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STUDY OF SOIL POLLUTED BY MTE IN THE GOUNTI YENA VALLEY (NIAMEY) FOR THE IMPLEMENTATION OF A PHYTOREMEDIATION TEST

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Abstract

The valley of Gounti Yena (Niamey-NIGER) is an area of strong market gardening activity. However, this valley is surrounded by multiple sources of pollution that contaminate soils. However, very little data is available on soil contamination by metallic trace elements (MTEs) in NIGER. Thus, in the interest of consumer safety and ensuring a healthy environment for the population, a study on soil pollution by the MTEs in the Gounti Yena Valley was initiated. The objective of this study is to contribute to new data on soil pollution on the one hand and on the other hand to remedy this pollution through a biological technique: phytoremediation. The results showed that standards were exceeded, particularly in Cu (369,42 mg/kg), Pb (725,66 mg/kg) and Zn (5 546,30 mg/kg). For example, the Zn contents were up to 18 times higher than the AFNOR NF U 44-041 standard. The study of transfer of these MTEs from soils to amaranth, sorrel, okra and tomato revealed a transfer of soil MTEs to these plants. To evaluate the possibility of setting up a phytoremediation technique, hyperaccumulative plant species were sought. For this purpose, 59 species of herbaceous and 24 species of ligneous were inventoried. Thanks to the literature, 14 plant species turn out to be hyperaccumulative. *Datura innoxia, Cyperus esculentus, Ricinus communis* were selected for the phytoremediation test. This phytoremediation test carried out has shown that these plant species have the capacity to reduce 44.27% for *Cyperus esculentus*, 41% for *Datura innoxia* and for 136% pour *Ricinus communis* the initial concentration of Zn in soils in one month of culture. These plant species are very good at phytoremediation of the soils of the Gounti Yena valley and could well clean up other soils polluted by the MTEs.

Key words: *Pollution, MTEs, soils, plant species, phytoremediation, Niger*

Introduction

Questions about environmental problems are at the center of debates around the world. In addition to the phenomena of climate change and degradation of the natural environment, there is the contamination of the environment linked above all to human activity. With the increase in anthropogenic pressure on the environment, contamination problems are becoming more and more crucial. These contaminants can be biodegradable or persistent. Non-biodegradable pollutants, which are essentially metals and metalloids or metallic trace elements (ETM), are difficult to control and eliminate because they occur in a more complex form in nature (Bourrelier et *al.* , 1998; ADEME, 2008). The transfer of ETM to aquifers or to plants can lead to deleterious effects on populations through the food chain.

In Niger, demographic growth and urbanization which result in the extension of cities, the evolution of insalubrity and the degradation of nature worsen the already worrying situation of the environment. The uncontrolled and reckless disposal of urban waste contaminates the air, water and soil. Non-biodegradable waste accumulates in nature contaminating the soil and thus reducing its ability to meet the demands of food production.

The city of Niamey, with a population of 1,011,277 inhabitants in 2012 (INS, 2012), has vast natural agricultural potential constituted by the Niger valley. There are a multitude of sources of metal pollution of soils, waters and plants, linked in particular to formal and non-formal industrial activities, agricultural activities, road traffic, waste water and wild dumps. The poor management of waste by piling it up in poorly controlled landfills is taking on a worrying proportion. The atmosphere, the soil, the waterways and the whole living environment become unhealthy. Industrial, domestic and hospital wastewater is discharged at various locations in the city of Niamey and then drained directly, without being treated beforehand, into the Niger River (Tankari Dan Badjo et *al.*, 2013). Work carried out in the city of Niamey on the levels of ETM in the soil show a high contamination in Cd, Cr, Cu, Pb, Zn, etc. (Tankari Dan Badjo et *al.*, 2013). However, some of these soils are used by market gardeners to produce fruits and vegetables for human consumption. Fodder is also produced there to feed the animals. However, research continues because environmental issues have become very crucial and the pollution database in Niamey is not very rich.

Gounti Valley Yéna , which is one of the longest kori (bottom) of the capital, is not spared by this phenomenon of pollution. Indeed, wastewater collected from several neighborhoods and small industries is directly discharged there without any prior treatment, as well as solid household and industrial waste. Moreover, Gounti Yéna is surrounded by busy highways, sources of environmental contaminants. Zinc, lead, cadmium and copper are present in ore extraction residues accumulated around mining operations. Their presence in the soils considerably modifies the floristic composition of the sites, only allowing the installation of a limited number of species supporting their toxicity (Antonovics et *al.*, 1971; Gartside and McNeilly , 1974).

