International Journal of Engineering and Technology Innovation, vol. 4, no. 3, 2014, pp. 170-181

Evaluation of Groundwater Pollution with Heavy Metals at the Oblogo No.1 Dumpsite in Accra, Ghana

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Received 17 February 2014; received in revised form 14 March 2014; accepted 31 March 2014

Abstract

The aim of this research study was to evaluate the groundwater pollution risks from heavy metal contaminants near the de-commissioned Oblogo No.1 dumpsite using a combination of USEPA leachate estimation and migration models. The Hydraulic Evaluation of Landfill Performance (HELP) model was used to determine leachate volumes from the base of the dumpsite whereas the Industrial Waste Evaluation Model (IWEM) was used to determine contaminant concentrations at groundwater wells located at various distances from the dumpsite. It was observed that there is a wide variation in the concentration of the contaminants measured at different sampling periods between 2004 and 2011. Pollution risks from chromium, lead, manganese, cobalt and zinc were determined to be very low since the simulated contaminant concentrations in the wells were less than the reference ground water concentrations. However, the concentrations of cadmium, copper and arsenic were determined to be high enough to constitute a potential risk to groundwater wells which are down-gradient of the dumpsite. It was also determined that the minimum buffer distance of 360 m specified in the Ghana Landfill Guidelines may not ensure adequate protection for groundwater wells located down-gradient of the Oblogo No.1 dumpsite.

Keywords: water balance model, landfill cover, landfill closure, waste disposal site, Ghana

1. Introduction

The Ghana Landfill Guidelines [1] requires the provision of appropriate site infrastructure and control measures to mitigate the likely environmental and health impacts of existing or closed waste disposal sites on the surrounding communities. Most of the waste disposal sites in the city of Accra do not have appropriate gas, leachate, groundwater or surfacewater management systems leading to uncontrolled releases of pollutants to the air, soil and water media. This includes the Mallam SCC, Mallam No.1, Mallam No.2, Oblogo No.1 and Oblogo No.2 dumpsites which are all located in the Ga South Municipal Area.

Leachate generation from these waste disposal sites is major concern because the Ga South Municipal Area has abundant surfacewater and groundwater resources. Research studies over the years have largely focused on the environmental impact of landfill leachate on surfacewater bodies such as the Densu River and the Sakumono wetlands [2-5]. Previous studies on groundwater quality near waste disposal sites in the Accra metropolis have been limited to sampling at very shallow depths not exceeding 2 metres [6]. All these past studies on leachate characterization have observed

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significantly high levels for various physico-chemical and microbiological water quality parameters including organics, heavy metals and xenobiotics.

Two main approaches used for assessing groundwater contamination include the experimental determination of contaminant concentrations or through computer modeling [7-8]. However, the absence of monitoring wells either up gradient or down gradient at dumpsites in the Ga South Municipal Area means that it is difficult to determine the subsurface fate and transport of these various contaminants experimentally. This would make it possible to characterize the risk posed to groundwater-based water supply systems near the individual dumpsites since the mere presence of toxic chemical does not necessarily constitute a risk [9-10]. The magnitude and severity of any risks have to be quantified taking into consideration the site specific conditions.

Risk assessment is typically conducted using a tiered approach. The United Kingdom Environmental Agency (UKEA) tiered risk assessment framework [10] recommends that its use should be such that if a high level of confidence is provided by simple risk assessment, then more complex work may not be necessary. Equally, if there is not sufficient confidence in the assessment when considered at a simple level, more complex work must be carried out to refine the risk assessment and test compliance with existing local and international regulations. The United States Environmental Protection Agency (USEPA) prescribes the use of a 3-tiered approach for assessing risk associated with air and water releases from waste management units [9]. Under this approach, an acceptable level of protection is provided across all tiers, but with each progressive tier the level of uncertainty in the risk analysis is reduced.

This aim of this research study was to evaluate the groundwater pollution risks from heavy metal contaminants near the Oblogo No.1 dumpsite using a combination of USEPA leachate estimation and migration models. The Hydraulic Evaluation of Landfill Performance (HELP) Model was used to determine leachate volumes from the base of the dumpsite whereas the Industrial Waste Evaluation Model (IWEM) was used to determine contaminant concentrations at groundwater wells located at various distances from the dumpsite.

