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RESEARCH ARTICLE

Impact of household waste and uncontrolled landfills on soil quality in the municipalities of Godomey and Abomey-Calavi in Benin

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Abstract

Disposal of solid waste is a major concern in Benin. The treatment method most used remains the traditional setting discharge. This study aims to assess the impact of uncontrolled waste on soil quality in in the districts of Godomey and Abomey-Calavi in Benin characterized by the greatest population and the highest human density. After characterization of landfills, six uncontrolled discharge sites were selected and 27 soil samples were taken. Particle size analysis of the samples was carried out according to the standards NF P 94-056. Physico-chemical analysis of soil samples was also performed. The collected data were analyzed using SAS 9.2 software. It appears from this study that there are 142 major uncontrolled landfills including 34 in Abomey-Calavi and 108 in Godomey. 46.36% of the sites were located in the lowlands of Godomey, while in Abomey-Calavi, 76.47% of the sites are on land ($p < 0.01$). The area of these sites varies between 9.8 and 2943.7m² with heights between 0.3 and 12m. Their distance from the first houses ranged from 0 to 30m. Sorting by category of waste was made according to the method recommended by MEDECOME and had revealed fourteen categories with a predominance of fine wastes, putrescible and plastics. Waste leachates flow into water bodies or seeps into the ground. They are low oxygen, rich in minerals, organic matter and metals then are polluted by oxidized organic matter (DCO), lead and copper. Landfill sites tend to influence soil quality even though they are currently only contaminated by cadmium in depth and by lead in surface. The near absence of pollution in soils is related to the recovery activity that led to the scarcity of these waste landfill sites containing these metals.

INTRODUCTION

Nowadays, the issue of waste has become increasingly complex for both the global North and those of the south. Waste production is increasing throughout the world. The main causes of this increase are population growth, the industrial revolution and the intensification of human activities accompanied by the improvement of living conditions. With this exponential growth in waste production worldwide, the management problem begins to be acute thanks to the awareness of environmental and health problems. The situation is more alarming in developing countries in this case those of sub-Saharan Africa face multiple problems and insufficient financial resources are unable to cope effectively with the issue of waste management (Gbinlo, 2010). Therefore landfilling is the most adopted means of waste treatment in most African cities. Then, uncontrolled discharges increase significantly in city neighborhoods, along the streets and on public roads. However, this method of waste poses a potential risk of environmental degradation by the emanation of foul odors, biogas production and as leachates which carry a significant pollutant load are sources of pollution for both the ground water table (Chofqi et al., 2004). Benin cities have similarities. They have experienced rapid urbanization. From the population census of 2002, Abomey-Calavi is the second most populous town of Benin (Baloubi, 2013). But this change is very remarkable in the boroughs of Godomey and Abomey-Calavi where there is a rapid growth in population. The population density of these two urban areas was about 2000 inhabitants / km^2 in 2002 (Baloubi, 2013).

This rapid growth of these two districts accompanied by changes in behavior patterns, production and consumption mode have generated increasing amounts of household waste. According to data provided by COSGAC (2007) on the districts of Godomey, Akassato and Calavi, 372 tonnes of waste is produced per day or 135780 tons per year. With this huge amount of waste generated, the method of waste management is still traditional. The pre-collection structures and households disposing of waste on unserviced plots in the holes of fortune, the shallows, the old sand pits, streams and lakes without any treatment (Yêmadjè, 2013). With the extension of the use of space and the high population density, open spaces have become scarce. Therefore people no longer find space near houses to dump their waste. The direct consequence of this is the intensification of waste disposal in the lowlands, water bodies and old quarries. The phenomenon is very pronounced in the district of Godomey. These landfill sites that have been subject to any prior impact assessment, effluent from landfills flow directly into surface water seeps into the ground and contaminate them. The soil is the intersection of several fields (biosphere, atmosphere, and hydrosphere), its contamination affects other environmental components such as fauna, groundwater and air (Piedrafita et al., 2007). Therefore, it is necessary to discuss as in the current study, the influence of uncontrolled landfills on floors in order to bring the sustainable solution to the waste management in the municipalities of Godomey and Abomey-Calavi.