The soil-plant transfer of ETM is one of the major routes of exposure and contamination of humans *via* the food chain (Cui et *al.*, 2004; Den et *al.*, 2008). Indeed, soil is a finite resource that provides essential support to ecosystems and our societies. However, inadequate management practices, such as industrial activities, lead to inexorable soil degradation each year. Due to specific physical and chemical changes, the magnitude of which is often unknown, these soils belong to a new class of soils today known as technosols (Claudia, 2012). The treatment of polluted soils by physico-chemical methods is very cumbersome and very expensive. This is why many authors focus on the use of biological methods.

The treatment of inorganic pollution, such as that of ETM, however, has limits due to their persistence in the environment. The restoration of soils polluted by heavy metals by means of physico-chemical techniques is very expensive. However, in recent years, more and more studies have been carried out on the biological remediation of soils contaminated by heavy metals. Biological or bioremediation methods that use natural components (plants, microorganisms) for the depollution of ecosystems seem to offer better prospects. Thus, phytoremediation using the ability of plants to accumulate, extract, destroy and transform these ETMs can contribute to sustainably depolluting the Gounti Valley Yena.

The general objective of this study is to quantify the levels of ETM at the level of an area heavily polluted by ETM, the valley of Gounti Yena, and to reduce its level of pollution by using a biological method, phytoremediation.

Material and methods

I. Soil contamination in the Gounti Valley Yena by ETM

1.1. Description of the study area

The study area where the soil samples were taken is located in the heart of Niamey and covers an area of about 26 hectares: it is the Gounti Yéna or bas fond in French. It is a more or less wide band which crosses several districts of the commune II of Niamey. Figure 1 illustrates the geographical location of the Gounti Valley Yena.

