Contamination Of Groundwater Around Garbage Dump.

Case Study At

The Pantang Landfill

Authors:

1) Dr. Francis Achampong, lecturer/geotechnical engineer, Earth Science Department, University of Ghana. (+233 271 811 363). achampongf@yahoo.com

2) Reginald Adjetey Anum, assistant researcher, Earth Science Department, University of Ghana. (+233 267 500 154). reginaldadjeteyanum@yahoo.com

3) Jimmy Obada, assistant researcher, Earth Science Department, University of Ghana. (+233 268 868 589). jimmysgotmails@yahoo.com.

4) Prof. Fred Boadu, Associate Professor Duke University, Durham, N, C. USA

Abstract

Despite the recent emphasis on source reduction of waste as well as the technological advancement of recycling, landfill, is the dominant form of solid waste disposal in developing countries. The leachate from poorly designed landfill sites contaminate groundwater.For this reason, this study sought to investigate the influence of landfill leachate on the underlying groundwater as well as the environment as a whole. The Pantang landfill was selected as a case study. Groundwater samples were collected from neighboring wells at the Pantang landfill for laboratory analysis. Results from tested samplese showed that, the leachate from the landfill has contaminated the groundwater making it unsafe to drink. Specifically, the results showed high level of heavy metals such as lead, iron, magnesium, zinc, cobolt and manganese in some of the neighboring wells. The concentration of these heavy metals exceeded WHO. (1996) admissible limits. Other parameters such as dissolved oxygen, pH, turbidity, total dissolved solids, conductivity, sulphate and hardness also exceeded WHO.(1996) admissible limits.The geology of the study area is not an ideal site for landfill due to high water table levels, the presence of numerous secondary porosities such as faults, joints and highly weathered rocks. The dumping of garbage at the Pantang landfill site should seize immediately, and technical audit should be performed to know the extent of groundwater contamination at the study area and beyond to suggest proper remediation methods for the clean-up exercise.

Keywords

Landfill; contamination; groundwater; leachate; remediation; waste; environment.

1. Introduction

1.1 *Background of the study*

Despite the recent emphasis on source reduction of waste as well as the technological advancement of recycling, landfill, is the dominant form of solid waste disposal in developing countries.

The deposition of solid waste in landfills carries the inherent potential for degrading the quality of the drinking water from wells to the extent that such water is no longer potable. Incidence of pollution of this form in developing countries leads to health hazards since few attempts are made to regulate and remediate the situation.

The goals of an engineered landfill are as follows:

- Protection of groundwater quality by minimizing leakage of leachates from landfill.
- Protection of air quality and conservation of energy by installing a landfill gas recovery system
- Minimizing the impact on adjacent wetlands by controlling and diverting or impounding surface runoff

To accomplish these goals the "ideal" landfill site should be defined in terms of geologic and hydrogeologic conditions such as deep soils with low hydraulic conductivity and deep occurrence of groundwater.

The Pantang-Abokobi landfill site which is operated by Zoomlion LLC, a waste management company, was selected as a case study.

The garbage dump has been in operation since 1992. The site receives sufficient rainfalls (total annual rainfall 2012 was 725mm, BBC weather) and has high infiltration rate due to numerous fractures of the weathered rocks.

1.2 *Objectives and scope*

The objectives of the investigation are as follows;

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I) To examine if the Pantang landfill has contaminated the neighborhood wells.

II) To determine the influence of the landfill's leachate on the chemical and physical characteristics of the geologic material directly below the landfill

III) To determine if chemical constituent that are present in the soil below the landfill can be released into the wells.

To accomplish these objectives, water and soil samples from wells beneath the landfill and from wells located both up and down the groundwater flow gradient in the area of the landfill were collected and tested in the laboratory to evaluate changes related to the landfill site.

1.3 Study area

Pantang – Abokobi is a north eastern suburb of Accra Metropolitan Assembly in the greater Accra region of Ghana.

The Pantang landfill location is shown in the topographical map below (Fig 1).