MATERIAL AND METHODS

Study area

The districts of Godomey and Abomey-Calavi are located in the southern part of the Commune of Abomey-Calavi (Figure 1). They cover a total area of 359.19 km^2 of which 208.75km² occupied by the borough of Abomey-calavi (Dossou, 2005) and 150.44 by the borough of Godomey (PCUG3C, 2012) with respective densities of 294.4 and 1020 inhabitants / km ² in 2002. These two districts are the most densely populated commune with the district of Godomey in mind. This district alone accounts for more than half the population (153,447 inhabitants) of the municipality (RGPH3 2002).

Siting of waste storage and sampling

Direct observation was the method used to locate sites for waste disposal. Landfill sites were identified and located using the GPS (Global Positioning System).

The number of discharge E to take into account for the study was determined by the following formula:

$$E = N \times T$$

E: Number of discharges selected; N: Number of uncontrolled landfills identified in the two districts; T: sampling rate; T = 4%. In the current study, N=142; then, 6 discharges were taken into account. The quota sampling method was adopted. The choice of the number of discharges in each district is 50% of the total discharge retained. Therefore three (03) discharges were taken by district. The choice of three landfills in the two districts is based on the following criteria: the magnitude of the discharge (size, volume, attendance) and landfills in use.

Waste characterization

Landfills selected were segmented into 10 categories. 25Kg in each category of waste were sampled randomly. Sorting by size was performed according to the method of sorting recommended by MODECOM (ADEME, 2007) and in accordance with the standards NF XP X 30-408.

Soil sampling

Examination of the soil is made up to 100 cm feet deep. The sampling levels are 0 cm, 20 cm and 100 cm. Samples were collected from landfill sites selected after stripping waste and the site of the control area. Total of 27 samples were collected at a rate of three samples per site. These samples were collected in cubic boxes in their natural structure.

Particle size and Physico-chemical analysis

Particle size analysis was carried out on samples of soils and aggregates by the different levels of depth according to standards NF P 94-056 and NF P 933-1. Leachate and soil digests and extra fine waste collected from landfill sites selected were used for different physico-chemical analyzes (pH, Conductivity, Dissolved oxygen, Total Kjeldahl nitrogen, Chemical Oxygen Demand and Biological oxygen demand after five days). The mineral deposit was used only for the determination of metals. The protocol used for the leaching test is the standard X31-210. The mineralization was done according to the standard AFNOR 7NF X31-151.
The pH measurement was carried out by the potentiometric method using a pH-meter pH 3110 SET 3 (WTW) provided with a glass electrode.
The conductivity measurements were performed with a conductivity meter pH/EC/TDS waterproof Family according to the NF EN 27888 (January 1994).
Dissolved oxygen was determined by a standard electrochemical method (NF T 90-106) with an Oxymeter Oxi 730 WTW inolab (oxygen sensor).
The Total Kjeldahl nitrogen content was measured according to standard NF EN 25663 (January 1994). The Chemical Oxygen Demand (COD) was determined according to AFNOR standard (NFT 90-101) by a volumetric titration of potassium dichromate by Mohr's salt.
The Biological Oxygen Demand after five days (BOD5) was performed by the method gauge OXITOP WTW without dilution. The metals were determined by spectrophotometry using atomic absorption spectrophotometer Thermo Electron Corporation.

