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Heavy Metal Pollution of Soil around Solid Waste Dumping Sites and Its Impact on adjacent Community: the case of Shashemane Open Landfill, Ethiopia

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Abstract
The study was aimed at determining the status of heavy metal pollution of soil around open landfill of Shashemane city and its potential impact on environment and local community. Accordingly, forty (among which four were control samples) soil samples and one leachate sample were collect following two meter circular diameter. The collected soil sample were allowed to dry under normal temperature within soil sample preparation room of Wondo Genet College of Forestry and Natural resources. The analysis for heavy metal was conducted at Hawassa University chemistry laboratory using Atomic Absorption Spectrometer. The result indicated that the concentration of manganese (Mn), cadmium (Cd), cobalt (CO), chromium (Cr), nickel (Ni) and lead (Pb) were 0.88, 0.08, 0.06, 0.29, 0.08, and 0.08 respectively within study area. This level of concentration were varying across soil sampling depth, among sampling point. It were also varying between control, leachate and soil samples. Based on their contamination factors, the heavy metals were order as Cd > Cr > CO > Pb > Mn > Ni. Accordingly, the area was highly strongly polluted by cadmium and chromium while less uncontaminated by nickel. The result of modified degree of contamination and degree of contamination also show that the area considerably polluted and deteriorated in terms of its quality. Hence, this open landfill should be closed from other use in future and immediate remedial action have to be undertaken in order to minimize future pollution problems.
Keywords: Heavy metal, Solid waste, dumping site, soil pollution, adjacent community

1.Introduction

1.1. Background and justification

Soil is a precious natural resource upon which economic activity like agriculture and existence of life depend. The properties and quality of soil can be adversely affected by the over-concentration of waste released from agriculture, industry, municipality and individual household (Soffianian et al., 2014). These waste deteriorate the quality of soil and influencing sustainable development.

Today at global scale the magnitude of soil deterioration were significantly increased due to rapid rate of industrialization, population increment and urbanization which contributed for changes in the composition and quantity of waste generated. According to UNIDO (2011), the increment of waste load were leading to environmental pollution and degradation in many cities of the developing world. It was estimated that in 2006 the total amount of municipal solid waste (MSW) generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003 (Global Waste Management Market Report, 2007). The UNEP (2009) further estimated that between 2007 and 2011, global generation of municipal waste raised by 37.3%, equivalent to roughly 8% increase per year. In urban centers throughout African regions, less than half of the solid waste produced was collected, and 95 percent of that amount indiscriminately thrown away at various dumping sites on the periphery of urban centers (Mohammed 2003). In similar fashion, the amount of solid waste generated and disposed to uncontrolled landfill site was increasing in Ethiopia. The report of Addis Ababa Sanitation beautification and park development (2003) indicated that the daily waste generation in Addis Ababa is 5.4 kg/capita/day and its density is 300kg/m^3. The current daily overall waste production of the city is 2,297 m3 or 765 tones of which about 35% is simply dumped on open sites, drainage channels, rivers and valleys as well as on the streets, while the other 65% is dumped in the open site Reppi/koshe. The was no appropriate solid waste management systems employed in most developing countries. Even the existing system was challenged by lack of appropriate management plan, institutional framework and financial resources (Antipolis, 2000 ; Obeng et al ,2008). Beyond these, rapid rate of urbanization and increment of population number that flow to urban area were the major bottleneck for undertaking appropriate waste management system. This poor waste management and open disposal put several challenges to the well-being of the city residents, particularly those living adjacent

the disposal sites due to the potential of the waste to pollute water, foods sources, land, air and vegetables (Njoroge, 2007 ; Hunachew and Sandip, 2011).
As a result of poor solid waste management, most African countries including Ethiopia, were becoming a dumping ground for electronic and other hazardous wastes containing lead, cadmium, mercury, cobalt, arsenic etc. Furthermore, small and large scale industries located in urban areas often dispose of their wastes along with municipal solid wastes. These heavy metals pose great effects on health of human being, living organisms and natural environmental (Amadi et al., 2010; Zurbrugg, 2003) when their concentrations are above the normal threshold. For instance, if compost prepared from municipals solid waste is used as manure, some of the heavy metals are being subjected to bioaccumulation and may cause risk to human health by passing through food chain. Exposure of heavy metals may cause blood and bone disorders, kidney damage and decreased mental capacity and neurological damage (NIEHS, 2002). The study of Arneth et al. (1989) and Aurangabadkar et al.(2001) also confirmed that landfill leachate from unlined landfills pose an important hazard for the environment and ground water and soil quality. Furthermore, Geenhuizen and Van Nijkamp, (1995) pinpoint that poor environmental quality of cities can deprive citizens of a good quality of life as it affects their health and consequently, adversely affect productivity and economic development.
The study areas also has such open solid waste dumping/landfill site for municipal and other types of wastes which poses both environmental and health problem for communities living around dumping site and beyond. The overall aims of this study is to determine heavy metal pollution of soil around solid waste dumping sites and its impact on adjacent community so as to help decision maker and city planner to propos proper waste disposal area.