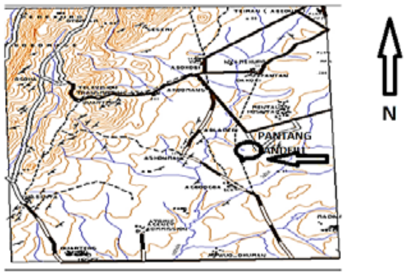

figure 1: topographical map showing the location of the pantang landfill site

1.3.1 Geology of the site

The area is covered by rock formation of the Precambrian Togo series. The Togo series occur in the south eastern part of Ghana. It is dominantly metamorphosed and highly folded arenaceous and argillaceous group of rocks in which the predominant rock types are quartzites, phyllites, quartzo-feldspartic gneiss and quartz sericite schist. The rocks are highly fractured.

1.3.2 Hydrogeology

The ground water table measurements had an average depth of 2.3-meters (Anum 2012), the saturated zone is as a result of secondary porosity such as faults, fractures and its associated weathered zone. Transmissivity values are generally low

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due to the clayey nature of the regolith (Anum 2012).

2. Methodology

2.1 Site Selection.

The Pantang landfill site had two separate garbage dumps which are close to each other. The old landfill (LF1) has uncovered garbage heap of about 13 meters high. LF1 has been in operation since 1992. The new landfill(LF2) has uncovered garbage heap of about 1 meter high. LF2 has been in operation since 2008. The two landfills cover an area of about 2062 m^2.

The characteristics of waste deposited at the landfill is a conglomerate of construction waste, domestic garbage, commercial waste, industrial waste and hospital waste. The place has foul smell and a lot of vectors such as vultures, flies and rodents at the dump site. The Pantang garbage dump is a typical un-engineered landfill with no leachate and methane gas control system.

The Pantang waste dump was selected for the research because the site receives sufficient rainfall and the infiltration rate is high. The topography of the site suits the model design for the research.

2.2 Sampling procedures

For a rationale sampling programme, an idealized model (Fig 2) was developed to monitor leachate migration and attenuation at the site.

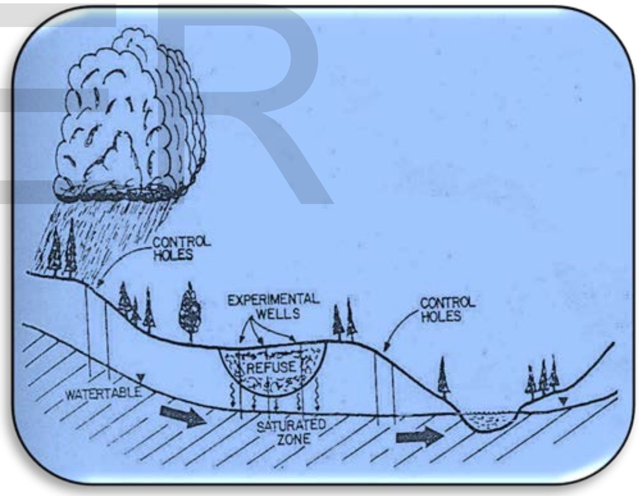

Fig 2:Sketch of typical landfill showing sampling plan. the updip control holes show background levels.The experimental wells and dowdip control holes show contaminant movement from the landfill. Bold arrows indicate direction of groundwater movement.

In this model, soils and groundwater were sampled beneath the landfill and wells very close to the landfill to give experimental data. Soils and groundwater from wells away from the experimental wells were also sampled as the control data. Background data were also accounted for by taking possible unaffected soils and groundwater nearby the landfill. In this model rainwater precipitating on the landfill saturates the refuse and percolates through the soil directly below the landfill. This then allows deposition of variable portion of the filterable and exchangeable materials in the leachate into the soil below the landfill which continues downward into the groundwater.

