INVESTIGATION OF POTENTIAL IMPACTS ON GROUND AND SURFACE WATER DUE TO GALLE MUNICIPAL COUNCIL DUMPSITE

K.D.B. Ruwan
Faculty of Engineering, University of Ruhuna
email: 87buddhikaruwan@gmail.com
R.M.A.S.K. Rathnayaka
Faculty of Engineering, University of Ruhuna
email: anandasaman@gmail.com
W.K.C.N. Dayanthi
Faculty of Engineering, University of Ruhuna
email: neetha@cee.ruh.ac.lk
D.D. Edirisinghe
Faculty of Engineering, University of Ruhuna
email: duminda@cee.ruh.ac.lk
N.H. Priyankara
Faculty of Engineering, University of Ruhuna
email: nadeej@cee.ruh.ac.lk

Abstract

Open dumpsites are the widely used practice in Sri Lanka for disposal of unsorted solid waste. Waste management of Galle Municipal Council (GMC) area has been done by the municipal council. Solid waste generated in the GMC area is collected by the GMC, and a small portion of biodegradable waste is used to produce compost. Rest of the waste is disposed on a semi-controlled dumpsite. Gin river is flowing by the side of the dumpsite. Therefore controls and precautionary measures are needed at this dumpsite because it is likely to generate highly contaminated leachate which may be a threat to Gin river and surrounding groundwater. The aim of this study was to investigate the potential impacts caused by the GMC dumpsite - leachate on Gin river water and surrounding groundwater. There were about 72 % of volatile solids reduction in the solid waste dumped for 8 years at the dumpsite as compared with the fresh solids wastes. This indicates the biodegradation of dumped solid waste. Therefore it is highly possible that leachate from this site is rich in organic matter. The reduction in electrical conductivity shows that the possible dissolution of ionized solids which were initially present with solid waste, into soil water. The leachate was found to have exceeded effluent discharge standards for the parameters such as biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), turbidity, total suspended solids (TSS), ammonium-nitrogen (NH_4^+ - N) , orthophosphate, selenium (Se), arsenic (As), chromium (Cr) and ferrous (Fe). Chloride (Cl^-), COD and turbidity values of the ground water sample were higher than the highest desirable standard levels for drinking purpose. Arsenic (As) and selenium (Se) exceeded the maximum permissible levels of drinking water standards. 'Se' concentration in leachate, Gin river water and groundwater was extremely high. The mean concentrations of BOD_5, COD, turbidity, Cl^-, conductivity, 'Se' and 'Cr' of the portion of Gin river which is in the immediate vicinity to the dumpsite exceeded the ambient water quality standards. The study revealed that the leachate from the dumpsite has adversely affected the surrounding ground and surface water.

Keywords: Galle Municipal Council dumpsite, leachate, water quality parameters, Gin river, groundwater

1. Introduction

With the rapid increase of population and technology, generation of solid waste has also increased in the world. Open dumpsites or semi-controlled landfills are the widely used practice in Sri Lanka for the disposal of unsorted solid waste. In Sri Lanka, appropriate land filling methods are not in practice to minimize the supplementary hazards.

Among the supplementary hazards, generation of leachate is the major issue. The landfill leachate is deemed to be one of the most serious pollution problems. Highly contaminated leachate may enter the ground and surface water if there is no appropriate method to collect and treat leachate. Since segregation is hardly practiced in most of the cases, the solid waste dumped is rich in biodegradable organic matter, which may increase the generation of leachate and lead methane, a greenhouse gas that emits into the atmosphere.

Galle is the capital of the southern province in Sri Lanka, with a population of 125,000 and an area of 16 km^2. Waste management of GMC area has been done by the municipal council over a hundred years. The GMC area is divided into fourteen wards. The solid wastes generated in all wards are collected by the GMC. A portion of biodegradable waste collected from two wards is used to produce compost. A very small portion of biodegradable solid waste is used in an anaerobic digester at GMC office to obtain biogas. Rest of the waste is disposed in a semi-controlled dumpsite located at Heenpanthala, Galle. Gin river is flowing in the immediate vicinity of the landfill site. Therefore controls and precautionary measures are needed at this landfill site because it is likely to generate highly contaminated leachate which may be a threat to Gin river and surrounding groundwater. Investigation of the impacts due to the dumpsite will be essential in deriving precautionary measures and controls. These results will also indicate the potential for long-term persistence and transport of some contaminants in ground water. Therefore the aim of this study was to assess impacts caused by the dumpsite-leachate on Gin river water and surrounding groundwater.