2. Material and Methods

2.1. Description of Study Area

Shashemane is one of the rift valley city located in Oromia administrative regional states at 254 km to the south of Addis Ababa, the capital of Ethiopia. Geographically, the city is located between 7°12' latitudes north and 38°36' longitudes east. Its altitude ranges from 1672 to 2722 meter above sea level. Mount Abaro is the highest point in the area. It receives an annual rainfall of 700 – 950mm and has an annual temperature range of 12 – 17 °C (SWARDO, 2006). Major crops grown around Shashemane area are cereals such as teff, barley, wheat, maize, sorghum and root crops like potato and sweet potato and vegetables such as cabbage, spinach and onion as cash crops. Annual crops are predominant and rain-fed agriculture is mainly practiced. The total human population of this area is 100,454 of whom 50,654 were men and 49,800 were women (CSA, 2007).

2.2. Data Collection

2.2.1. Soil Sampling and Preparation

Soil sampling was conducted using circular plot method. The distance between two consecutive circle two meter diameter whereas between consecutive sampling point is about three meter (fig.1). A total of 40 soil samples and 1 leachate sample was collected from the study area at depths of 0 to 15; 15 to 30; 30 to 45; and 45 to 60 cm using a depth calibrated soil auger. Each sample was immediately placed in plastic bag and tightly sealed to avoid contamination form environment. After collection , the soil samples were taken to Wondo Genet College of Forestry and Natural Resources for preparation and then to Hawassa University Chemistry laboratory for pH, cation Exchange capacity and heavy metal analysis. Control soil samples were also collected from uncontaminated/pollution free area so as to use for comparison of pollution level.
The collected soil were placed on clean plastic sheet, oven dried for three hours and then sieved through a 0.2 mm mesh size to remove stones, plant roots in order to have uniform soil particle size. Following a method developed by Berghof Microwave Digestion Application (2011), a soil sample of 500 mg were transferred to digestion vessels with 7.5 ml of HCl and 2.5 ml of concentrated HNO_3(3:1 HCl : HNO_3). The vessels were carefully shacked and placed in a fume hood for about 20 min for pre-digestion and to avoid foaming before they were placed on the turntable of the microwave system. Then the pre-digested samples in the digestion vessels were closed and heated on microwave oven following the optimized procedure shown in Table 1. The total concentrations of CO, Pb, Ni, Mn, Cr and Cd in filtrates were then determined using a Flame Atomic Absorption Spectrometer (model 210 VGP,USA) using air acetylene flame.
Table 2: Optimized temperature, time and power program of the microwave oven for soil samples

Steps	Temperature (⁰C)	Time (min.)	Power (W)
1	160	15	70
2	205	15	90
3	50	10	0

Data related to the effect of open landfill on the local community were collected randomly from a total of 60 household using focus group discussion, interview and questionnaire.

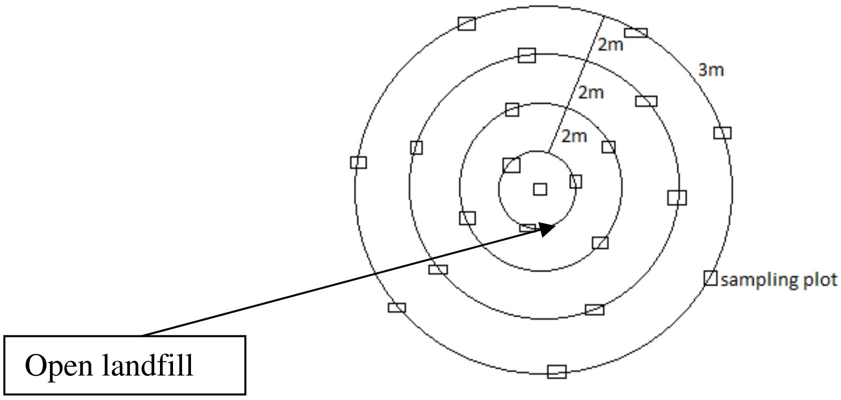

Figure 1: Layout of the soil sampling plots

2.3. Data analysis

2.3.1. Heavy metal analysis

After collection of all necessary data, analysis of pH, cation exchange capacity and conductivity were conducted using standard data analysis techniques. For instance, pH of the soil samples will be estimated by dipping the pH electrode meter in the saturation paste. In the same suspension, conductivity was measured using conductivity meter (Orion, EA940 USA). In order to determine contamination level of heavy metals in soil around landfill, pollution calculation methods such as Contamination factor and degree of contamination developed by Hakanson (1980); modified degree of contamination (Abrahim (2008) and pollution load index (Thomlinson et al. 1980) and Geoaccumulation index (Muller, 1969) were used as indicated in 1 - 5 equations below.

$$C^i_f = \frac{C^i_o}{C^i_n} \quad \text{.. Equation 1}$$

Where, C^i_f is the contamination factor for the element I; C^i_o is the mean content of metal from at least five sampling sites and C^i_n is the concentration of the individual metal in control.