The sampling scheme called for 17 boreholes around the landfill site, all the 17 boreholes sampled were assessed. A minimum of one borehole (well 17) was examined beneath the landfill. The others were collected both up-gradient and down-gradient of the landfill. These wells and their elevation as well as their coordinates are shown in Table 1.

From the theoretical model, the updip wells with background levels are wells 11,12,13 and 14, the downdip wells which served as controls are wells 1, 2, 3 and 4. The landfill well is the experimental well (17). the leachate was also sampled and analyzed. Groundwater from the wells under study were sampled into clean, dry and airtight plastic containers, which were kept in ice ($\leq$4°C) to minimize the effect of micro-organisms.

The soil samples were taken by pitting, which was done with a digger, the samples were taken directly below the landfill and outside the landfill at comparable depths of one to two meters. The elevations, hydraulic heads as well the coordinates of the wells are shown in the table 1 below.

Table (1) shows well location, elevation and hydraulic head .

Wells	elevation/(m)	hydraulic heads/(m)	latitude/(°)	longitude/(°)
1	58.52	56.21	0.2008	5.7067
2	59.13	58.14	0.2004	5.7064
3	61.87	60.9	0.2002	5.7062
4	55.47	55.17	0.2000	5.7059
5	81.38	75.16	0.1986	5.7019
6	74.37	68.15	0.1963	5.6997
7	78.33	73.45	0.1967	5.7019
8	69.49	66.75	0.1962	5.7032
9	76.5	70.95	0.1956	5.7004
10	58.45	57.56	0.2012	5.7071
11	72.43	68.97	0.1918	5.7072
12	71.17	68.16	0.1909	5.7112
13	69.19	68.2	0.1909	5.7078
14	83.42	82.16	0.1981	5.6994
15	68.2	66.68	0.1865	5.7035
16	60.35	57.27	0.201	5.7073
17	62.79	59.53	0.1971	5.7074 .

