suggestions are recommended

(i) Limiting the infiltration of the water through the landfill cover by providing impermeable clay cover. Due to this, it is possible that less water will enter and subsequently less leachate will be generated, thereby reducing the amount of leachate reaching the landfill base.

(ii) Extraction of the leachate collected at the base can be done and recycled, so that less amount will enter the aquifer lying below.

(iii) Organized household hazardous material collection programs be introduced to reduce the amount of hazardous chemicals discarded from homes.

(iv) Education of waste operators on hazardous materials should be organized.

(v) Introduction of waste checking/tracking programme be established.

(vi) Compulsory development of groundwater-monitoring programme be put in place.

(vii) Development of criteria for proper landfill disposal facility.

(viii) Introduction of a waste reduction programme.

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