The sum of individual contamination factor of the pollutant will give degree of contamination (Hakanson, 1980). Hence, degree of contamination (Cd) is computed by the following equation:

$$c_d = \sum_{i=1}^{n} Cif \quad \text{.. equation2}$$

The degree of contamination is aimed at providing a measure of the degree of overall contamination in surface layers in particular sampling site. Abrahim (2008) presented a modified and generalized form of the Hakanson (1980) equation for the calculation of the overall degree of contamination at a given sampling or coring site and this was used in this study.

$$_mC_d = \frac{\sum_{i=1}^{n} Cif}{n} \quad \text{.. equation3}$$

where, $_mC_d$ is modified degree of contamination, n is the number of analyzed element and C^i_f is the contamination factor

$$I_{geo} = \log 2 \frac{Cn}{1.5Bn} \quad \text{.. equation 4}$$

Where I_{geo} is geoaccumulation index of the metal; Cn is the measured concentration of the element in the sample and Bn is the geochemical background value. The constant 1.5 allows us to analyze natural fluctuations in the content of the given substance in the environment as well as very small anthropogenic influences.

The pollution load index which was proposed by Tomlinson et al. (1980) was also calculated for comparison of pollution level between sites and propose necessary action that should be taken. It was obtained as a concentration factor of each heavy metal with respect to the background value in the soil.

$$PLI = n\sqrt{Cf1 * Cf2 * \ldots\ldots * cfn} \quad \text{.......................................equation 5}$$

After collection of all the necessary data, further data analysis techniques such as ANOVA and Correlation matrix were conducted using statistical package for social science (Spss) of version 20.0.

The overall data including the socio-economic data were analyzed using statistical package for social science (SPSS version 20.0) and Microsoft excel.

3. Result and Discussion

3.1. Chemical Concentration and Pollution Status

The sample wise mean concentration of heavy metals was given table 2 below. The mean pH values of the study area were 5.96 $\pm$ 0. 31 which is lower than the finding of similar study at Addis Ababa city Solid waste dump site (8.17 $\pm$ 0.95) by Hunachew and Sandip (2011). This value implies that the soil were acidic which might be as a result of chemical absorption in the soil.

The mean concentrations of heavy metals were varying per sample of sampling location as indicated in Table 2. The concentration of manganese (Mn), cadmium (Cd), cobalt (CO), chromium (Cr), nickel (Ni) and lead (Pb) were 0.88, 0.08, 0.06, 0.29, 0.08, and 0.08 respectively. The concentration of manganese is relatively higher followed by cadmium, nickel and lead which had equal concentration (0.08) values. Chromium showed least concentration value compared to the other heavy metals under investigation. The concentration of the metals also varies within soil sampling depth as in Figure 2. The possible reason for the variation might be mobilization of heavy metals as result of rainfall occurring during soil sampling. This was also in line with the study of Yahaya (2009) which confirmed that the concentration of heavy metal in soil is higher in dry season than in rainy season because of more heavy metal loss due to run-off and infiltration in rainy season.