RESULTS

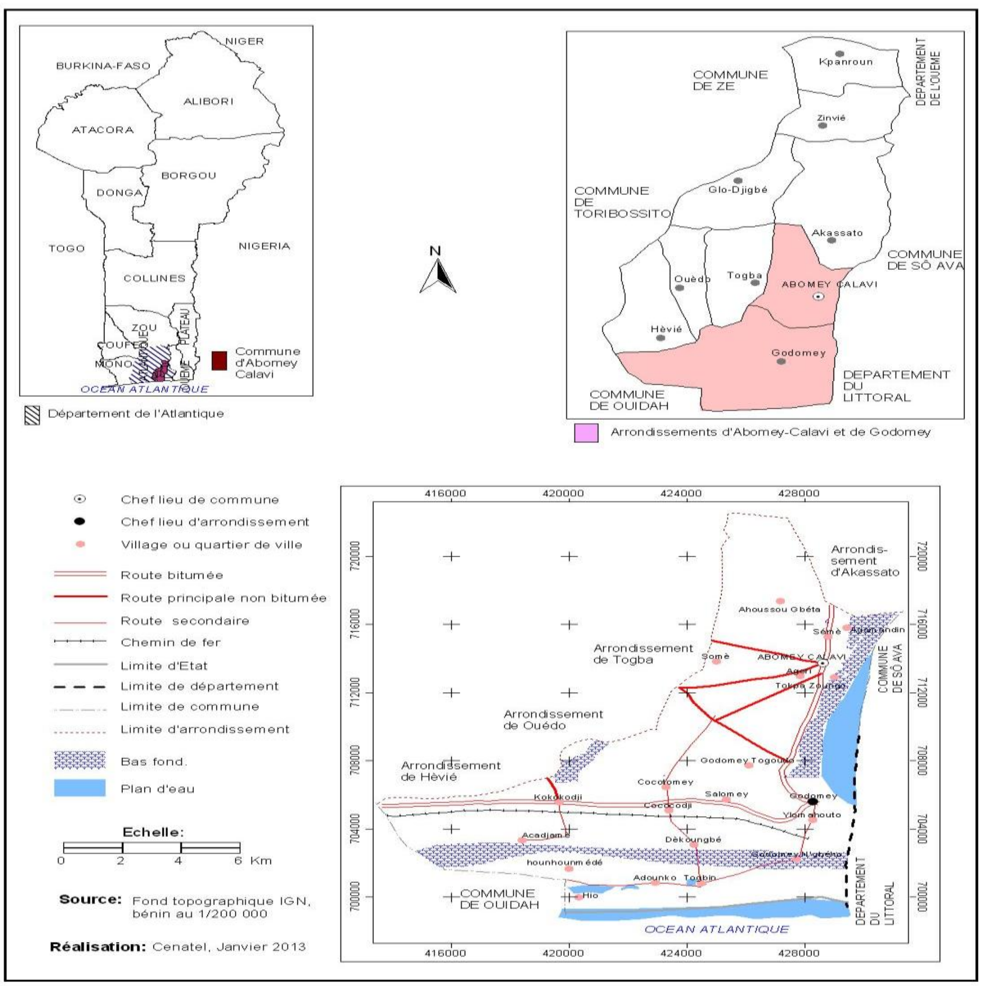

Figure 1: Study area (Abomey-Calavi and Godomey)

Characteristics of landfill sites in the districts of Abomey-Calavi and Godomey

It comes out from the current study that it exists 142 important uncontrolled landfills of which 34 in the district of Abomey-Calavi and 108 in Godomey (Figure 2). These wastes are located near homes. Their distance from the first houses varies between 0 m and 30 m. They are located on parcels that sit along Lake Nokoué, lagoon Djonou and in swamps. They are also found on lateritic and ferruginous soils in dry land and in the former sand quarries.