2. Methodology

2.1 Study area

The GMC dumpsite is situated beside the Gin river and the lagoon at the river mouth. Figure 2.1 shows the location of the GMC dumpsite. It approximately covers an area of three and half acres and is surrounded by a residential set up. The operations of the dumpsite began nearly 6 years ago. About 35 tons of Municipal Solid Waste (MSW) is handled per day at the dumpsite. Solid waste generated in two wards are separated as biodegradable and non-biodegradable wastes. The biodegradable portion is composted while the non-biodegradable portion is sold for recycling. However there is no well established segregation process.

2.2 Sampling of leachate, surface water and groundwater

Five samples (from GMC-LE-01 to GMC-LE-05) were collected from different places of the leachate ditch surrounding the dumpsite, which ultimately enters Gin river. Five samples (from GMC-SW-01 to GMC-SW-05) were collected from the portion of Gin river which is adjacent to the dumpsite. Three sampling points of Gin river were located on the upstream area to the leachate drain. They were located along the river beside the old dump. Other two sampling points were selected on the downstream area to the leachate drain, which were close to the drain and the lagoon area. A sample (GMC-GW) was collected from a well located within 100 m distance from the dumpsite in order to represent groundwater. Figure 2.2 shows the sampling locations of leachate, surface water and ground water. In addition several plots on the dumpsite were selected according to the age of the solid waste dumped, and a solid waste sample was collected from each plot for characterization. Table 1 gives a description for each surface water sampling point.

Figure 1: Location of GMC dumpsite

Table 1: Description of surface water sampling locations

Sample	*Description*
GMC-SW-01	*An old dumpsite locates on the river bank adjacent to this point. A storm water ditch enters the river at a place immediately upstream to this point.*
GMC-SW-02	*Water from this portion is used for human activities.*
GMC-SW-03	*Leachate outfall to Gin rive locates close by this point.*
GMC-SW-04	*This point is immediately downstream to the leachate outfall.*
GMC-SW-05	*Lagoon area (Low flow rate)*