Table 3: Mean Concentration of Heavy metals per sample within study area

s. location	pH	Cond.(ms/cm)	exchangeable bases Cmol(+)/kg soil			heavy metals in mg.kg $^{-1}$					
			K	Ca	Mg	Mn	Cd	Co	Cr	Ni	pb
S1	6.68	0.81	0.39	0.43	0.16	0.31	0.02	0.02	0.10	0.06	0.04
S2	5.82	1.73	0.68	1.31	0.59	0.54	0.06	0.07	0.31	0.07	0.14
S3	6.15	1.83	0.67	0.79	0.61	1.14	0.08	0.06	0.32	0.08	0.10
S4	5.83	1.68	0.76	0.97	0.60	0.90	0.06	0.06	0.36	0.08	0.07
S5	5.86	1.59	0.85	1.60	0.46	1.13	0.19	0.06	0.33	0.08	0.10
S6	5.72	1.75	1.14	1.54	0.60	1.09	0.07	0.06	0.27	0.08	0.06
S7	5.96	1.65	0.68	1.33	0.47	0.89	0.06	0.06	0.30	0.09	0.10
S8	5.65	1.57	0.66	0.86	0.37	0.95	0.08	0.07	0.32	0.08	0.07
S9	6.01	1.83	0.62	1.03	0.52	0.96	0.07	0.07	0.33	0.08	0.07
Mean + SD	5.96 $\pm$ 0.31	1.60 $\pm$ 0.31	0.72 $\pm$ 0.20	1.10 $\pm$ 0.38	0.49 + 0.15	0.88 $\pm$ 0.28	0.08 $\pm$ 0.04	0.06 $\pm$ 0.01	0.29 $\pm$ 0.07	0.08 $\pm$ 0.01	0.08 $\pm$ 0.03
Range	5.65 - 6.68	0.81 - 1.83	0.39 - 1.14	0.43 - 1.60	0.16 - 0.61	0.31 - 1.14	0.02 - 0.19	0.02 - 0.07	0.10 - 0.36	0.06 - 0.09	0.04 - 0.14
Control	6.76	0.53	0.36	0.40	0.11	0.57	0.02	0.02	0.08	0.06	0.04
leachate	6.24	1.26	0.72	0.82	0.54	0.24	0.57	0.05	0.29	0.08	0.08

