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Management of electronical and electric equipment wastes and environmental and sanitary risks in Godomey and Abomey-Calavi boroughs in Bénin

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Abstract

The inadequate elimination of electronic wastes causes environmental pollution and dangers for human health. This study aims to analyze the health and environmental risks related to waste treatment processes for TV sets and computers at the dismantling sites in the Godomey and Abomey-Calavi boroughs. The chemical analysis of four soil samples taken from the dismantling sites was carried out. Heavy metals are measured. The average mercury (0.4064 µg/kg), lead (124.5 mg/kg) and cadmium (2.18 mg/kg) concentrations indicate soil pollution as a result of decommissioning and incineration of E-waste. Incineration sites are more exposed to lead in view of the high concentrations recorded at the sites, notably at Godomey-station (238 mg/kg) and Cococodji (188 mg/kg). Moreover, the lack of personal protective equipment (eyeglasses, gloves, work wear, mask) exposes workers' site to frequent discomfort signs of serious pathological. The relative risk (RR) calculation to assess the relationship between the wearing of personal protective equipment PPE and the occurrence of discomfort among workers at dismantling sites for electrical and electronic equipment (WEEE) gave RR = 0.24 <1. The calculated fraction RPF risk = 0.76 or 76%. This led to the conclusion that the wearing of PPE makes it possible to avoid 76% of the discomforts in the ranks of site workers. In view of these findings, it is necessary that measures be taken to control and regulate metal recovery activities in WEEE and that modern procedures that can reduce health and environmental risks are implemented.

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Introduction

Our old computers create death. So is the approach used by Geo magazine to warn on the negative impacts of the electronical and electric equipment out of use (ait Daoud, 2013). Despite these numerous advantages they give, the public since years has been aware of one of the main consequences of TIC, such as the quantity and multiplicity of dangerous wastes produced by those products.

This problem of management of electronical and electric equipment wastes (WEEE) comes within a more problematic of management of dangerous wastes of which they represent an increasing part (Bensebaa & Boudier, 2010).

Each year, 20 to 50 millions of tons of those wastes are globally produced in the world (PNUE, 2005).The problem of electronic wastes in west Africa is still made worse by a continuous flow of used equipment by industrialized countries, important volumes of WEEE that are unclean to be used again and contribute to the quantity of electronic wastes generated locally (PNUE, 2012).

The inadequate elimination of dangerous wastes on the earth and in water in states members of ECOWAS has caused environmental pollution that poses dangers for human health because, those countries lack of infrastructures and the executive regulation for an ecologically rational management of those wastes.

This weakness has been used in the past and dangerous wastes such as industrial and electronic that come from developed countries have been illegally unloaded in some countries.

In Benin, the flow of WEEE is constantly increasing and the majority ends in dump (Aïna and Rochat, 2011).

In lack of a politic of those wastes management, it's developed some fields of recuperation and dismantling sites violation of law n°98-030 of February 12th 1999 concerning environment in Benin Republic that stipulates in its article70 ''Every field intended to the realization of warehousing site, transfer, treatment or elimination of wasters no matter its nature should be studied to see the preliminary impacts that should be submitted as well as the exploitation need to the Minister by the instigator.

This study aims to describe the way WEEE are managed on the dismantling sites and to analyze the environmental and sanitary effects of this management.

Materials and methods

Study frame

Godomey and Calavi boroughs are part of the nine boroughs included in the commune of Abomey-Calavi (South Benin). Located between 2° 13'14" and 2°23'5" East longitude, and between 6°19'45' and 6°30'34" North Latitude, they are bounded at north by Akassa to borough, south by Atlanlic ocean, East by the commune of Cotonou and west by Togba, Ouèdo and Hèvié boroughs, as shown by figure 1. The surface is 187, 68 km² and they take 29, 92% of Abomey-Calavi area (INSAE 2016).