2. Study Design

2.1. Description of study area

The Oblogo No.1 dumpsite is located in the Ga South Municipality of the Greater Accra Region. This dumpsite covers an estimated footprint area of 5.31 hectares and was in operation as the main waste disposal facility for the city of Accra between January 2002 and July 2007 [11]. Fig. 1 shows a location map of the site.

The Oblogo No.1 dumpsite was officially decommissioned in January 2012 with the provision of a final capping and a sub-surface leachate recirculation system. Other site infrastructure that would be provided includes perimeter fencing and surfacewater drains. An aftercare management plan is also being developed [12]. The construction works were ongoing at the time of this study. Fig. 2 shows the pre- and post-capping conditions at this dumpsite.

The Oblogo No.1 dumpsite lies within the dry equatorial climatic zone of Ghana. This zone has a bimodal rainfall regime with annual rainfall of ranging between 331 and 1223 mm. The first season is between May and July and the second from August to October. Rainfall is usually convectional in nature with the highest occurring in June.

The regional geology is the Togo series lithological group which is characterized by both arenaceous and argillaceous overburdens. The arenaceous overburden has very low attenuation capacity and high infiltration rates. The argillaceous overburden has good attenuation capacity and low infiltration rate. The soils in this geographical area belong to the Mamfe-oyarifa and Densu/Chichewere local series. There is occurrence of groundwater at shallow depths [13].

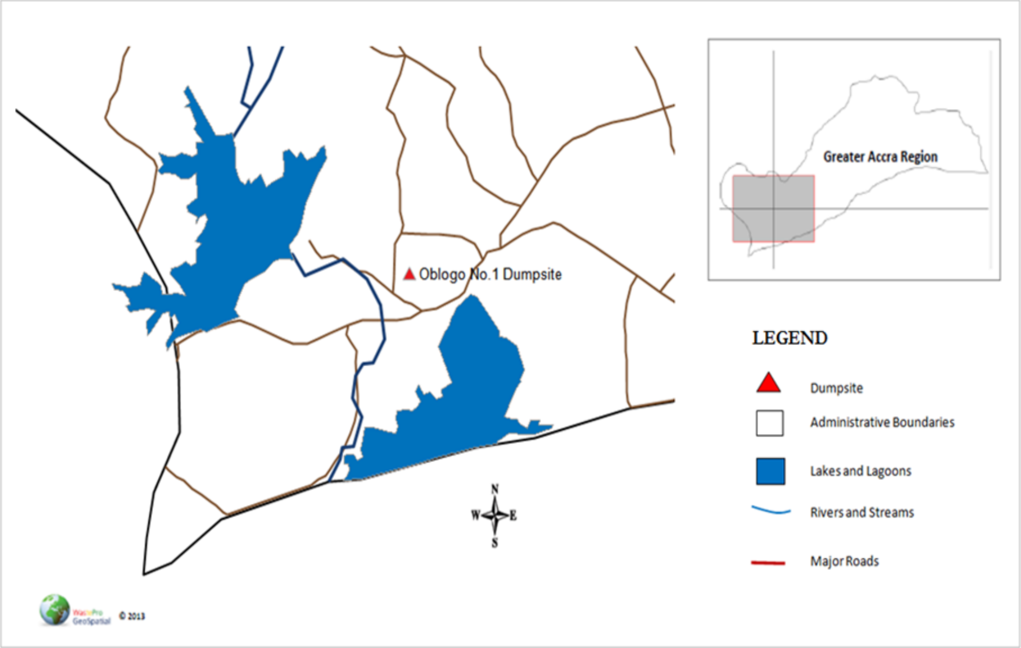


Fig. 1 Location map of the Oblogo No.1 dumpsite

Before capping

After capping

Fig. 2 Conditions at the Oblogo No.1 dumpsite

2.2. *Leachate characterization*

A review of publications on leachate characterization at the Oblogo No.1 dumpsite between 2004 and 2011 was done to determine the maximum, minimum and average concentrations of heavy metals. Table 1 presents the list of the specific heavy metals considered. The range of values reported in literature [14] for each chemical species is also provided.

Table 1 Heavy metal contaminants in landfill leachate

Contaminant	Concentration range (mg/l)
Chromium	0.02 – 1.5
Lead	0.001 - 5
Manganese	0.03 - 1400
Arsenic	0.01 - 1
Cadmium	0.0001 – 0.4
Cobalt	0.005 – 1.5
Copper	0.005 - 10
Zinc	0.03 - 1000

2.3. Estimation of annual leachate volumes

The annual leachate volume that percolates beneath the Oblogo No.1 dumpsite was estimated using the Hydraulic Evaluation of Landfill Performance (HELP) model. The HELP model is a computer model developed to assist landfill designers and regulators in evaluating cover systems, bottom liners and leachate collection systems [15-16]. Fig. 3 illustrates the various hydrological processes that are simulated by the HELP model for a closed landfill.