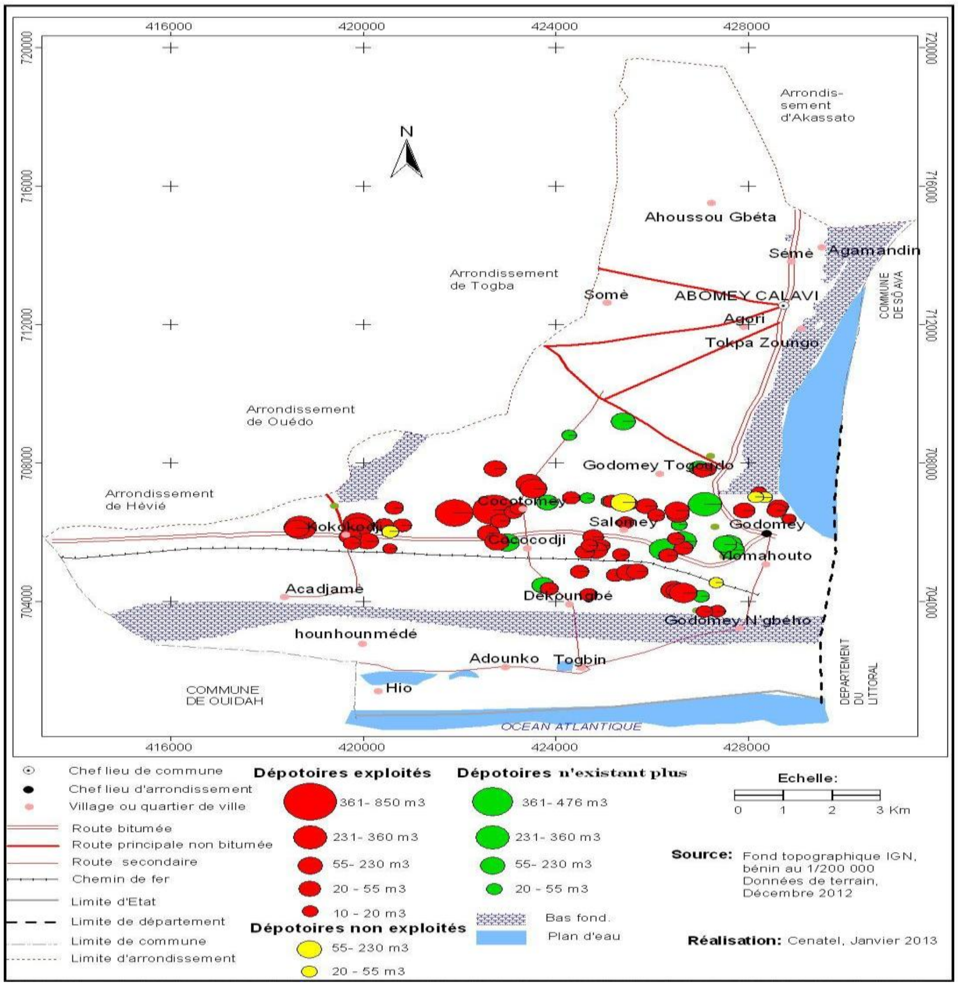

Figure 2: Distribution of landfills in the municipalities of Abomey-Calavi and Godomey

From figure 2, it appears that the uncontrolled landfills are more concentrated in the district of Godomey. In this district, 46.36% of the landfills are located in the lowlands and water bodies; while in Abomey-Calavi, 76.47% of these sites are found on dry land. Uncontrolled discharges found in the two districts are open sky. Their superficies ranging between 2943.7m² and 9.8m² and their heights between 0.3m and 12m. Their volume varied between $10m^3$ and $850m^3$. They are places of defecation and dumping of wastewater. Leachate flow into water bodies, seeps into the ground, or runs around the landfill, especially during the rainy season. As biogas, he escapes into the environment. Around these discharges two main activities are conducted: agricultural activities and recovery practiced by children, adults and also carters.

Physico-chemical parameters of waste by district and by category

The figure 3 shows the waste categories found by district and by category.

Table 1: Physico-chemical traits of leachates and digests of extra fine wastes by region

Variables		Abomey-Calavi		Godomey			ANOVA
	Parameters	**Mean**	**SE**	**Mean**	**SE**	**Norm**	
Leachates of soil	pH	6,87	0,05	7,1	0,19	**5,5-8,5**	NS
	Cond (µS/cm)	815,33	135	595	110	**2100**	NS
	OD (mg/l)	2,2	0,81	2,37	1,07	**> 5**	NS
	DCO (mg/l)	291,2	66,1	425	144	**125**	NS
	DBO5 (mg/l)	26,66	5,36	19,66	3,21	**30**	NS
	DBO/DCO	-	-	-	-	**-**	-
	DBO5/DCO	-	-	-		**-**	
	NTK (mg/l)	2,99	0,57	2,52	0,74	**30**	NS
	DBO5/NTK	-	-	-	-		-
Digests of soil	Ni (mg/l)	2,06	0,11	1, 38	441	**1**	NS
	Cd (mg/l)	nd	nd	nd	nd	**-**	-
	Cu (mg/l)	10,03	1,82	4,21	0,33	**1**	*
	Pb (mg/l)	520	516	4,42	2,29	**0,1**	NS