Materials

Many equipments have been used as a GPS (to take geographic coordinates of sampling sites), a numeric camera to take pictures. Besides those equipments, we have used in laboratory: a spectrophotometer DR4000, a magnetic agitators, reactifs for different dosages, a hotplate, erlenmeyers, diggers, bottles, pipettes for chemical analysis.

Sampling

To reach this study's goals, the principle of reasoned choice has permitted to select persons or groups directly implicated in WEEE management.

For investigations and interviews, the following sampling rate has been taken.

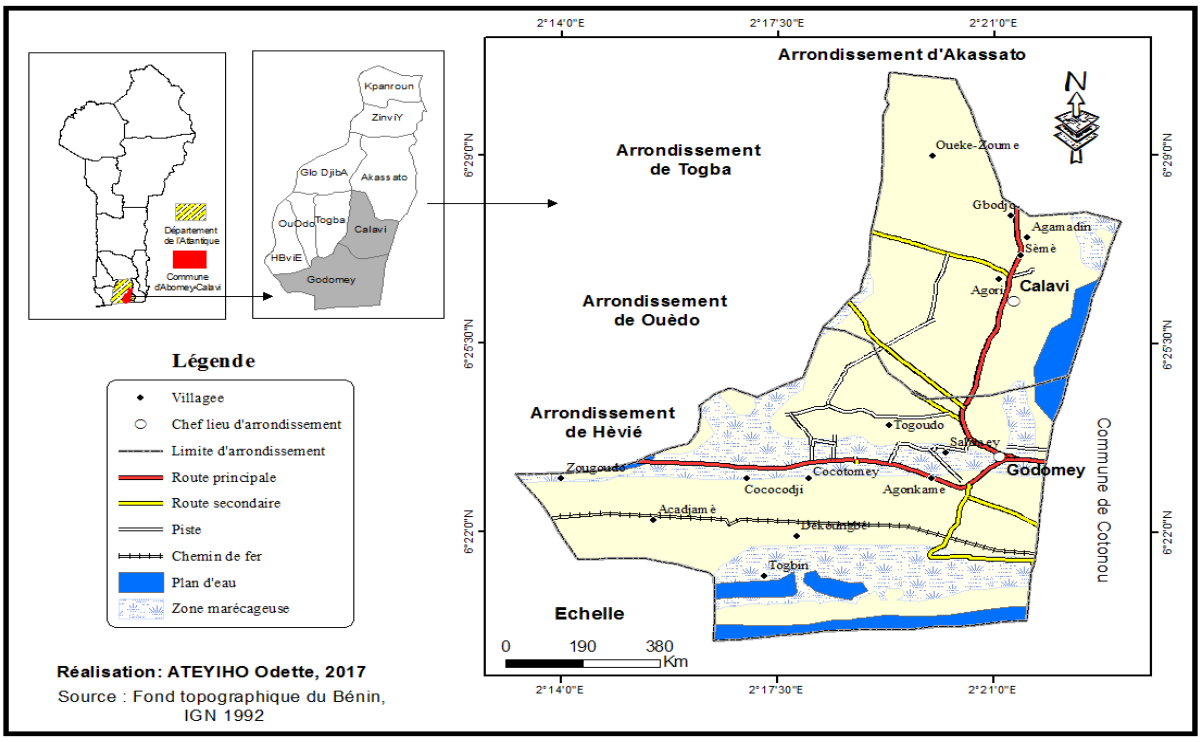

Fig. 1. Geographic situation of the study sector(IGN, 1992).

35 Prefects of the dismantling sites of WEEE have been interviewed on the point of WEEE collection, their management method in their working environment. Each site has at least 3 agents of collection and dismantling. 111 heads of riparian households of WEEE dismantling sites, 3 houses per site to know their view on the present management of WEEE on the sites.

Some samples have done on four sites, then analysed to know their contents in lead, cadmium and mercury. The samples have been taken at Togoudo, Cococodji, Agonkanmè, Godomey – station, and at Sèmèin CALAVI.

Treatment and data analysis

The survey cards have been manually examined. Soft wares (SPSS21, EPI Info7, and Qgis 2.3) have been used to treat the examined data according to their specificity or their nature.