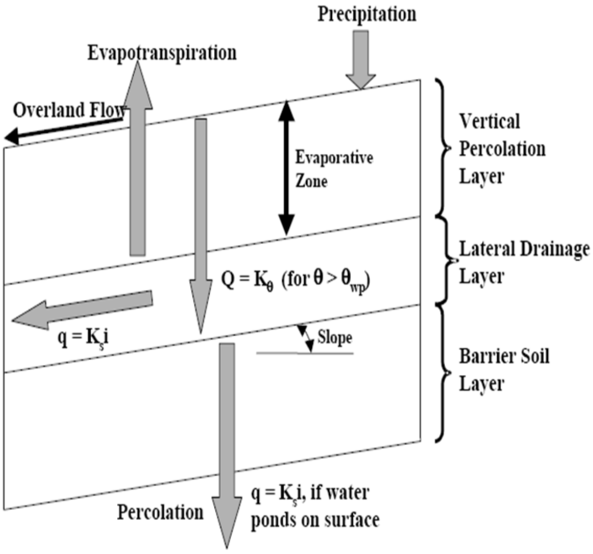


Fig. 3 Landfill profile and hydrological processes modelled with HELP

Vertical drainage is modeled by Darcy’s law using the Campbell equation for unsaturated hydraulic conductivity based on the Brooks-Corey relationship. Saturated lateral drainage is modeled by an analytical approximation to the steady-state solution of the Boussinesq equation employing the Dupuit-Forchheimer assumptions [16].

The input data required include climatologic, vegetative cover, soil characteristics, and landfill design site data. The output results includes daily volumes, monthly totals, annual averages, annual totals of leachate collected and the percolation rates through the bottom of the landfill. The simulation period used for this study was one calendar year. A fair stand of grass vegetation condition and a surface slope of 5% having a horizontal slope length of 50 meters were used. Even though the Oblogo No.1 dumpsite is partially lined [12], a worst case scenario of no lining was assumed for this study. Table 2 presents HELP Model setup for Oblogo No.1 landfill profile.

Table 2 HELP model setup of Oblogo No.1 landfill profile

Layer material	Type of layer	HELP model classification	Thickness (mm)
Topsoil	Vertical percolation	8	100
Coarse aggregate	Lateral drainage	21	150
Compacted clay	Barrier soil	16	150
Waste materials	Vertical percolation	18	35000

2.4. Risk assessment of groundwater wells

A risk assessment of groundwater wells located at various distances from the dumpsite was done using the USEPA Industrial Waste Management Evaluation Model (IWEM) software. The IWEM software [17] was originally developed for risk assessment at waste disposal sites in the United States, but it has also been used in other parts of the world [18-19]. IWEM uses the USEPA's Multi-Med and Composite Model for Leachate Migration and Transformation Products (EPACMTP) fate and transport model to calculate leachate contaminant threshold values (LCTVs) for each of the contaminants under consideration. An LCTV is the maximum concentration of a constituent in the leachate that is protective of ground water [20].

The EPACMTP computational engine treats the subsurface aquifer system beneath the landfill as a composite domain, consisting of an unsaturated zone and an underlying saturated zone [20]. The two zones are separated by the water table. EPACMTP simulates one-dimensional (1-D), vertically downward flow and transport of constituents in the unsaturated zone beneath a waste disposal unit as well as ground-water flow and three dimensional (3-D) constituent transports in the underlying saturated zone. The unsaturated zone and saturated zone modules are computationally linked through continuity of flow and constituent concentration across the water table.

Flow in the vadose zone is governed by the 1-D steady-state Richards flow equation. The soil underneath the landfill is assumed to be uniform with hydraulic properties described by the Mualem-Van Genuchten model. The unsaturated zone is assumed to be initially constituent-free and constituent transport processes in this zone are assumed to occur by advection and dispersion. In the case of metals which are subject to nonlinear sorption, EPACMTP uses a method-of-characteristics solution method that does not include dispersion [20]. In this case, transport is dominated by the nonlinear sorption behavior and dispersion effects are minor. For non-linear sorption isotherms, the value of the partition coefficient is a function of contaminant concentration.