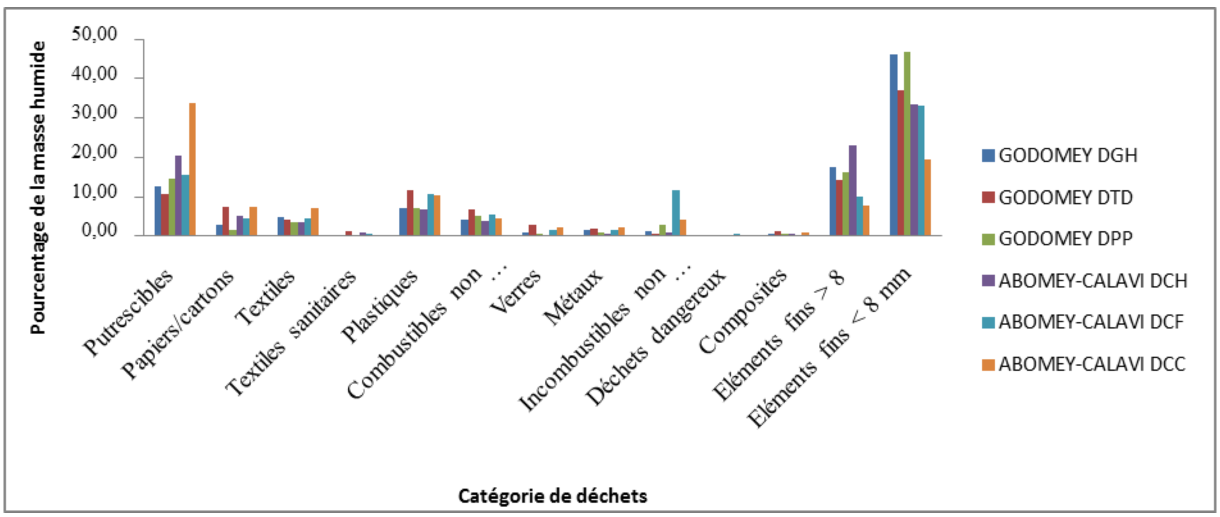

Figure 3: Composition of waste from landfills in the municipalities Godomey and Abomey

According to figure 3, there are 4 categories of waste: extra fine waste, putrescible waste, fine waste and plastic waste. The table 1 shows physico-chemical parameters of leachates and digests extra fine wastes collected from the landfill sites selected herein. It comes out from this study that apart from the content in Copper, all other physicochemical parameters measured did not change significantly (P> 0.05) according to the districts. However in these districts the average values of the measured parameters in Abomey-Calavi tend to be higher than in Godomey except average levels of conductivity and dissolved oxygen which are more important in Godomey. Copper content were significantly higher in the district of Abomey-Calavi (10.06 mg/) than Godomey (4.21 mg/l; p <0.05). The average values of certain physico-chemical parameters (pH, conductivity, BOD5 and TKN) were below or within the range of values recommended by the quality standards of waste water in the Republic of Benin. However, those of COD, lead and copper contents were beyond the limit values indicated by the standards.

SE : Standard error NS : Non significant * : p <0.05 ; DO : Disolve Oxygen ; DCO : Chemical Oxygen Demand; Cond: Conductibility; DBO5: Biological Oxygen Demand after 5 days; NTK: Nitrogen content.

The variation of physical parameters of soil leachate by region and level of sampling is given in Tables 2 and 3. Overall, the physical parameters of soil leachate were not affected by the region (p> 0.05) except conductivity and COD where a significant difference was noted according to the level of sampling (p<0.05). The highest electrical conductivity was found at 0cm depth while the lowest values were recorded at 20 and 100cm as well as in soils of the control area and landfill sites. These values reflect a strong soil mineralization at surface level than in depth. The chemical oxygen demand (COD) also decreases when sampling depth increase. These results show that organic matter is more concentrated at surface than in depth and indicate their migration to the ground. Average concentrations of these parameters seem to be lower in the control area comparatively to the landfill sites (Table II and III). Examination of the tables shows that the average values of the other parameters also appear lower in the control area than at landfill sites. These values also tend to decrease when depth increase. The average concentrations of metals (copper, cadmium, nickel and lead) recorded whatever the site of collection and sampling level are lower than the standards values indicated for normal soil physico-chemical quality with the exception of the content in lead and cadmium. By comparing the mean levels of these metals to those of the AFNOR standards, it was noticed that only the average lead content of soil digests collected in Godomey at surface was not conform or disappointed by the AFNOR standards (Table II). Confirming the lead pollution of the soil at 0cm and also indicates that the level of soil contamination at 100 cm by cadmium in Godomey is not yet critical. Also among the soils studied, only the soil of Godomey has a pollution index greater than 1 (IP> 1). Overall, the average values of the parameters studied in soils from landfill sites appears to be higher than in control areas and show that these sites have an influence on the quality of soil.