Evaluation of exposition-risk relation

The relative risk calculation RR has been done to estimate the relation between personal protective equipment (PPE) wearing and the survival from sicknesses of the agents on the dismantling sites of WEEE. We affirm the existence of an association as soon as we observe an in equation $RR < 1$

- If$RR > 1$

When RR is superior to 1, we talk about positive association between exposition and sickness: the frequency of sickness increases when the exposition level increases. The exposition has an unfavourable effect.

The etiologic fraction of risk for reports is equal to FER $(RR - 1)/RR.$

If $RR < 1$

If RR is inferior to1, we talk about a negative association between the exposition and the sickness: the frequency of sickness decreases when the exposition level increases. The exposition has a favorable effect. The exposition factor is associated to a reduction of risk and a warning fraction risk WFR =1-RR that allows to evaluate the efficiency of PPE wearing in sickness reduction.

We have then precised the limits of confidence interval of RR.

If the limits of confidence interval of RR include the value 1, RR is not statistically significant at the considered doorstep. In the opposite case, RR is statistically significant at the considered doorstep.
Thus, the conclusion is that it exist a link between PPE on the dismantling sites and the survival from sicknesses.

Analysis methods of samples of the sites
The analysis is done at the supervision laboratory of pollutions of the General Direction of environment and climate (DGEC) of Ministry of environment and Sustainable development. The analysis results are compared to admitted norms of heavy metals contents in the soils (table 1) (INERIS, 2003). The soil samples collected have been pretreated. The samples have been freezed and dried with lyophilisator at -25°C during at least 72 hours. It has been then got rid of lump before passing on sieve and then ground in order to obtain a powder of granulometrie inferior to 0,63um.

The mineralization is realized on 200 mg and 8 ml HMO_3 concentrated at 67%. This step is done at 200°C during 50 minutes on a stove with a maxi 44^{é} rotor. The mineralisation has been diluted at 100 ml after samples filtrations with filters papers, we dose the pH by adding to them sodium hydroxid to increase the pH in solutions where it's very low. Concerning the samples with high pH, we add to them sulfuric acid to adjust them.

The mercury has been measured using analyser DMA 80 for mercury concentrations analysis in solids and liquids with detection limits that can come to 0,0015 mg of mercury. The analyzer DMA 80 doesn't need pretreatment of sample, unlike other analytic technic that require a dissolution or mineralization of products to be analyzed, and it shows directly mercury analysis results.

Results
Chemical analysis results, different investigations on the site (direct observations and interviews with agents) have been obtained and have been presented according to the different study objectives.

Table 1. Admitted norms for heavy metals in soils.

heavy metals	mercury	cadmium	lead
Soil (PNEC)	23-27 ug/kg	12 mg/kg	19 mg/kg

Source : INERIS, 2003.
PNEC (Predicted No effect concentration): intense concentration of the substance without risk for the environment (www.ecotoxicologie.fr/reglementer-methode.php).

Dismantling process of WEEE
Figure 1 and 2 show the processes used by agents to dismantle the old electronical and electric equipments.

The dismantling of a televisor consists to separate the different elements such as plastic shell, cathode tube, electronical cards, deviator cables, electron cannon, metallic parts to be recuperated and the valorization of different raw materials.

We use a hammer to open the shell, a screw driver, pliers to select cables. The hammer is then used to separate recalcitrant elements and destroy the cathode tube for metal recuperation (aluminum, iron), magnetic elements and electronical cards like TV set; the computer is composed of a plastic shell that covers central processing as well as screen. The screens dismantling allows to extract cathode tube.

The agent separates manually, using screwdriver, case, cables, electronical cards, electrons cannon and cathode tube. A part from the screen, the computer is composed of central processing which dismantling is done specifically.

Table 2. Chemical composition of WEEE.