The pseudo-3-D module simulates ground-water flow using a 1-D steady-state solution for predicting hydraulic head and Darcy velocities. The flow solution is formulated based on the Dupuit-Forchheimer’s assumption of hydrostatic pressure distribution. A key distinction between the way the saturated zone module handles constituent fate and transport, as compared to the unsaturated zone module, is the approach for constituents with nonlinear sorption isotherms. The saturated zone module only simulates linearized isotherms [20]. For constituents with nonlinear sorption isotherms, the unsaturated zone module simulates partitioning by using concentration-dependent partitioning coefficient; the saturated zone module uses a linearized isotherm, based upon the maximum constituent concentration at the water table. The reason is that upon dilution of the leachate in the ambient ground-water as the leachate enters the saturated zone, concentrations will be reduced to a range in which constituent isotherms generally are linear.

The IWEM software accounts for biological and chemical transformation processes as first-order degradation reactions. It assumes that the transformation process can be described in terms of a constituent-specific half-life. It also allows the degradation rate to have different values in the unsaturated zone and the saturated zone, but the model assumes that the value is uniform throughout the unsaturated zone and uniform throughout the saturated zone for each constituent.

The IWEM software can be used to conduct either a Tier 1 or Tier 2 risk assessment [20]. A Tier 1 evaluation involves comparing the leachate concentrations of various contaminants in the buried solid waste against a set of constituent-specific LCTVs for three pre-defined landfill liner scenarios i.e. no liner, single liner or composite liner. There is a potential risk to groundwater if the leachate concentration exceeds an LCTV depending on the liner scenario used at the particular waste disposal site. Tier 1 assessment has minimal data requirements, i.e. the concentration of the various contaminants but has a higher level of uncertainty

A Tier 2 evaluation involves comparing the expected 90th percentile leachate concentrations of various contaminants at a groundwater well located at a given specific distance from the landfill site with the corresponding constituent-specific Reference Ground-water Concentrations (RGCs). The 90th percentile exposure concentration is determined by running EPACMTP in a Monte Carlo mode for 10,000 realizations. For each realization, EPACMTP calculates a maximum average concentration at a well, depending on the exposure duration of the RGC of interest. The RGCs used for this study are the USEPA’s Maximum Contaminant Levels (MCLs) and Health-Based Numbers (HBNs) which are in-built in the IWEM software. There is a potential risk if the expected contaminant concentration in the groundwater well exceeds an RGC. The input data requirements for a Tier 2 assessment include the contaminant concentrations, annual leachate volume, landfill dimensions, well locations, hydro-geological characteristics, soil and climate parameters. Fig. 4 depicts the contaminant plume from the bottom of the landfill to the well location in the plan and sectional views.