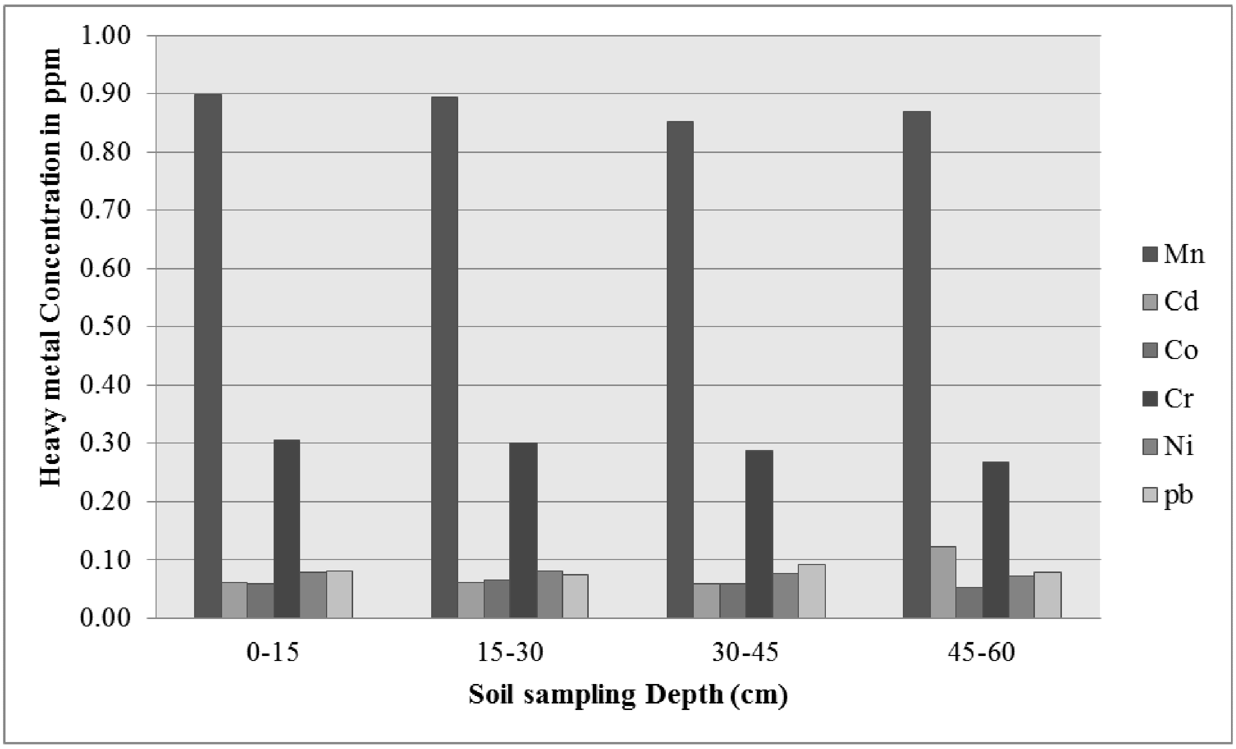

Figure 2: The variation of heavy metal concentration across soil sampling depth

There is also variation of mean concentration of heavy metals between soil samples, leachate collected from landfill and control as indicated in table 2. For instance, the mean concentration of heavy was relatively higher compared to mean concentration in control soil sample. The mean concentrations of all parameters were greater in the case of leachate samples. This might be as a result of leaching of heavy metals with run-off in the area. The concentration of manganese ranges from 0.31 - 1.14 mg.kg^{-1} with a mean concentration of 0.88 $\pm$ 0.28 mg.kg^{-1} (Table 2). The values of manganese in this study are higher than the concentration of control sample from uncontaminated area. The result of sample wise geoaccumulation index (table 3) also showed that except sampling point one and two, the remaining sampling areas were polluted by manganese and the contamination level ranges from uncontaminated to moderate contamination. Sampling point five is strongly polluted by cadmium and moderately contaminated by chromium while it is uncontaminated by nickel. Based on the result of sample wise geoaccumulation index, as indicated in table 3, the study area is completely free from nickel contamination. The overall geoaccumulation index (table 4) of heavy metal under investigation also show the study area is uncontaminated by nickel.

Table 4: Sample wise geoaccumulation index of heavy metals within study area

S. location	Mn	Cd	Co	Cr	Ni	pb
S1	-1.48	-0.37	-0.44	-0.22	-0.55	-0.67
S2	-0.65	0.91	1.04	1.36	-0.36	1.24
S3	0.41	1.29	0.76	1.41	-0.20	0.72
S4	0.08	0.91	0.93	1.58	-0.06	0.17
S5	0.39	2.60	0.90	1.45	-0.15	0.75
S6	0.35	1.18	0.92	1.16	-0.07	0.14
S7	0.06	1.07	0.81	1.31	-0.05	0.75
S8	0.15	1.37	1.08	1.43	-0.19	0.18
S9	0.16	1.14	1.01	1.45	-0.14	0.33

Based on Hankson (1980) and Abrahim et al (2008) description (table 5 and 6), the result from degree of contamination and modified degree of contamination indicated that the study area is moderately contaminated by heavy metal under investigation. The value of pollution load index also show that the soil quality of study area was deteriorated. According to Begum et al., (2009) heavy metal contamination in soil would have great impact on human life and environment through food chain. Hence, the study area requires concern for its rehabilitation and maintenance of its normal function.

Table 5: Overall contamination factor, degree of contamination, modified degree of contamination, pollution load index and geoaccumulation index of heavy metals.

Parameters	Mean con.	Control	Cf	Cd	mCd	PLI	$G_{eo}I$
Mn	0.88	0.57	1.5	15.5	2.58	1.17	-0.06
Cd	0.08	0.02	4.0				1.12
CO	0.06	0.02	3.0				0.78
Cr	0.29	0.08	3.6				1.12
Ni	0.08	0.06	1.3				-0.20
Pb	0.08	0.04	2.0				0.40

Table 6: Contamination factors and degree of contamination categories with their terminologies for description

S.N	Cf classes	CF and Cd terminologies	Cd classes
1	Cf < 1	Low Cf indicating low contamination/low Cd	Cd < 8
2	1 ≤ Cf < 3	Moderate Cf /moderate Cd	8 ≤ Cd < 16
3	3 ≤ Cf < 6	Considerable Cf/Cd	16 ≤ Cd < 32
4	Cf ≥ 6	Very high Cf/Cd	Cd ≥ 32

source: Hankson, 1980

Table 7: Modified Degree of Contamination classification and their description

S.N	${}_{m}C_{d}$ classes	Description
1	${}_{m}C_{d} < 1.5$	Nil to very low degree of contamination
2	$1.5 \leq {}_{m}C_{d} < 2$	Low degree of contamination
3	$2 \leq {}_{m}C_{d} < 4$	Moderate degree of contamination
4	$4 \leq {}_{m}C_{d} < 8$	High degree of contamination
5	$8 \leq {}_{m}C_{d} < 16$	Very high degree of contamination
6	$16 \leq {}_{m}C_{d} < 32$	Extremely high degree of contamination
7	${}_{m}C_{d} \geq 32$	Ultra high degree of contamination

source: Abrahim et al., 2008

3.2. Impact of Open dumping site on Local Community

3.2.1. Socio-economic Characteristics

Among the total percentage of household interviewed, about 69.9% were male while 31.1% were female. Regarding the marital status, about 82% of the respondent were married followed by 14% single as indicated in figure 4 below. Based on the result socio-economic data analysis, about 84.4% of the respondent in the study area were illiterate and their mainly livelihood strategy was agriculture.