WEEE	Chemical substances	Location
Poste TV et Ordinateurs	Baryum oxide	Slab
	Lead oxide	cone
	Brominated flame retardants	Plastics
	Mercury	Screens
	Luminescent powder	Cathode ray tubes
	PCB/PBB	Cables and plastics

The central processing case is removed and disintegrated. As for alimentation case, it's devoice of its components such as radiator, ventilator, cables, and connectors and formed circuit. A computer contained many cards of formed circuit. Pieces like memory toggles and microprocessors are recuperated too by a visual sort.

Treatment of WEEE dismantled

Once dismantled, WEEE undergoes a manual sorting to separate plastics, electronical cards, cables that should be treated. Electronical card are made with resin, doubled with fin copper layer spitted to sustain a manual sort in view of metals recuperation. As shown in figure 3, those electronic cards derived from dismantling of wastes of TV sets and computers are simply burnt in order to recuperate copper and aluminium.

Table 3. Exposition of heavy metal and health being.

Wearing of PPE	Sickness	Wholesome	Total
Yes	6	16	22
No	25	27	52
Total	31	43	74

Table 4. content of heavy metals on the sites and admitted norms for the heavy metals in the soil.

	heavy metals		
DS/IS	Leadmg/kg	Cadmiummg/kg	Mercuryµg/kg
Norms	19	12	23-27
DS Togoudo	43	1,4	0.578
DS Sèmè	29	1,8	0.394
ISGodomey-station	238	-	0.162
IS Cocotomey	188	3.3	0.491

As for plastics, especially derived from shells of dismantled WEEE, they are composed of Acrylonitriles Butadiene Styrene (ABS), polycarbonate (PC), or (PVC).They are gathered on dumps and burnt too. Thus, plastics are not valued and don't submit any particularly treatment in present field of recuperation.

Sanitary risks and environmental impacts

Sanitary risks

They are inherent to the content in toxic materials and to practices with risk of present WEEE management. The risks result from the liberation of toxic products during wastes dismantling operation, material extraction and residues elimination. They are numerous because of the toxicity of equipment component of TV set and computer.

The analysis of table II shows that WEEE contain toxic chemical substances such as Lead, Antimoine, Baryum oxide, beryllium, cadmium, lithium, mercury, brominated flame retardants. This needs adapted processes in the frame of dismantling operations, material extraction (iron, copper, aluminum, etc) and WEEE residues elimination but the reality is different in wastes dismantling sites.

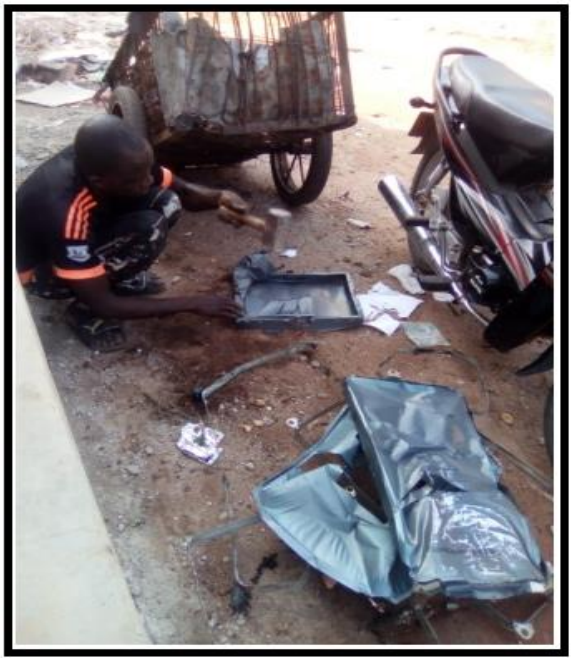

Fig. 1. Dismantled televisor

Wounds and frequent sicknesses

The agents are often confronted to wounds and sicknesses during some activities on the site. The dismantling with hammer, especially without any personal protective equipment (PPE), gives rise to projections of pieces of irons, plastics and glasses which injure the agents. The cases of injuries at the face and fingers are frequents as shown in figure 4.

A lot of them have cicatrices because of their work. The scrap ironmen interviewed have confirmed the existence of some sicknesses they are confronted with, that may be related to the activities on the site.