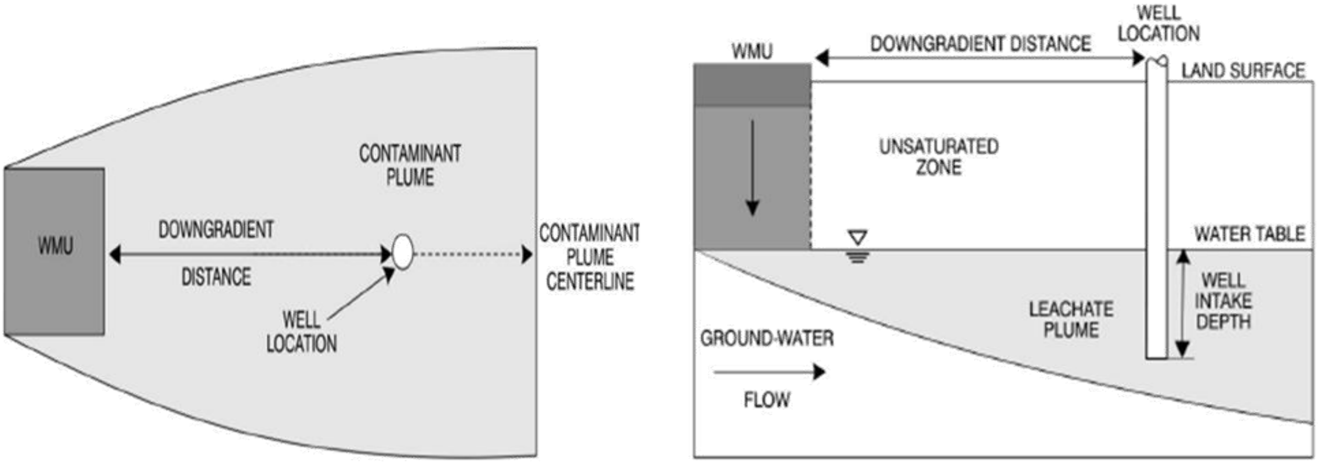


Fig. 4 Plan and sectional view of contaminant plume from landfill to well

3. Results

3.1. Leachate characterization

Five separate research studies on leachate sampling and characterization with respect to heavy metals at the Oblogo No.1 dumpsite were reviewed. Table 3 presents the dates of sampling and the source of information. Table 4 presents the maximum concentration for the various constituents at the given sampling dates.

Table 3 Leachate sampling at Oblogo No.1 dumpsite

Sampling ID	Sampling Period	Reference
OBG-S1	January – June 2004	[5]
OBG-S2	October 2007 – March 2008	[3]
OBG-S3	August – December 2008	[6]
OBG-S4	June – November 2009	[4]
OBG-S5	August 2011	[12]

Table 4 Maximum heavy metal concentrations in Oblogo No.1 leachate

Constituent	Concentration (mg/l)				
	OBG-S1	OBG-S2	OBG-S3	OBG-S4	OBG-S5
Chromium	-	0.022	0.23	-	-
Lead	-	0.009	-	0.104	0.021
Manganese	0.12	-	2.38	0.210	-
Arsenic	-	-	0.27	-	-
Cadmium	2.45	0.019	0.14	-	-
Cobalt	-	0.012	-	-	-
Copper	-	0.006	13.78	0.025	-
Zinc	0.28		7.42	0.172	0.146

It was observed that there is a wide variation in the concentrations of the contaminants measured at different sampling periods. The values obtained for OBG-S3 were comparatively higher for chromium, manganese, copper and zinc compared to other sampling periods. The maximum concentrations were within the ranges specified in literature [14] with the exception of copper and cadmium.

3.2. *HELP model simulation results*

Table 5 presents the water balance results obtained from the HELP Model simulations. It was determined that the percolation from the base of landfill would be 34.6 mm/yr which corresponds to 1835.6 m^3.

Table 5 Annual water balance estimates for Oblogo No.1 dumpsites

Parameter	Rate (mm/yr)
Precipitation	1051.300
Evapotranspiration	755.095
Percolation through layer 4	34.633

3.3. *Tier 1 risk assessment results*

Table 6 presents a comparison of maximum concentrations of each of the constituent with the pre-defined MCL based LCTVs for no liner, single liner and composite liner scenarios. It is observed that there is a potential risk of pollution from lead, arsenic, cadmium and copper in the no liner scenario since the maximum concentrations exceed the prescribed LCTVs. The potential risks from cadmium and copper are high for the single liner scenario. It is also observed that the composite liner offers no protection against cadmium pollution. It should be noted that for the composite liner scenario the LCTVs for chromium, lead, arsenic and cadmium are capped by the toxicity characteristic rule exit level (TC Level) of the constituent [20]. The LCTV for copper is also capped at 1000 mg/l. There are no specified MCLs for cobalt, zinc and manganese.

Table 7 presents a comparison of maximum concentrations of each of the constituent with the pre-defined HBN based LCTVs for no liner, single liner and composite liner scenarios. It is observed that there is a potential risk of pollution from chromium, arsenic and cadmium in the no liner scenario since the maximum concentrations exceed the prescribed LCTVs. The potential risks from arsenic and cadmium are high for the single liner scenario. It is also observed that the composite liner offers no protection against cadmium pollution. There are no specified HBNs for copper and lead.