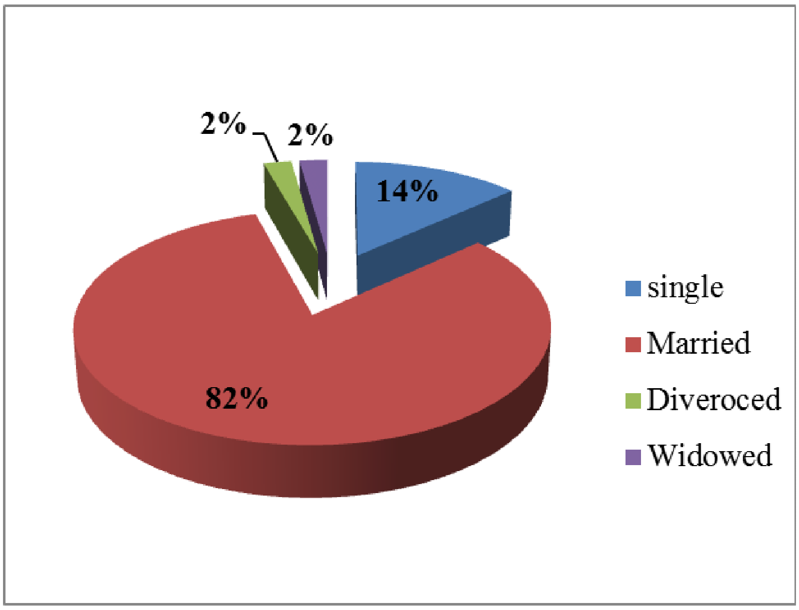

Figure 3: The marital status of respondent within study area

About 80.0 percent of the respondent interviewed were living in less than 500 meter radius from the open landfill area. However, the remaining 11.1 % and 8.9% were living at 500 meter and greater than 500 meter distance from solid waste dumping site (table 7). The implies that most the respondent were living in minimum distance that residential area should away from the dumping site of solid waste.

Table 8: The distance household living from open landfill within study area

	Frequency	Percent(%)	Valid Percent(%)	Cumulative Percent
<500 meter	36	80.0	80.0	80.0
=500 meter	5	11.1	11.1	91.1
> 500 meter	4	8.9	8.9	100.0
Total	45	100.0	100.0	

3.2.2. Human Impact of Open landfill

The impact of this open local landfill on the local community were investigated within this study. About 91% of respondent within study area explained that they were facing horrible impact and unpleasant smell which leading to different respiratory health problems like asthma, frequent coughing, stomachache, headache. Accordingly, the major and frequent occurring health problems identified during the study was bronchitie infection (24.4%) followed by the combination of all diseases (common could, eye diseases, diarrhea, asthma, bronchitie infection and skin irritation) which account about 17.8%; common could (15.6%), skin irritation (13.3%) and asthma (11.1%) (Figure 5). Diarrhea and eye diseases were also another health problem that account about 8.9% within study area. This was in line with the study of Abul (2010) which states that diarrhea, asthma, branchiate infection and skin irritation as common disease that frequently occurring around solid waste dumping site. The report of UNEPA (2006) also showed that the bad odor released from dumpsite have serious effects to the people settled around or next to dumpsites.

The result from data analysis and focus group discussion reveal that, the children are more prone to these disease since they were playing with the solid waste they collect from the open dumpsite and the problem became more prevalent during rainy season following by mid-day, dry season and morning. It was also more significant while hauling the waste by truck, spreading and leveling by bulldozer and compacting. In addition to seasonal variability, most of the children more prone to these health problems since they directly in contact with waste in open landfill while collecting different types of recyclable materials for selling and playing.

The focus group discussion held with health worker and extension servant were also clearly confirmed that the disease identified by local peoples around dumpsite were correct and communities mainly children were frequently looking for medication and other health services.