Table 2: Effect of region and sampling depth on metal contents (Cu, Pb and Ni Cd) of soil

Variables		PI		**Cu**		**Ni**		**Pb**		**Cd**	
	Depth (cm)	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	0	0,03	00	4,98	0,13	1,95	0,14	4,15	0,20	00	00
Control Zone	**20**	0,01	00	1,10	0,10	1,85	0,15	0,86	0,06	00	00
	100	0,08	00	4,46	1,24	4,43	0,11	00	00	00	00
Abomey-Calavi	**0**	0,07	0,027	9,23	1,97	3,39	0,63	3,2	0,88	0,17	0,17
	20	0,02	0,01	2,89	1,87	2,62	0,49	0,79	0,70	00	00
	100	0,06	0,035	10,45	6,84	3,32	1,58	5,78	4,03	00	00
	0	1,80	1,80	5,30	4,95	1,47	0,80	713	713	00	00
Godomey	**20**	0,02	0,015	2,24	2,24	2,30	1,54	0,87	0,40	00	00
	100	0,08	0,06	2,34	2,05	0,89	0,65	2,09	1,73	0,52	0,52
Zone Effect	**-**	-	-	**NS**		**NS**		**NS**		**NS**	
Sampling level effect	**-**	-	-	**NS**		**NS**		**NS**		**NS**	
Norm of normal soil	**-**	-	-	30		50		35		**0,35**	
Norm AFNOR	**-**	**-**	**-**	100		50		100		2	

SE : Standard error NS : Non significant * :p <0.05 ; PI= Pollution Index

Tableau 3: Effect of region and sampling depth on physico-chemical traits of soil leachates

Variables		**pH**		**Cond**		**DO**		**COD**		**DBO5**		**NTK**	
	Depth	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	0	6,13	0,18	36	1,73	6,90	0,12	37,65	0,66	2,33	2,33	3,92	0,04
Control zone	20	5,80	0,35	17	1,73	7,8	0,17	19,46	1,17	2,00	2,00	0,00	0,00
	100	5,50	0,17	19	2,31	8,3	0,231	9,41	0,18	2,67	2,67	0,00	0,00
Abomey-Calavi	0	6,28	0,54	273	30,2	4,7	1,46	1667	1137	26,7	12	1,96	0,81
	20	6,24	0,74	212,3	46,1	5,63	0,95	1380	1191	40,7	29,7	6	5,41
	100	5,69	0,92	156	56,9	6,57	0,52	467	326	4,67	2,91	2,80	1,29
Godomey	0	6,88	0,23	312,7	77,9	6,50	0,20	1199	423	40	15,3	9,89	4,71
	20	6,10	0,31	194	146	5,97	1,53	577	247	30,67	9,33	16,67	1,67
	100	6,50	0,20	142,3	90,08	7,83	0,32	198,8	70	1,47	1,23	0,84	0,42
Effect of region		**NS**		**NS**		**NS**		**NS**		**NS**		**NS**	
Effect of depth		**NS**		*		**NS**		*		**NS**		**NS**	

SE : Standard error NS : Non significant * : p <0.05 ; DO : Disolve Oxygen ; COD : Chemical Oxygen Demand; Cond: Conductibility; DBO5: Biological Oxygen Demand after 5 days; NTK: Nitrogen content.

Discussion

It appears from the current study that the traditional setting discharge is the only way to deal with waste in Abomey-Calavi and Godomey. This is due mainly to the lack of final discharge in the municipality (Yêmadjè, 2009). The waste is mostly discharged into the shallows, along the lac, lagoon and the former sand quarries. So leachate from waste seeps into the soil and can contaminate both soil and water. In the current study, the soil sampled on surface are neutral excepted soil sampled in Godomey, while those sampled in 20 cm of depth become slightly acid. At 100cm the soils collected were moderately acid. According to Mbonigaba Muhinda et al. (2009), these soils slightly acidic or neutral are certainly rich in nutrients and are therefore highly suitable for cultivation. Regarding the low acidity of soil leachate from landfill sites compared to those in the control area, it can be linked age landfill sites which is 5 (five) and 10 (ten) years. The electrical conductivity was also higher in soils from landfill sites than in the control area and a significant variability in the level of sample with peak values at 0cm level values (between 36 and 312,7µS / cm) and the minimum at 20 and 100 cm (17 to 212.3 S/cm). These values reflect low soil mineralization in depth. This decrease in conductivity in depth may be due to the gradual reduction of waste as soon as one moves in depth. For Bodjona (2012), the highest electrical conductivity values recorded in soils from landfill sites can only be due to the advanced degradation of waste deposited resulting in a strong presence of minerals.