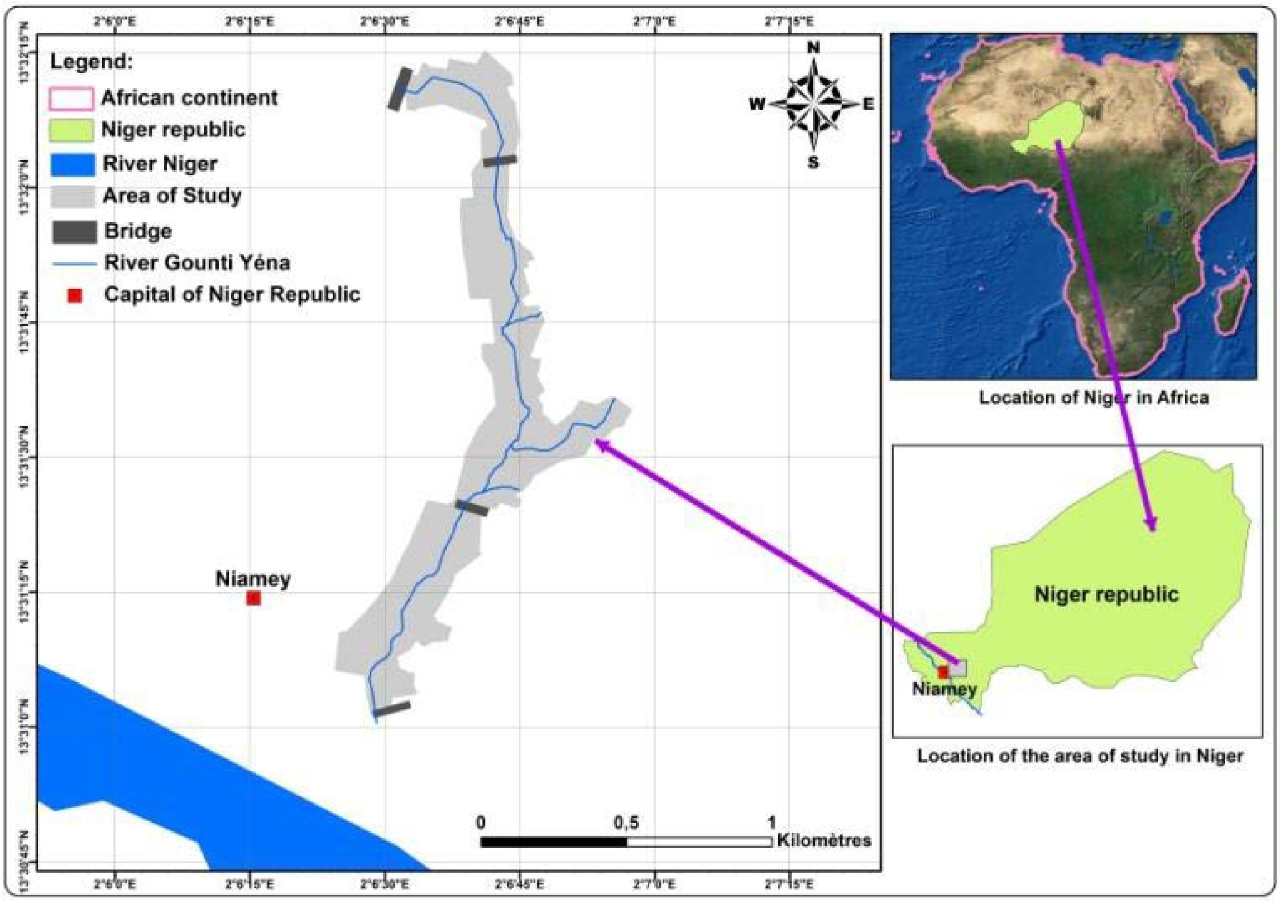

Figure 1: Location of the Gounti Valley Yena within the urban community of Niamey.

1.2. Soil Sample Collection Methods

Soil samples are taken along the valley on 21 transects using a helical auger so as to cover the entire surface and at a depth between 0 and 10 cm. On each transect, 3 soil samples are taken. The sample is taken in a tube 10 cm high and 10 cm in diameter. The sample is placed in a plastic bag and clearly identified. Universal Transverse Mercator (UTM) coordinates are determined for each sampling point.

Figure 2 shows all sampling points along the Gounti Valley Yena.