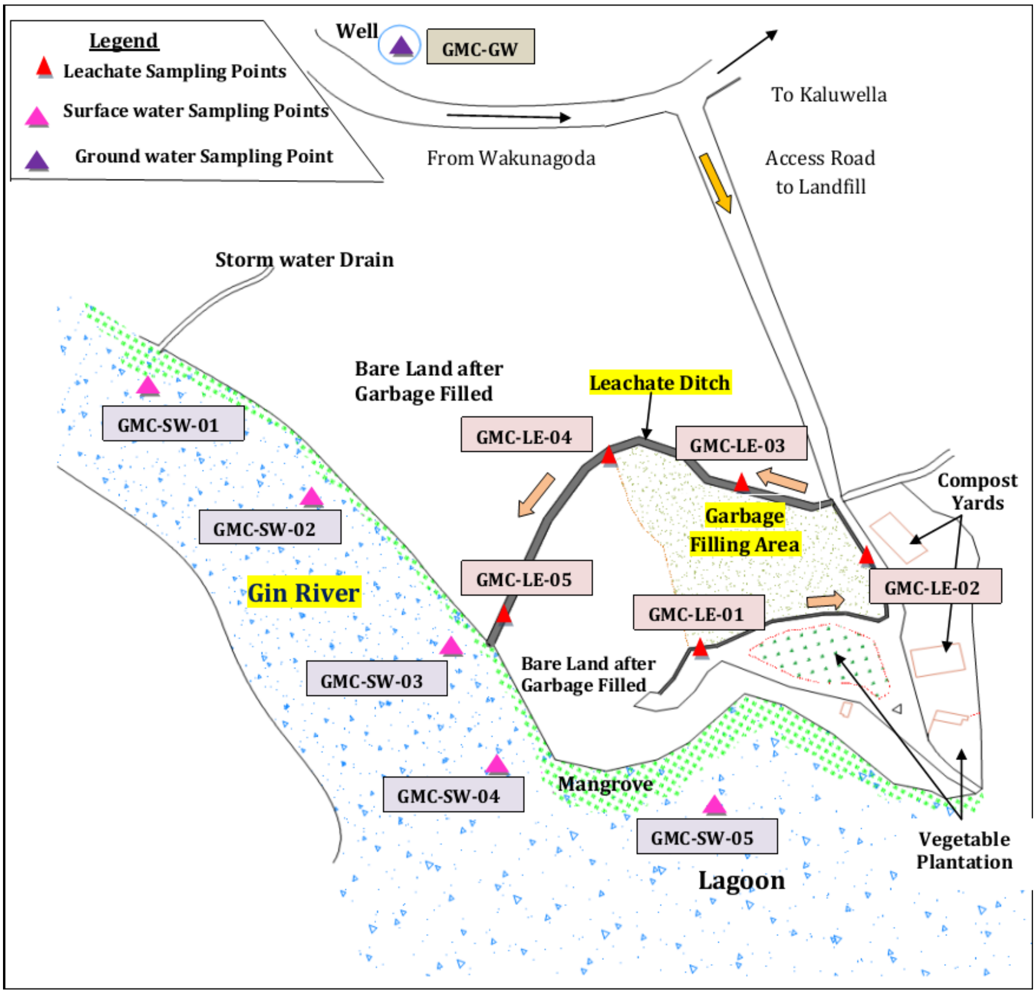

Figure 2: Sampling locations of leachate, surface water and ground water

2.3 Laboratory analyses

Leachate, surface and ground water samples were analyzed in terms of BOD_5, COD, total organic carbon (TOC), total-N, NH_4^+ -N, NO_3^{2-} -N, total-P, orthophosphate, sulphate (SO_4^{2-}), Cl^-, pH, turbidity, electrical conductivity, dissolved oxygen (DO), salinity and heavy metals in accordance with "Standard Methods for the Examination of Water and Wastewater, 1998". Parameters such as DO and temperature were measured at the site. All the samples were immediately transferred to the laboratory and stored at a temperature about 4 °C. The entire tests were conducted within the sample holding time. Solid waste samples were collected in air-tight bags and were characterized in terms of composition, moisture content, particle density, volatile solids, pH and electrical conductivity.

3. Results & Discussion

3.1 Characteristics of MSW

Table 2 shows the characteristics of municipal solid waste buried in GMC dumpsite. The bulk density of the solid waste dumped for 8 years has increased 1.8 fold as compared with the solid waste dumped at the surface. There were about 72 % of volatile solids reduction in the solid waste dumped for 8 years at the dumpsite as compared with the fresh solids wastes. This indicates the biodegradation of dumped solid waste. Therefore it is highly possible that leachate from this site is rich in organic matter. The reduction in electrical conductivity shows that the possible dissolution of ionized solids which were initially present with solid waste, into soil water. These ions may include toxic heavy metals and micro pollutants.

Table 2: Characteristics of municipal solid waste in GMC dumpsite

Parameter	*Fresh SW sample*	*SW at surface of dump*	*SW at 1m depth of dump*	*SW dumped 8 years ago*
Moisture content (%)	*44.54*	*44.73*	*28.70*	*4.62*
Bulk density (kg/m^3)	*219.51*	*451.2*	*552.8*	*820.9*
Volatile solids (%)	*68.5*	*47.88*	*39.7*	*13.48*
pH	-	*7.587*	*7.510*	*7.640*
EC (mS/cm)	-	*2.198*	*2.004*	*1.003*

3.2 Characteristics of leachate, ground water and surface water

Table 2 shows the average concentrations of leachate and ground water parameters with the tolerance limits for discharge in surface water in Sri Lanka and drinking water standards. Parameters that do not comply with respective standards are highlighted. TSS, NH_4^+ - N, orthophosphate, COD and BOD_5 exceeded the tolerance limits for discharge in surface waters in Sri Lanka. COD concentration of leachate was more than 27 times the respective tolerance limit. Both NH_4^+ - N and BOD_5 values were 9 fold higher than the respective tolerance limits. Heavy metals such as ‘Se’ and ‘As’ far exceeded the discharge tolerance limits. ‘Fe’ marginally exceeded the standard level. A comprehensive note on heavy metals concentrations has been given in the end of this section. The above results indicate that the untreated leachate from this site is not suitable to be discharged into Gin river.