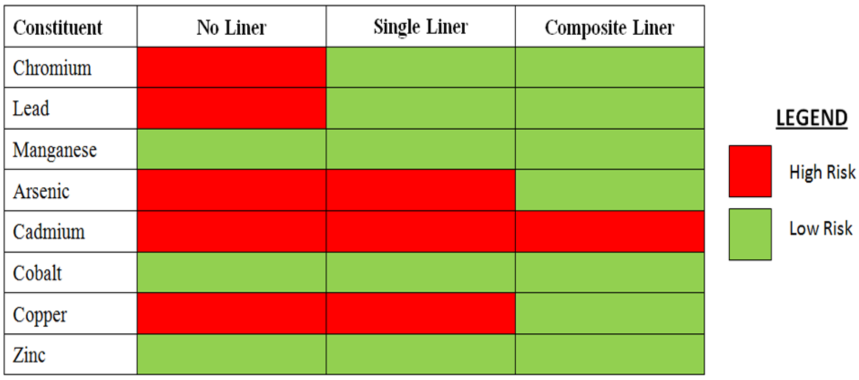
Table 6 Comparison of leachate concentrations with MCL based LCTVs

Constituent	Max. Concentration (mg/l)	No Liner LCTV (mg/l)	Single Liner LCTV (mg/l)	Composite
Chromium	0.23	0.25	0.98	5
Lead	0.104	0.037	0.015	5
Manganese	-	-	-	-
Arsenic	0.27	0.11	0.33	5
Cadmium	2.45	0.011	0.033	1
Cobalt	-	-	-	-
Copper	13.78	3	9.4	1000
Zinc	-	-	-	-

Table 7 Comparison of leachate concentrations with HBN based LCTVs

Constituent	Max. concentration (mg/l)	No liner LCTV (mg/l)	Single liner LCTV (mg/l)	Composite liner LCTV (mg/l)
Chromium	0.23	0.19	0.75	5
Lead	-	-	-	-
Manganese	2.38	2.5	8	1000
Arsenic	0.27	0.0002	0.0013	5
Cadmium	2.45	0.027	0.083	1
Cobalt	0.012	1.1	3.1	1000
Copper	-	-	-	-
Zinc	7.42	16	51	1000

Fig. 5 presents a colour-coded groundwater pollution risk characterization for various heavy metal contaminants based on both MCLs and HBNs for various liner scenarios.



Constituent	No Liner	Single Liner	Composite Liner
Chromium	🟥	🟩	🟩
Lead	🟥	🟩	🟩
Manganese	🟩	🟩	🟩
Arsenic	🟥	🟥	🟩
Cadmium	🟥	🟥	🟥
Cobalt	🟩	🟩	🟩
Copper	🟥	🟥	🟩
Zinc	🟩	🟩	🟩

LEGEND

🟥 High Risk

🟩 Low Risk

Fig. 5 Tier 1 groundwater pollution risk characterization for heavy metals

3.4. *Tier 2 risk assessment results*

Table 8 presents a comparison of expected heavy metal contaminant concentrations at groundwater wells located at various distances away from the dumpsite with the MCL based RGCs. The results seem to suggest that there may be a minimal risk of contamination from chromium and lead at distances greater than 100 m from the dumpsite. There seems to be a potential risk of pollution from arsenic and copper at groundwater wells that are less than 750 m and 1000 m respectively from the dumpsite. Pollution from cadmium seems to be a high risk even when wells are located more than a 1000 m away from the dumpsite. There are no specified MCLs for cobalt, zinc and manganese.

Table 8 Comparison of expected groundwater well concentrations with MCL based RGCs

Constituent	RGC (mg/l)	100 m (mg/l)	200 m (mg/l)	300 m (mg/l)	400 m (mg/l)	500 m (mg/l)	750 m (mg/l)	1000 m (mg/l)
Chromium	0.10	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Lead	0.015	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Manganese	-	-	-	-	-	-	-	-
Arsenic	0.05	0.0989	0.0767	0.0684	0.0631	0.0559	0.0415	0.0324
Cadmium	0.005	0.9110	0.6659	0.6006	0.5381	0.4842	0.3652	0.2837
Cobalt	-	-	-	-	-	-	-	-
Copper	1.30	3.593	2.985	2.556	2.351	2.144	1.586	1.178
Zinc	-	-	-	-	-	-	-	-

Table 9 Comparison of expected groundwater well concentrations with HBN based RGCs

Constituent	RGC (mg/l)	100 m (mg/l)	200 m (mg/l)	300 m (mg/l)	400 m (mg/l)	500 m (mg/l)	750 m (mg/l)	1000 m (mg/l)
Chromium	0.073	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Lead	-	-	-	-	-	-	-	-
Manganese	1.20	0.8734	0.6781	0.6173	0.5616	0.5037	0.3741	0.2998
Arsenic	0.0073	0.0985	0.0762	0.0683	0.0630	0.0558	0.0414	0.0324
Cadmium	0.12	0.8930	0.6447	0.5881	0.5381	0.4755	0.3632	0.2811
Cobalt	0.49	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Copper	-	-	-	-	-	-	-	-
Zinc	7.30	3.31	2.098	1.892	1.731	1.532	1.119	0.8545