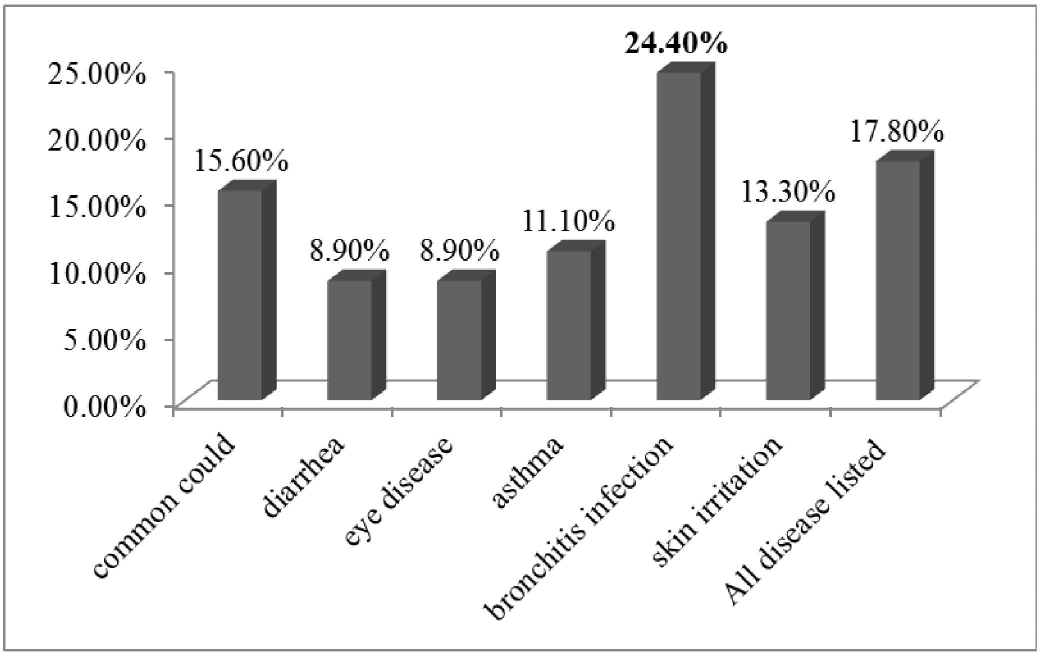

Figure 4: Major types of problems encountered by communities within study area.

Furthermore, there were other problems that the local community faced due to this open waste dumping site. Accordingly majority of respondent identified emission of bad smell (51.11%) followed by scavengers attack (17.78%), children entrance in waste dumping area (11.1%), rat infestation (8.9%), flies dominance (6.7%) and cattle entrance in open landfill area as major other problems they encountered in addition to its health problem (Figure 6).This was in line with the UNEPA (2006) report states that waste dumping sites attract flies, rats and other creatures that spread diseases to the communities around dumpsites. According to Wrensh (1990), solid waste dumping sites emit obnoxious odors and smoke that cause illness to people living in, around and closer to them. Furthermore, it is a source of airborne chemical contamination via off site migration of gases and the particles and chemicals adhering to dust, especially during the period of active operation of the site.

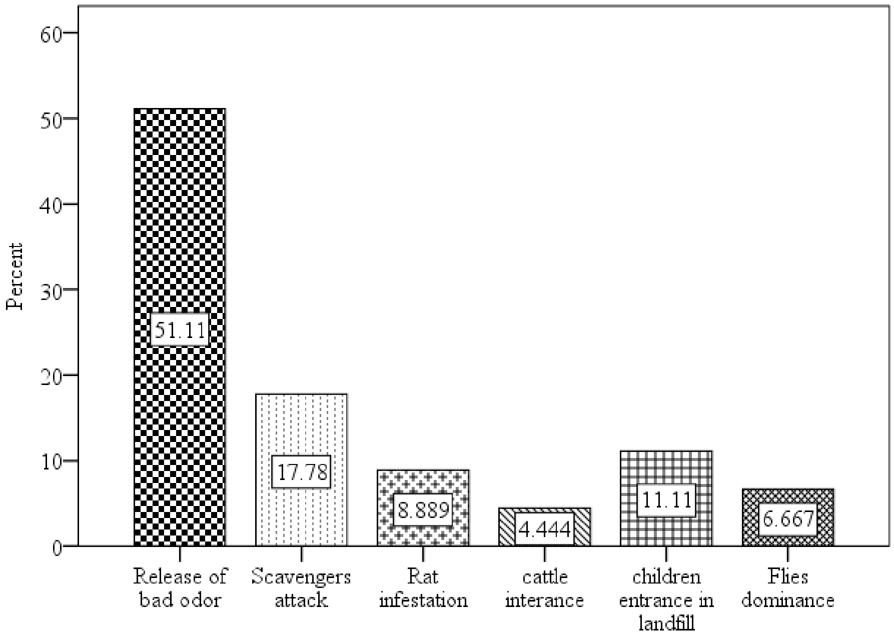

Figure 5: Major other problems encountered by respondents around local landfill.

Personally, the researchers observed the following technical and social problems: the landfill is open which allow cattle and other living thing to inter; the natural landfill were already full, the area is unprotected from children entrance, it lack odor and vector control techniques, the water pipe pass nearby the open landfill. There no waste segregation activity and recycling activities practiced by municipality and other concerned body. Even the biomedical wastes were disposed with together with other waste types to landfill which is illegal and un recommended due to their toxicity effect.

Though the communities were facing great problems from waste dumping site, unfair compensation aimed to be given to them, they were forced to live around this noxious area. The Shashemane city administrations was aimed to provide land in city for building but most of the respondent were farmer and doesn't have alternative source of income other than their agriculture and loss of their property (cattle, sheep, farm land, etc) by thief when they leave the area makes them to live around solid waste dumping site. The result of socio-economic data showed that about 48.9% of the respondent were not satisfactory with alternative measures (compensation) given by concerned while 42.2% of them were in fear of losing their property by thief and wild animals when they leave the area.