For lack of epidemiologic study or the agents working in the Firm an evaluation on the sanitary risks on the basis of the symptoms collected on the concerned has been done. The figure 5 presents the frequency of the different sicknesses collected among the workers on the dismantling sites.

Fig. 2. Dismantling of a televisor

The analysis of figure 5 reveals that the tiredness is the most registered sickness, 25%. It's followed by cough and cold respectively with 22% and 22%. After that come headache (17%), nausea (7%) is well as poking eyes (7%). Those diseases can be caused by the expositions to chemical products. Thus, while dealing with the dismantling operations of shells and intense concentrations of pollutants. It's important to deal with a deep epidemiologic study to determine if it's the toxic substances which cause the registered sicknesses however, the probabilities of risks reduction by personal protective equipments (PPE) wearing have been calculated. Table 3 presents the proportions of those who wear PPE and the frequency of the sicknesses.

The analysis of table 3 shows that 22 agents out of 74 interviewed wear at least one personal protective equipment, 29.72%. Among them, we find nevertheless 6 agents who present the exposition to dusts symptoms (cold, cough, etc) out of 16 who say they are healthy. The calculated relative risk RR= 0.24<1, thus we have a negative association between the exposition and the disease.

The frequency of the diseases reduces when the wearing of PPE level increase. At 5%, IC= [0.084; 0.711] the interval of trust (IC) doesn't contain 1, so

the RR is statistically significant to the required sill with. RR= 0.24 < 1, the calculation of the prevented risk fraction PRF= 1- 0, 24= 0.76; 76%. This allows to conclude that the wearing of PPE allows to avoid 76% of sicknesses among the workers working on WEEE dismantling sites.

Fig. 3: Electric cables burnt at godomey- station.

Apart from those sicknesses often registered, the intense physical activities and/or regularly and the constrained working position during dismantling, sorting, loading and unloading also favour the development of musculo- skeleton troubles.

Impacts on the environment

Soil pollution

The results of the chemical analysis of the taking soils on the dismantling sites show the degree of the environment pollution. The table IV presents the contents in lead, mercury and cadmium in the dismantling sites (DS) and the incineration sites (IS) taking as well as the norm of the heavy metals introduced in soils.

The obtained contents in heavy metals in the taking samples are presented in the table above. They are compared to the admitted norms for heavy metalsin the soils according to INERIS, 2003. From the table analysis, it's noticed that in average the dismantling sites are polluted by heavy metals: mercury (0.4064 Mg/Kg), lead (124.5 mg/kg) and cadmium (2.18mg/kg). The presence of those chemical pollutants in soils may be related to the dismantling activities and the elimination of electrical and electronical equipement wastes. It's noticed that the concentrations in lead at incineration sites are more intense than the registered contents, especially at Godomey- station (238 mg/kg) and cococodji (188 mg/kg).

However, while comparing the admitted norms according to INERIS, (2003), only the contents in lead in the soils exceed largely the limits.

The concentrations in mercury and in cadmium are less important. This can be in one hand related to the characteristic of soluble cadmium to be migrated on the surface of soluble of the soil towards deep water resources (Ablain, 2002).

On the other hand, the poor content in mercury on the sites soils can be justified by its characteristic of Volatility. A capacity that permits to it to move in the atmosphere.

Fig. 4. Injuries on an agent's fingers at sèmè.

Aesthetical and water pollution

The figure 6 presents the sites of dismantling and incineration and problems of insanitary and environmental pollution that poses the activity metal recuperation.