Table 9 presents a comparison of expected concentrations of each of the constituent at groundwater wells located at various distances away from the dumpsite with the HBN based RGCs. The results seem to suggest that there may be a minimal risk of contamination from chromium, manganese, cobalt and zinc at distances greater than 100 m from the dumpsite since the concentrations of these particular heavy metal contaminants are very low. Pollution from arsenic and cadmium seems to be a high risk even when wells are located more than a 1000m away from the dumpsite. There are no specified HBNs for copper and lead.

Fig. 6 presents a colour-coded risk characterization at various distances based on both MCLs and HBNs. Fig. 7 presents a comparison of Tier 1 and Tier 2 risk characterization which seems to indicate that the severity of the pollution risks from chromium and lead may be overstated if only the Tier 1 assessment are relied upon. The Tier 2 assessment also makes it possible to specify a safe distance in the case of copper.

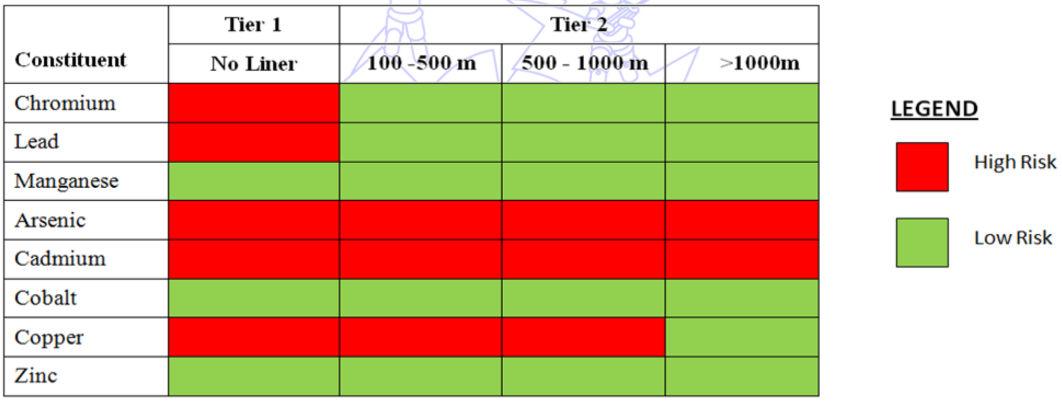
Constituent	100m	200m	300m	400m	500m	750m	1000m
Chromium	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Lead	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Manganese	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Arsenic	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Cadmium	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Cobalt	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Copper	🟥	🟥	🟥	🟥	🟥	🟥	🟩
Zinc	🟩	🟩	🟩	🟩	🟩	🟩	🟩

LEGEND

🟥 High Risk

🟩 Low Risk

Fig. 6 Tier 2 groundwater pollution risk characterization for heavy metals



Constituent	Tier 1	Tier 2		
	No Liner	100 -500 m	500 - 1000 m	>1000m
Chromium	🟥	🟩	🟩	🟩
Lead	🟥	🟩	🟩	🟩
Manganese	🟩	🟩	🟩	🟩
Arsenic	🟥	🟥	🟥	🟥
Cadmium	🟥	🟥	🟥	🟥
Cobalt	🟩	🟩	🟩	🟩
Copper	🟥	🟥	🟥	🟩
Zinc	🟩	🟩	🟩	🟩

LEGEND

🟥 High Risk

🟩 Low Risk

Fig. 7 Comparison of Tier 1 and Tier 2 risk characterization for heavy metals

4. Discussion of Results

4.1. *Maximum concentrations of heavy metal contaminants*

The maximum concentrations of the heavy metal contaminants observed at the Oblogo No.1 dumpsite with the exception of copper and cadmium are all within the ranges reported by [14]. The value of 13.78 mg/l observed for copper by [6] is above the upper value of 10 mg/l whereas the value of 2.45 mg/l observed for cadmium by [5] is above the upper value of 0.4 mg/l. Elevated cadmium levels of 8.8 mg/l have also been observed by [21] at the Solous waste disposal site in Nigeria. The occurrence of these heavy metals in such elevated concentrations at landfill sites in West Africa may be due to the co-disposal of domestic and industrial wastes which is typically not the case in Europe and North America.