4. Conclusion and Recommendation

The result of study showed that, the soil resource in the study area were polluted by heavy metals under investigation. The main pollutant was cadmium followed by chromium, cobalt, lead, manganese and nickel based on their order of the contamination. This show that the area was deteriorated by its quality and service. This is the result of inappropriate solid waste (open landfill) disposal system and absence of pollution control method practiced by municipality. Hence, the authors recommend that, the area (open landfill) should be closed and treated to minimize the impact of these toxic heavy metals by application of different remedial action like phytoremediation and bioremediation so as reduce the rate of contamination and future cumulative pollution problems. Appropriate landfill area and modern sanitary landfill should also be selected and developed in order to replace this open landfill.

5. References

Abrahim GMS, Parker RJ (2008) Assessment of Heavy Metal Enrichment factors and the degree of Contamination in Marine Sediments from Tamaki Estuary, Auckland, New Zealand. Environ. Monit. Asess.136: 227 – 238.

Abul S (2010). Environmetnal and Health impact of Solid Waste Disposal at Mangwaneni Dumpsite in Manzini, Swaziland. Journal of Sustanable Development in Africa,12(7) ISSN: 1520 - 5509

Amadi AN, Ameh MI, and Jisa J (2010). The Impact of Dumpsites on Groundwater Quality in Markurdi Metropolis, Benue State. Natur. APPl. J., 11(1):90-102

Arneth, J.D., Midle, G., Kerndoff, H. and Schleger, R., (1989). "Waste in deposits influence on ground water quality as a tool for waste type and site selection for final storage quality". Landfill reactions and final Storage quality. Baccini, P.(ed) Springer Verlag Berlin pp.339.

Aurangabadkar, K., Swaminathan,S., Sandya, S. and Uma, T.S., (2001). "Impact of Municipal Solid waste dumpsite on ground water quality at Chennai", Environ. Pollu. Control, 5, pp. 41-44.

CSA (2007) Population and Housing Census of Ethiopia: Results for Oromia Region, Vol. 1, Tables 2.1, 2.5, 3.4 (accessed 26 June, 2013)

Hakanson L (1980) An Ecological Risk Index for Aquatic Pollution Control, a Sedimentological approach. Water Res. 14:975-1001.

Hunachew Beyene and Sandip Banerjee (2011). Assessment of the Pollution Status of the Solid Waste Disposal Site of Addis Ababa City with Some Selected Trace Elements, Ethiopia. World Applied Sciences Journal 14(7):1048-1057.

Mohamed N, Elsa Z 2003. Waste Management Programme. UNIDO View Document, No. 3765. Tokyo, Japan.

Muller G (1969) Index of Geoaccumulation is Sediments of the Rhine River. Geo.J. 2:108 – 118

Obeng Peter, Donkor Emmanuel and Mensah Anthony, (2008). Assessment of Institutional Structures for Solid Waste Management in Kumasi, Ghana.

Soffianian A, Madani ES and Arabi M (2014). Risk Assessment of Heavy Metal Soil Pollution through Principal Components Analysis and false Color Composition in Hamadan Province, Iran. Environmental System Research 3:3. Available at http://www.enviornmetnalsystemresearch.com/content/3/1/3.

Tomlinson DL, Wilson JG, Harris CR, Jeffrey Dw (1980) Problems in the assessment of heavy metal level in eastuaries and the formation of a pollution index. Helolaender Meesesunter. 33:566 - 575

UNEP, (2009). Waste characterization and quantification with projections for future. In: UNEP (ed). Developing integrated solid waste management plan training manual, vol.1 International Environmental Technology CenterOsaka/ Shiga, Japan.

United Nations Environmental Program Agency (2006). Informal Solid Waste Management. http://www.unep.org?PDF/Kenyawastemngntsector/sector/chapter1.pdf.

United Nations Industrial Development Organization,(UNIDO), (2001). Industrial Environmental Policy and Strategy for Ethiopia, Volume 2(draft), EPA/UNIDO, Addis Ababa.

Wrensh M. (1990). Hydrogeologic Assessment of Exposure to Solvent Contaminated drinking Water. New York: Archives of Environmental Health.

Yahaya M.I., Mohammad S., and Abdullahi B.K (2009). Seasonal Variation of Heavy Metal Concentration in Abattoir Dumpsite Soil in Nigeria. Journal of Applied Science and Environmental Management 13(4): 9-14.

Zurbrug C., (2003). Solid Waste Management in Developing Countries. Retrieved from http://www.eawag.ch/organisation/abteilungen/sandec/publikationens-swm/downloads swm/basicsofSWM.pdf