The high values of BOD_5 and COD indicate the high organic strength of leachate. The BOD_5 /COD ratio was about 0.04. Metcalf and Eddy (2003) stated that if BOD_5 /COD ratio is below about 0.3, either the wastewater may have some toxic components or acclimated microorganisms may be required in its stabilization. Very high electrical conductivity and total dissolved solids values indicate the presence of dissolved organic and inorganic impurities such as heavy metals and micro pollutants. Electrical conductivity determinations are useful in aquatic studies because they provide a direct measurement of dissolved ionic matter in the water. Low values are characteristic of high-quality, low-nutrient waters. High values of electric conductance can be indicative of salinity problems but also are observed in eutrophic waterways where plant nutrients are in greater abundance (Surface water sampling methods and analysis, 2009).There is no dissolved oxygen in leachate. The nutrient constituents such as NO_3^- -N, Total – N, NH_4^+ - N orthophosphate were high. Total nitrogen includes all forms of nitrogen, such as (in order of decreasing oxidation state) nitrate, nitrite, ammonia and organic nitrogen. The concentration of nitrogen can be used to assess nutrient status in waterways. Enrichment by nitrogenous compounds may lead to related problems such as nuisance or toxic algal blooms. High levels of phosphorus and/or other key nutrients may lead to related problems such as nuisance or toxic algal blooms, although some waterways are naturally eutrophic (Surface water sampling methods and analysis, 2009).

Table 2 : Average concentrations of leachate and ground water parameters

Parameter	*Leachate*	*Tolerance limit for discharge in surface waters*	*Ground water*	*Drinking water standards (Highest desirable levels)*
Turbidity (NTU)	-	-	***4.65***	***2***
Electrical conductivity(mS/cm)	*19.1*	-	*0.347*	*0.75*
Total solids (mg/L)	*17459*		*105*	*500*
Total Suspended Solids	***250***	***50***	*24*	-
Total Dissolved Solids (mg/L)	*6467*	-	-	-
Total Alkalinity (mg/L as	*5844*	-	*30*	*200*
Sulphate (mg/L)	*375.05*	-	*83.97*	*200*
Chloride (mg/L)	*3530.17*	-	***999.69***	***200***
Salinity (mg/L)	*>10*	-	*0.1*	-
Dissolved Oxygen (mg/L)	*0*	-	*3.75*	-
pH (pH units)	*7.88*	*6.0-8.5*	*6.95*	*7.0 – 8.5*
NO_3^- -N (mg/L)	*72*	-	*1.66*	*10*
Total – N (mg/L)	*3412.18*	-	*125.86*	-
NH_4^+ - N (mg/L)	***464.82***	***50***	*0.026*	-
Total – P (mg/L)	*8.22*	-	*Negligible*	-
Orthophosphate (mg/L)	***6.27***	***5***	*Negligible*	-
COD (mg /L)	***6833.9***	***250***	***23.61***	***10***
BOD_5 (mg/L)	***293***	***30***	***9.8***	-
TOC (mg/L)	*371.2*	-	*0.42*	-
As (ppb)	***1511.3***	***200***	***66.2***	***50****
Cr (ppb)	*389.4*	*500*	*6.0*	-
Se (ppb)	***4870.8***	***50***	***249.1***	***10****
Fe (ppb)	***3213.8***	***3000***	***23.1***	-

Note: * maximum permissible level for drinking purpose

Cl^-, COD and turbidity values of the ground water sample were higher than the highest desirable standard levels for drinking purpose (SLS 614, 1983). ‘As’ and ‘Se’ exceeded the maximum permissible levels of drinking water standards. ‘As’ concentration of leachate was about 7 fold higher than the standards for discharge in surface water while ‘Se’ concentration was about 100 times greater than the standard value. 'Se' concentration in groundwater was 25 times greater than the maximum permissible level for drinking purpose while 'As' concentration exceeded the value by 16 mg/L. These figures show a close correlation between heavy metal concentrations in leachate and ground water. Therefore high 'As' and 'Se' concentrations in ground water may be an obvious sign for the contamination of the surrounding ground water with heavy metals present in leachate.

The ambient water quality standards enacted by Central Environmental Authority (CEA) were obtained from Priyanka *et al*. (2007) to correlate the specific beneficial uses of surface water with the existing parameter concentrations. Figure 3 shows the variation of DO, pH, salinity, turbidity and conductivity along the portion of Gin river that is adjacent to the dumpsite. In terms of DO concentration, water from this portion of river cannot be used for drinking even with simple treatment. pH at any point of this portion complied with the standards for any application. Turbidity at any point of this portion did not satisfy the standards for this water to be used for drinking following simple treatment. Turbidity in the far downstream which is close to the dumpsite was very high. High level of turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity level is extremely unsuitable for drinking. Water is not suitable for irrigation and agriculture according to the conductivity values at all the points.