However, other leachate sampling results for cadmium at Oblogo No.1 [3, 6] and Solous [22] are all within the ranges reported in landfill literature. Background concentrations of heavy metals species in surface and groundwater water samples taken at points adjacent to the Oblogo No. 1 dumpsite but not within potential leachate plume flow paths were also observed to be less than 0.1 mg/l and 3.0 mg/l for copper and cadmium respectively [3, 6]. It is significant to note that there is spatial variability of leachate composition at landfill sites to the extent that high contaminant concentration areas tend to occupy a lesser footprint of up to 10% to compared to the low contaminant concentration areas [23-25].

4.2. Heavy metal pollution risks from the Oblogo No.1 dumpsite

Heavy metals are generally not considered a major groundwater pollution problem in landfill leachate plumes, because concentrations are usually low in leachate and because heavy metals are strongly attenuated by sorption and precipitation [14, 26]. Sulphide producing conditions also result in extremely low solubilities of heavy metals. However, the fate and transport simulation results seem to indicate that high concentrations of arsenic, copper and cadmium would most likely lead to pollution of groundwater wells located near the Oblogo No.1 dumpsite.

Arsenic, cadmium and copper are classified by the USEPA as primary groundwater contaminants [27]. Arsenic is a carcinogen which causes acute and chronic toxicity, liver and kidney damage and decreases blood hemoglobin. Copper and cadmium can cause liver and kidney damage, and anemia in high doses. As stated earlier, high contaminant concentration areas tend to occupy a lesser footprint compared to the low contaminant concentration areas therefore any inferences made from the simulation results about potential health risks should be viewed within that context.

4.3. Buffer distances for groundwater well development

The Ghana Landfill Guidelines [1] stipulates that the minimum buffer distance for the location of groundwater wells near a closed or operating waste disposal site should be 360 m. However, the fate and transport simulation results may seem to indicate that this buffer distance may not offer adequate protection against pollution risks from arsenic, copper and cadmium if the groundwater well is located downgradient of the Oblogo No.1 dumpsite. Studies on leachate migration from unlined landfills [28-30] show that plumes do not usually exceed a length of 1000 m and so buffer distances of 500 m would in most cases be adequate.

There are currently no large scale groundwater resources development activities in the Ga South Municipal Area [31]. However, increasing urbanization in this municipality means that residential and commercial properties are increasingly being constructed very close to the de-commissioned Oblogo No.1 dumpsite. There is, therefore, a high likelihood that small scale groundwater abstraction points for domestic uses may in the future be constructed close to the Oblogo No.1 dumpsite to supplement irregular municipal water supply services.

5. Conclusion and Recommendation

This research study evaluated the groundwater pollution risks from eight heavy metals near the de-commissioned Oblogo No.1 dumpsite using a combination of USEPA leachate estimation and migration models. The Hydraulic Evaluation of Landfill Performance (HELP) Model was used to determine leachate volumes from the base of the dumpsite whereas the Industrial Waste Evaluation Model (IWEM) was used to determine contaminant concentrations of heavy metals at groundwater wells located at various distances from the dumpsite.

It was observed that there is a wide variation in the concentration of the contaminants measured at different sampling periods between 2004 and 2011. Pollution risks from chromium, lead, manganese, cobalt and zinc were determined to be very low since the expected contaminant concentrations in the wells were less than the reference ground water concentrations. However, the concentrations of cadmium, copper and arsenic were determined to be high enough to constitute a potential risk to groundwater wells which are downgradient of the dumpsite. It was also determined that that the minimum buffer distance of 360 m specified in the Ghana Landfill Guidelines may not ensure adequate protection for groundwater wells located down-gradient of the Oblogo No.1 dumpsite.

The inherent limitation of the IWEM model does not make it possible to account for the cumulative risk due to simultaneous exposure to multiple constituents or contaminants. IWEM also simulates biodegradation in a relatively simple way by assuming the rate is the same in both the unsaturated and the saturated zones. Recommendations for further study include a detailed Tier 3 risk assessment [20] using industry standard groundwater fate and transport models such as MODFLOW and MT3DMS.

Acknowledgement

The work for this paper was carried out with technical support from Kspyx HR Consult Ltd. The author also wishes to thank the Dean and faculty members at the Department of Civil and Geomatic Engineering of Kaaf University College.

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