The high level of organic matter in extra-fine waste collected at surface (0cm depth) shows low oxygen levels obtained in surface soils and particularly in soils from landfill sites. Indeed, the microorganisms present in these fields use the dissolved oxygen to oxidize organic materials; this process lead on poor soil on surface level mainly above land disposal sites dissolved oxygen (Hassoun, 2006). This probably reflects the high values of COD and BOD5 at the surface of soil and primarily soil on landfill sites. The low values in nitrogen kjeldhal content recorded at 0cm may be related to low dissolved oxygen at this level that has resulted in the loss of nitrogen in volatile form (Bodjona, 2012).

The analysis of the soil content in heavy metals has shown that there is no significant difference between sampling levels and sites. However, their content tends to increase with the depth. According Alouémine (2005), the high values of this metal recorded at landfill sites are linked to the presence of the waste on these soils when copper comes mainly from waste categories such as: paper and cardboard, textiles, metals, composites and possibly fine elements that are based on categories of waste found at landfill sites selected (Figure 3). The side of the cutoff level, the highest concentrations of copper in surface can be justified by the significant presence of organic matter and the pH at this level (Table II) (Weissenhorn 1994; Lebourg et al., 1996). However, the highest content in copper found in depth (100m) is due to the migration of the metal in the soil favored mainly by organic matter, pH and soil texture (Kouame et al., 2006). As for nickel, it should be noted that some differences follows the same pattern in depth as copper. The high average content in nickel at 0 and 100cm in sampled soils would be related to the type of metal that may have the facility to migrate to depths (Elass et al., 2003). Studies have pointed out that the mobility of nickel increases at low pH and in environments rich in organic matter (NRC, 1981 and Bodjona, 2012) and confirm the results found herein. Unlike nickel, the highest lead contents were recorded at the surface of sampled soils (0cm) except soil disposal sites in Abomey-Calavi where they are found at 100cm of depth. The highest concentration of

713mg/l recorded at 0cm in Godomey may be related to hazardous waste mainly from agriculture (fertilizers, insecticides, herbicides ...) and composite (packaging of agricultural products) observed in the waste collected at these sites during discharge sorting by category. The accumulation of lead in soils could be explained by the fact that this metal concentrates more in the surface horizons (Steckeman et al., 2000) and more specifically in horizons rich in organic matter (Bodjona, 2012). According to Pichard (2002), a pH greater than 5 in soil having organic matter content of at least 5%, favor the accumulation of lead. The soil contamination by cadmium reflects the migration of cadmium to depth. Its transfers to the depth are favored mainly by the pH value in these soils that generally is around six (6) (Citeau, 2004). The low cadmium content found in surface of soil may be due to early mobilization of this metal. His presence on the landfills sites could come from the composition of the waste made of batteries, used batteries, plastics and especially agricultural inputs found in waste. For Bouchakor (1999), cadmium can be generated by batteries but also plastics, glasses (dyes) and metals (alloys). Our results are similar to those of Bouchakor (1999) and Bodjona et al. (2012) who found deep in the soil a great mass of discharge rich in cadmium. Comparison of average concentrations obtained for these metals compared with the AFNOR NF U 44-041 and those authorized for normal soil shows that these average means recorded herein are lower than those set by the standards except averages lead content at 0 cm and cadmium content in soil at 100cm in Godomey. Our finding is comparable to those repported by Bodjona (2012) in discharge soil of the city of Lome in Togo.

Conclusion

It appears from the current study that the traditional setting discharge is the only way to deal with waste in Abomey-Calavi and Godomey. The waste is mostly discharged into the shallows, along the lac, lagoon and the former sand quarries. The most dominant type of waste was putrescible and plastics. The soil sampled on surface are neutral excepted soil sampled in Godomey, while those sampled in 20 cm of depth become slightly acid. Leachate produced by waste flow into water bodies or seeps into the ground. These leachates are low oxygen, rich in mineral salts, organic matter and metals. The values of the average levels of COD, lead and copper exceed the limit values indicated by the standards. Thus these landfill sites are a great danger for the ground. However, most of the sampled soils are pollution-free except their content in lead and cadmium which indicate significant contamination and pollution of soil. Furthermore, the electrical conductivity and COD varied according to the depth of sampling. The presence of the different contaminants determinate herein in the soil indicates the migration of these contaminants from the discharge to the ground. The pH, organic matter and soil texture were very active in the transfer of the studied contaminant to the soil, while the recovery activity had played a large role in reducing the soil pollution by metals. Thus the valuation of this business would be an asset in the treatment of waste by setting traditional landfill waste. However, it would be better to accompany this activity by the modern waste treatment process.

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