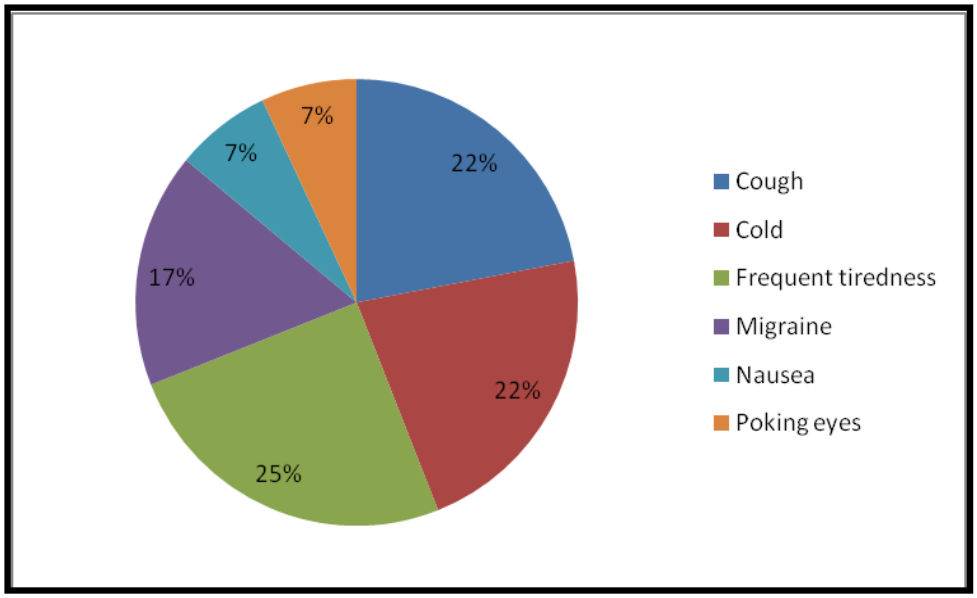

Fig. 5. Frequency of the different sicknesses collected among the workers on the dismantling sites.

Fig. 6. Site of incineration and dismantling at cococodji and sèmè.

The analysis of the figure 6 reveals the conditions in which the sites of dismantling, incineration and wastes eliminations are found. It shouts the insanitary problems and water pollution caused by the activities on the sites. The majority of dismantling sites are located near paths and marshy areas. Even in agglomeration, the sites supervisors eliminate ecologically little wastes result from their activities.

The figure 7 shoes the distance between the site and water paths of the study sector.

The figure 7 analysis shows that (20) twenty dismantling sites out of (37) thirty-seven, 54.05% are located at less than 500m from marshy areas and stretch of water. There is then a deficit of ecologic coherence between the activities done on dismantling sites and their implantation areas.

The consequences are: stretch of water pollution, the introduction of those metals in food chain. In fact, after extracting useful material, the rest of WEEE is either burnt, throw on the pile of junk or in shallows, buried or collected by NGDs which collect garbages. The figure 8 shows the process of elimination of these residues on the sites.

Thus, some components' of WEEE are found in the environment. It's the case of heavy metals of which cadmium, lead and mercury. Lixivials got from burying provoke environmental and sanitary dangers because of mercury, lead, PCB or cadmium presence (Bahers, 2012). Containing those heavy metals, rubbishes can contaminate phreatic expanse of water through infiltration and the contact with nearest wells of the dismantling sites. The pollution by metals, burying garbages is long-term problem, which arouses a lot of worries (Aïna, 2006).