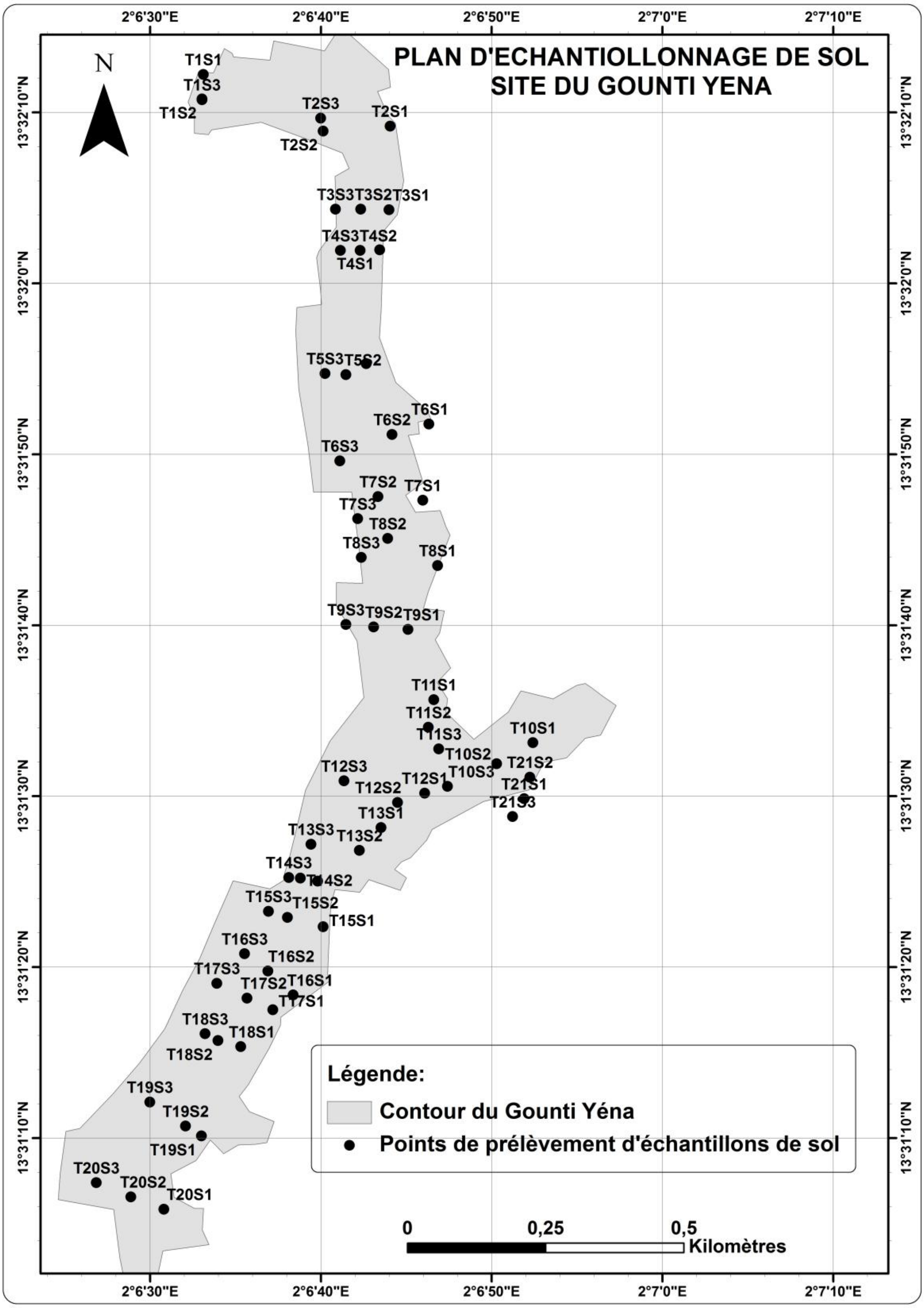

Figure 2: Map of soil sampling points along the Gounti Valley Yena.

1.3. Extraction and determination of ETM in soil samples

Laboratory analysis of MTEs first requires a sample preparation phase (drying, grinding, sieving), then a phase for extracting pollutants from the solid matrix and finally a phase for assaying pollutants.

Thus, the soil samples taken were dried at ambient temperature for one week (<40°C), crushed and sieved to 2 mm in the laboratory of the Soil Science Department of the Faculty of Agronomy of Niamey. The extraction and assay of total TMs in soils were carried out at the Petrochemical and Geochemical Research Center of Nancy (France) by the Rocks and Minerals Analysis Service. The dissolution of the MTEs (As, Cd, Co, Cr, Cu, Hg, Ni, Pb and Zn) was carried out using a mixture of hydrofluoric and perchloric acid (HClO4) according to standard NF X 31-151.

The analysis is carried out by mass spectrometry with inductively coupled plasma (ICP/MS) (Tankari Dan Badjo et *al.*, 2011). The results are expressed in mg/kg of soil dry matter.

II. Transfer of ETM from soils to cultivated plants

2.1. Material

The plant material consists of leafy vegetables (Sorrel and Amaranth) and fruit vegetables (Tomato and Okra). The seeds come from the local market (Niamey).

2.2. Plant species under study

a. Amaranth *(Amaranthus hybridis)*

With a height of 1 to 2 m, amaranth is an edible annual plant belonging to the Amarantaceae family, native to Georgia. This plant appreciates a draining, humid and humus-rich soil even if it tolerates drought well. Amaranth leaves can be eaten after steaming. The seeds have exceptional nutritional value and can be roasted and eaten like popcorn. They are remarkably rich in lysine, an essential amino acid for the human body and absent in most cereals. They are richer in protein (13%) than cereals (about 10%) with much better quality protein. Its mineral content is also remarkable: it is an excellent source of calcium, iron, magnesium, potassium, copper, manganese, selenium, phosphorus. It also contains zinc.

b. Okra *(Hibiscus esculentus)*

Okra is an annual plant from the Malvaceae family. The plant measures 50 cm to 2.50 m in height. Sun-drying (in a designated area) of fruits cut into slices or small whole fruits ensures very good preservation (Fondio et *al.,* 2007).

It is among the legumes, a plant providing products with appreciable nutritional value (Hamon and Charrier, 1997). The fruits are mainly used in the preparation of sauces.

Its high levels of carbohydrates, proteins, vitamins A and C, iron, phosphorus, potassium and magnesium have been demonstrated by Hamon (1988) and Koechlin (1989).