Experimental well; Up dip wells; Down dip wells

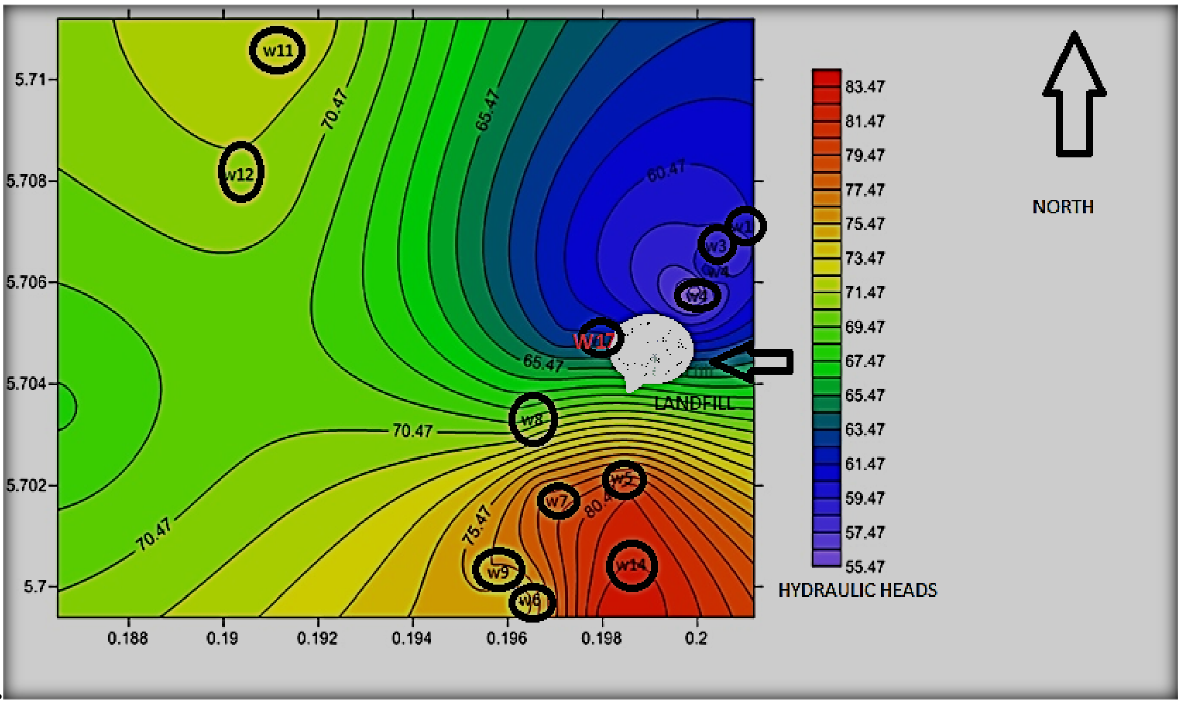

Fig 3. Three dimensional graph showing well locations and elevations

2.3 Testing of physical parameters of groundwater.

The Physical parameters such as pH, color, total suspended solids, turbidity, conductivity and total dissolved solids (TDS) of groundwater were measured on site. The instruments used were pH meter, spectrometer, turbidimeter and conductivity meter (Hanna meter) respectively. The in-situ testing was fast and economical. The results of the physical parameters of the groundwater are tabulated in table 2.

2.4 Chemical analytical methods.

Properly stored samples for chemical analyses where filtered and tested at Ecolab (University of Ghana). The chemical parameters measured included PO_4, SO_4, NO_3, Na, K, heavy metals (Fe, Mg, Mn, Co, Zn, Ni, Cr). The instruments and methods used for the chemical analyses were Standard turbidimetric method, DR2011 model spectrometer, Flame photometer and Atomic absorption spectrometer (model Perlin Eimer Analyst 400). The results of the chemical analyses are tabulated in table 3.

3. Results

3.1 Physical testing of groundwater

Table 2 shows results of the physical parameters of groundwater .

Wells	pH	Colour-(PCU)	Cond-(µs / cm)	DO	Turbidity- (NTU)	TDS-(mg/ l)
1	7.69	20	3998	4.7	1.64	2000
2	6.52	43	1487	4.6	3.10	743
3	6.57	60	2153	4.0	4.20	1077
4	6.88	199	3999	3.8	39.8	2007
5	4.47	19	1400	3.4	1.3	689
6	4.32	6	1546	4.4	3.77	773
7	6.22	463	789	5.6	92.9	395
8	4.18	13	5660	5.1	1.45	2830
9	5.70	22	7134	4.6	2.94	2947
10	7.16	32	3381	4.5	6.98	1689
11	5.50	12	1131	5.3	3.50	566
12	5.72	23	1451	5.8	5.98	723
13	6.93	27	1375	4.6	5.06	687
14	5.14	13	2201	6.7	4.11	1100
15	6.02	12	1022	6.2	4.27	519
16	6.43	24	638	4.8	5.91	318
17	6.10	271	1760	2.8	85.9	880
Lcht	12.31	2813	>106	0.8	1810	28000 .

(DO - dissolved Oxygen, Lcht- leachate. Nd = not detected . Cond-conductivity)

3.2 *Chemical analysis of groundwater.*

Table 3 shows results of the chemical analyses of groundwater .