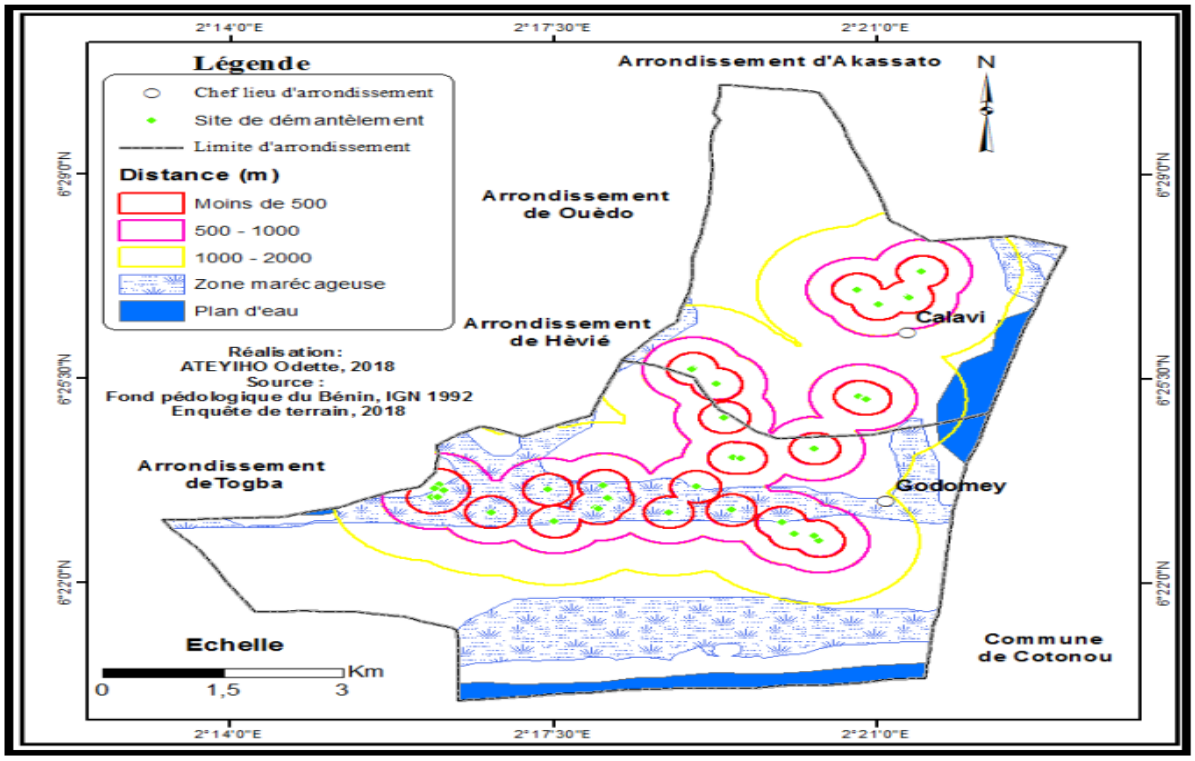

Fig. 7. Map of distance from the sites to hydrographic networks.

Air pollution

The sites of dismantling of electronically and electrical wastes are most of the time in the air. The volatile pollutants in bags evaporate easily in air.

This is intensified by craft practices of precious material recuperation and wastes elimination (Figure 9).

The figure 9 shows plastics and cable burning at or near dismantling sites. A study of united Nations Program for environment in 2005 shows that such practices of precious materials recuperation and elimination of this type of waste present negative effects for the environment.

The smoke contain persistent organic pollutants (POPs) such as dioxines and furanes.

Those contaminants come from combustion of Poly Chloro Byphenyl (PCB), used as electric insulators in transformer and condensators making.

In fact, electric wires and other components of WEEE burning for steel and copper recuperation, brings out

those pollutants and insupportable odours which make air toxic and unpleasant.

Discussion

The results analysis reveals that the agents of the dismantling sites resort to dangerous practices to recuperate precious materials that should be sold. They burn electric cables, dismantle used apparatus without wearing gloves, protective glasses or scarf. The same for plastics and others, they are thrown in the nature. This confirm Aïna *et al.*, (2011)'s observation in WEEE national diagnostic report: districts services and NGO are not specialized in WEEE management. Those wastes are collected as well as garbages. Moreover, they note that the tethnics of those wastes treatment are still craft. This study shows the frequency of some sicknesses amount agents, probably linked to permanent exposition to some products and working conditions.