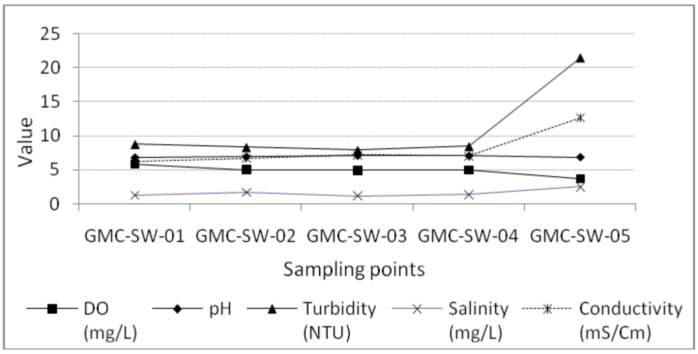

Figure 3: Variation of DO, pH, turbidity, salinity and conductivity along Gin river

Figure 4 shows the variation of both COD and BOD_5 concentration of several points along the portion of Gin river which is adjacent to the dumpsite. The highest COD concentration was at the sampling point near the leachate outfall. The COD values at the points downstream to the leachate outfall were higher in COD than those points upstream. Both COD and BOD_5 concentrations at any point cannot be used for the following applications: drinking water with simple treatment; bathing; fish and aquatic life; drinking water after conventional treatment, irrigation and agriculture and none of other uses. In terms of COD and BOD_5 concentrations, water in this portion did not satisfy the minimum quality for any application. The consequence of high BOD is low levels of dissolved oxygen in affected waterways resulting in aquatic organisms becoming stressed and in extreme cases, suffocating and dying (Surface water sampling methods and analysis, 2009). Henry et. al. (1996) stipulated that metabolic activity by bacteria requiring oxygen may reduce the normal DO content in a stream or lake to less than 1 mg/L below which most fish cannot survive.

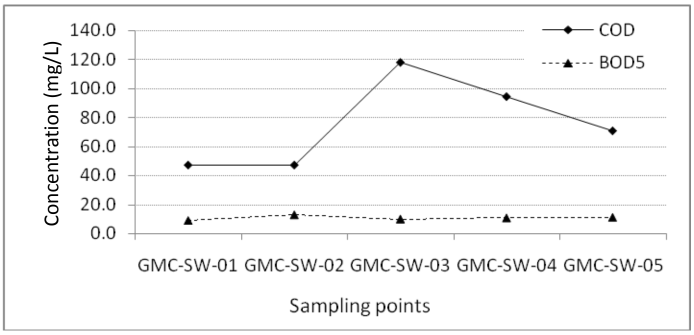

Figure 4: Variation of BOD_5 and COD concentration along Gin river

Figure 5 shows the variation of concentrations of nitrogenous compounds such as total-N, NH_4^+-N and NO_3^{2-} -N. Both NH_4^+-N and NO_3^{2-} -N concentrations complied with the standards for all the applications listed in the 1st paragraph of this section. The values of total phosphorus and orthophosphate concentrations were negligible. The amount necessary to trigger algal blooms are not well established, but concentration as low as 0.01 mg/L for phosphorus and 0.1 mg/L for nitrogen may be sufficient for euthrophication when other elements are in excess (Henry et. al., 1996). Therefore it cannot be exactly said that there will be no nutrient enrichment condition that may lead to euthrophication. Total-N concentration at the leachate out fall was the lowest value. Thus it can be said that dumpsite may not contribute significantly to the nitrogenous compounds concentration in Gin river.

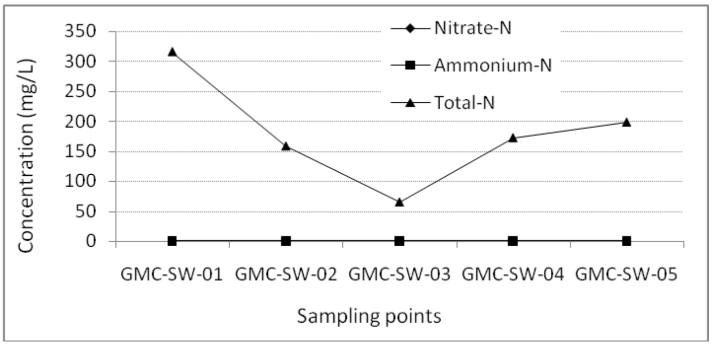

Figure 5: Variation of concentrations of nitrogenous compounds along Gin river

Figure 6 shows the Cl^- and SO_4^{2-} concentrations along Gin river. In terms of SO_4^{2-} concentration, water at any point of this portion of river is suitable for any applications listed in the 1st paragraph of this section. However Cl^- concentration did not meet standards for any application.