Well	Fe-(mg/l)	Na-(mg/l)	K-(mg/l)	Mg-(mg/l)	Mn-(mg/l)	Zn-(mg/l)	Co-(mg/l
1	Nd	141.8	9.30	462.3	0.033	Nd	0.139
2	Nd	67.6	23.2	37.45	0.479	Nd	0.005
3	0.21	83.2	50.3	139.7	2.864	Nd	0.122
4	0.47	115.1	109.2	592.8	2.729	Nd	0.087
5	Nd	67.5	28.1	11.05	0.057	0.04	0.047
6	Nd	78.1	32.5	78.10	0.062	Nd	0.12
7	Nd	59.7	20.7	1.36	0.012	Nd	0.019
8	Nd	401	67.0	164.0	0.321	0.09	0.139
9	Nd	172	47.8	188.9	0.302	0.26	0.173
10	1.11	92.3	30.1	432.2	2.484	0.07	0.053
11	Nd	75.5	15.1	8.91	0.032	0.01	0.015
12	Nd	95.1	11.4	14.6	0.012	0.01	0.021
13	Nd	85.1	10.4	11.78	0.084	0.01	0.013
14	Nd	98.9	38.5	47.62	0.111	0.07	0.011
15	Nd	60.3	5.8	10.39	0.021	0.80	0.047
16	Nd	55.1	4.1	11.45	0.112	Nd	0.098
17	0.94	214	140	33.85	3.217	Nd	0.136
Mean	0.685	115.43	37.32	132.15	0.76	0.14	0.07
Lhte	2.34	2670	4980	246.5	5.02	1.01	0.412

Nd:Not detected.

Table 3 continued

Well	Pb-(mg/ l)	NO_{3-}mg/ l)	TSS-(mg/ l)	Ca-(mg/ l)	$S0_4$-(mg/ l)
1	0.240	0.4	1	142.3	314
2	0.106	0.8	4	98.1	188
3	0.150	0.8	20	101.9	204
4	0.168	1.3	39	161.8	214
5	0.196	1.8	5	78.2	114
6	0.168	1.3	5	81.1	128
7	0.172	1.2	26	73.4	64
8	0.181	1.1	1	131.2	284
9	0.281	1.3	4	142.1	502
10	0.184	0.1	1	45.6	202
11	0.127	0.1	3	56.3	110
12	0.169	0.1	2	72.4	118
13	0.130	1.5	2	81.3	120
14	0.136	0.2	6	68.5	164
15	0.127	0.5	4	57.7	125
16	0.139	0.0	2	61.9	118
17	0.197	8.2	136	142.1	78
Mean	0.17	1.21	15.35	93.88	-
Lhte	0.268	19.2	1281	3081	- .

Table 4: World health organization (WHO) water quality permissible standards.(1996)

Parameter	Unit	WHO values
Turbidity	NTU	5
Colour	PCU	15
Odour	-	Inoffensive
Ph	pH units	6.5-8.5
Conductivity	µs - cm	-
TSS	mg- l	-
TDS	mg- l	1000
Sodium	mg- l	200
Potassium	mg- l	30
Calcium	mg- l	200
Magnesium	mg- l	150
Total iron	mg- l	0.3
Sulphate	mg- l	250
Phosphate	mg- l	-
Manganese	mg- l	0.4
Nitrate	mg- l	10

4. Discussion

***4.1** Relevance of the general geology to the concentration of the elements detected in groundwater wells.*

As stated earlier, The general geology of the terrain is the Togo series (Precambrian) which consist of garnet-Quartzites, Quartzo-Feldspartic gneiss, Quartzite Sericite Schist and Phyllites. Significant elements detected in the groundwater filtrate included Na^+, K^+, Ca^{2+} and Mg^{2+}. The abundance of Na^+ than K indicates that the K^+ which are less resistant to weathering were leached away from the rock, leaving the Na^+. Also, the high concentration of Calcium ions indicates the resistant potential of Ca-Plagioclase to weathering. The Mg^{2+} was from the biotite mineral contained in the quartzo-feldspatrtic gneiss. Generally the water from the wells around the landfill was hard due to high concentration of Ca^{2+}, Mg^{2+} and SO_4^{2-}.

***4.2** pH variance*

pH is a measure of $[H^+]$* and $[OH^-]$* in a solution, showing how acidic or basic the solution is. It ranges from 0 to 14. If pH of the solution is greater than 7, it is alkaline. The solution is acidic if the pH is less than 7. pH of 7 is considered neutral. Drinking acidic waters can lead to the stomach ulcer .