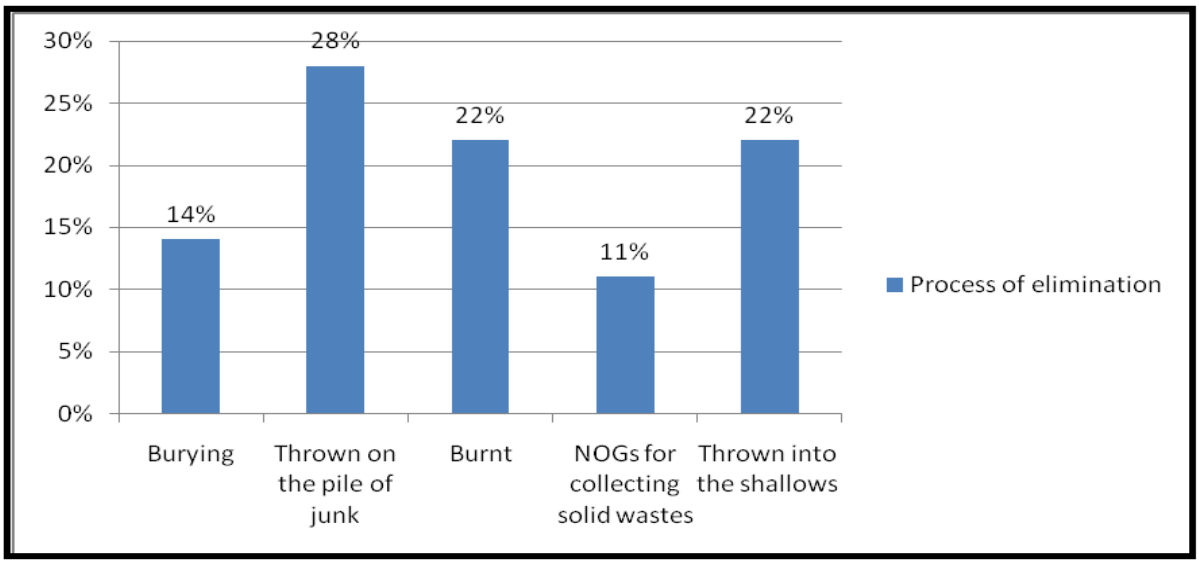

Fig. 8. Process of WEEE elimination on sites.

The present management of wastes explains the important contents of mercury (0.4064 mg/kg), lead (124.5mg/kg) and cadmium (2.18mg/kg).This pollution results from tragic products freeing during waster wastes dismantling operations, materials extraction and residues elimination.

A study of Lecher in 2012 on WEEE fields shows that they present many chemical risks that are particularly concerns. The lack of eco-conception, flow augmentation as well as the organization of workstations and the processes of those old equipments treatment are in majority, responsible for professional expositions (lead, cadmium, barium, yttrium and mercury) in the principal field of primary treatment of screens with cathode tubes and used lamps, electronic cards, plastics and electric cables. This research has proved that apart from negative impacts of those activities on health environment, the organization of a field of WEEE management in Godomey and Abomey-Calavi boroughs is a source of wealth creation, environment protection and human health. The personal protective equipment wearing permits to avoid 76% of sick sits. This work as (Evanno, 2004; Bahers, 2012) comes to conclusion of the necessity of ecologically rational installation of WEEE treatment sites to reduce the impacts of those wastes on the environment. It has identified all the steps of electric equipment after its abandon and ways of incineration or burying of garbages.

It's what (Laqueche, 2010) enlightens, in Ecology and Technologies of Information and Communication (TIC) by showing that there isn't any other solutions to stop the impact of TIC on environment and health but by ecologic wastes management, for lack of stopping the development of TIC and its products consumption.

WEEEs constitute an important ressource but of which the potentialities are for the time being less defined. The lack of a strategy of those specific wastes management gives way to a ration field of which the processes don't respect any sanitary and environmental norm.

Fig. 9. Burning of plastics and electric cables at Godomey-station.

The risk analysis done has highlighted agents exposition and dismantling sites with heavy metals, especially lead, cadmium and mercury. Nevertheless, it's difficult to establish clearly a link between the toxicity of WEEE and sicknesses notified by Firm agents and any compartment of environment, surface water or soil, polluted, can be source of contamination and human exposition to toxic metals.

This work requires mainly epidemiologic but in this new perspective, it should be pertinent to proceed to such study on pathologies which affect directly the agents of the sites and which have as source heavy metals.

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