Total boron (B), aluminium (Al), nickel (Ni), copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb) concentrations of both leachate and groundwater did not exceed the effluent discharge standards and maximum permissible levels for drinking water, respectively. However 'Cr', 'Fe', 'As' and 'Se' concentrations in leachate exceeded the effluent discharge standards and caused those concentrations in groundwater to have increased as described in a previous paragraph.

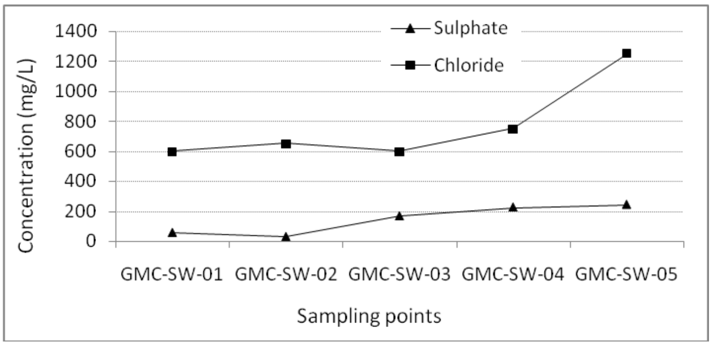

Figure 6: Variation of sulphate and chloride concentrations along Gin river

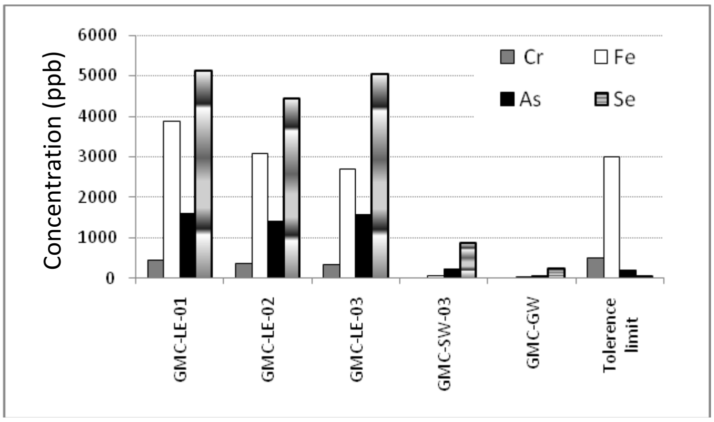

Figure 7: Heavy metals concentration

Figure 7 shows the variation of concentrations of these heavy metals with the respective discharge tolerance limits. 'As', 'Cr' and 'Se' have been identified as priority pollutants (Metcalf and Eddy, 2003). In accordance with Metcalf and Eddy (2003), 'As' is a carcinogen and mutagen which may cause fatigue and loss of energy at long term exposure; 'Cr' is carcinogenic and corrosive on tissue which may cause skin sensitization and kidney damage at long-term exposure; 'Se' may cause red staining of fingers, teeth and hair, general weakness, depression, irritation of nose and mouth at long-term exposure. In terms of 'Cr' concentration, water at any point from the portion of Gin river adjacent to the dumpsite is not suitable for fish and aquatic life. 'Se' concentration at any point of this portion did not satisfy the standard for any application. Low concentrations of heavy metals are toxic to living organisms including humans and to the microbial population utilized in wastewater treatment processes (Henry et.

al., 1996). Therefore it should be cautious with heavy metal concentration of this leachate when designing biochemical treatment facilities as it may inhibit microbial population.

4. Conclusions

The study revealed that the leachate of the GMC dumpsite is highly polluted with organic contaminants, nitrogenous compounds and priority pollutants such as ‘As’, ‘Cr’ and ‘Se’. ‘Fe’ concentration was also not within the tolerance limits. As a result the portion of Gin river adjacent to the dumpsite has got its organic matter concentration and concentrations of few heavy metals exceeding the ambient water quality standards. The correlation between ‘As’ and ‘Se’ concentrations of groundwater and leachate indicates that the groundwater surrounding and underneath the dumpsite have got contaminated by these contaminants. The organic matter content in groundwater also did not satisfy drinking water standards. Hence it can be concluded that the water quality of this portion of Gin river is lower than the demanded quality of water for many applications and groundwater surrounding the dumpsite is not suitable for drinking. The leachate should be given proper treatment before discharging into Gin river. The principal contaminants of concern should be biodegradable organic matter, toxic organic matter, nitrogenous compounds and heavy metals such as ‘Se’, ‘As’, ‘Cr’ and ‘Fe’in treating leachate. If leachate is treated with biochemical means acclimated microorganisms may be required because the ratio BOD_5/COD was about 0.04.

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