The pH of the landfill's leachate was 12.31, whiles the up-dip wells and down-dip wells measured pH of 5.40 and 6.82 respectively. The pH of the up-dip wells could be affected by the gradual chemical weathering of the quartzite, which predominantly contains SiO_2. The silica forms acidic compounds which influence the pH of the groundwater. Other extraneuos factor which could have affected groundwater pH include dissolved CO_2 in rainwater. The pH of the up-dip waters did not meet WHO standards (pH: 6.5 -8.5) for portable water.

The difference in pH of the down-dip wells compared to the up-dip well could be as a result of the highly alkaline leachate plume contaminating groundwater flowing from the up-dip wells through the landfill to the down-dip wells.

***4.3** Turbidity*

Well (4) and well (17) had turbidity levels of 39.8-NTU and 85.9-NTU, which exceed W.H.O water quality standard of 5-NTU. Micro-organisms such as viruses and bacteria become attached to the suspended particles, where they can be protected from bactericidal and varicidal effects of chlorine, ozone and other disinfecting agents. Some diseases likely to be caused by bacteria and virses are typhoid fever, cholera and aseptic meningitis.

4.4 Nitrate

The nitrate concentration of the leachate was 19.2- mg/l which exceeds W.H.O.standard of 8mg/l. Higher nitrate concentration in water can cause convulsion and micarriages in pregnant women. Presently, the nitrate concentration in the neighbouring wells are within WHO standard. but with time, leachate plume at the landfiull site can be transported by advection, diffution and dispersion mechanism to contaminate the existing wells, especially the down-dip wells.

4.5 *Heavy metals*

The heavy metals found at the landfill's leachate and the neighbourhood wells were iron , lead and manganese. From table 3, the conductivity of the leachate and the wells were very high and can be attributed to the presence of the metallic ions.

Iron in grounwater is objectionable even at low concentration because it causes brown coloration ln laundered clothing and water becomes distasteful. Moreover, high concentration of iron can cause stomarch upset.

From the results, only wells 3,4,10 and 17 were detected for Fe, as well as the landfill's leachate. This could have been as a result of iron concentration in the leachate plume contaminating wells 3 and 4. The concentration of iron in well (17) and well (4) were 0.94-mg/l and 0.47-mg/l respectively. These values are above WHO water quality standard of 0.3-mg/l.

The average concentration of lead in the groundwater was 1.7-mg/l which exceeded the WHO water quality standard of 0.01-mg/l. The souces of the lead are car batterries and paints. Lead compounds turn both to prersist and bioaccumilate in the environment. In humans, low level lead poisening results in kidney and neurological cell damage. Lead contributes to hypertention and resulting heart disease. In animals studies, lead has been shown to reduce fertility and cause birth defects.

The presence of high Mn comcentration in wells 3,4 and 17 (table 3) could be attributed to the leachate plume . all the wells, excluding the above mentioned were below WHO water quality standard 0f 0.5-mg/l. Like iron, Mn ions are noted for staining porcelain fixtures. andcauses a brown color in laundered clothing and make the water distasteful to drink.

5. Conclusions

From the study of the pantang landfill the following conclusions can be drawn:

The pantang landfill is not an ideal landfill (garbage dump).

The heavy metals, especially lead, exceed WHO stardards for all the wells, The leachate from the landfill site has contaminated the neighborhood wells, especially the wells in the downdip of the landfill results in high turbidity, hardness, low pH and high conductivity results, The wells in the up- dip exceeds the WHO acidity standards for portable water.

Unless remediation (eg.pump and treat, constructing impervious layer to prevent contaminants mobility etc.) is undertaken at the site, drinking water from the neighborhood wells is health risk.

The geology of the area is not an ideal site for landfill due to presence of numerous secondary porosities such as faults, joints and highly weathered rocks.It is recommended the landfill should be shut down and replaced with properly engineered landfill to mitigate the contamination of groundwater in the area.

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Appendix A.

Giant heap of solid waste at Pantang

Tunnel through which emanated leachate from Pantang landfill gets into the environment

Abandoned well due leachate contamination

Well 3.

Well 4. Contaminated with iron from leachate