Roasted okra seeds are used in parts of Nigeria as a coffee substitute (Siemonsma and Hamon, 2004).

c. Sorrel *(Hibiscus sabdariffa)*

Sorrel is a genus of herbaceous plants of the family Malvaceae (Polygonaceae), growing in the wild, several species of which are cultivated as vegetable plants for their edible leaves. This plant measuring 25 to 30 cm in height is easy to grow and has the ability to multiply on its own. Rich in water and low in energy nutrients, sorrel is low in calories.

It is a very good source of provitamins A and vitamin C and provides large amounts of minerals and trace elements (iron, magnesium, calcium, manganese, copper, zinc). This plant also contains organic acids responsible for its marked tart flavor.

d. Tomato *(Solanum lycopersicum)*

The tomato is an annual plant of the Solanaceae family, native to Mexico. The term also refers to this fleshy fruit, which is one of the most important foods in the human diet and which is eaten fresh or processed. From a botanical point of view, the tomato is unquestionably a fruit, since it derives, including its seeds, from the transformation of the ovary of a flowering plant. It is a very demanding neutrophilic species, which requires deep and well-manured soil. Most of its energy intake is provided by its carbohydrates (fructose and glucose). It is a good source of vitamin C and B vitamins, including B3, B5 and B9. This vegetable contains many minerals: a lot of potassium, phosphorus, magnesium as well as trace elements: iron, zinc, cobalt, nickel, fluorine, boron (Hanan et *al.,* 2009).

2.3 . Soils under study

Three soils with different levels of pollution are concerned by this study. It is :

2.4. Protocol and experimental device

The protocol consisted in cultivating amaranth, sorrel, okra and tomato plants in soils (namely three types: control, moderately polluted and highly polluted) for four (4) weeks. Analyzes of metals in soils and in plants were carried out by ICP-MS.

To do this, surface samples of each of the three types of differently polluted soils were taken (CV: control, SR: moderately polluted, SD: heavily polluted). These samples were taken (0-10 cm) using a shovel and introduced into clean and clearly numbered bags.

The soil samples are transported to the laboratory of the Soil Science Department of the Faculty of Agronomy of Abdou Moumouni University in Niamey for physico-chemical analyses.

2.4. Physico-chemical soil analyzes

A soil sample is particularly complex. However, certain parameters provide immediate information on the main physico-chemical properties to be expected in the context of the site. These are the particle size, the pH, the organic matter content, the CEC. Their determination must be systematic in addition to the pollutant concentrations usually measured. For each type of soil, certain physico-chemical parameters were determined. These analyzes were carried out at the Soil Science laboratory of the Faculty of Agronomy of Niamey (see appendices).

2.5. Cultivation in pots

The seeds of the four plant species from the local market, Niamey, were introduced into the pots containing the three soil types. The pots are then watered daily with tap water and the development of the plants is monitored.

Culture was carried out under controlled conditions (25-30°C). These cultures were maintained for four (4) weeks until harvest.

2.6. Collection and processing of plant samples

After one (1) month of cultivation, the species for each type of soil are sampled. Sampling was carried out in such a way as to preserve the information: no losses, no pollution. We also avoided contact between the plant sample and the soil.

Thus, the samples are sent to the laboratory of the Soil Science Department of the Faculty of Agronomy of Niamey. The different parts of the plant (roots, stems and leaves) are separated, weighed (weight of fresh material) then dried at room temperature (30 to 35°C). After drying in an oven (60o C) for complete dehydration, each totally dry part is ground and the ground material is sent to the laboratory (LSE) in Nancy, France, to carry out the MTE assay.

2.7. Dosage of ETM in the three soils and in each part of the plants

0.5 g of each sample is dissolved using a mixture of hydrochloric and sulfuric acids and hydrogen peroxide (H2O2).

The extraction and dosage of TMs (in soils, roots, stems and leaves) was carried out by mass spectrometry coupled with an inductive plasma. It is an instrumental technique based on the separation, identification and quantification of the constituent elements of a sample according to their mass. The results are expressed in mg/kg of dry matter (DM). These assays were carried out at the Nancy laboratory in France.

2.8. Statistical analyzes of data

The XLStat version 2014 software was used to perform the statistical analyzes of the various data.

The Principal Component Analysis (PCA) made it possible to see the correlation between the different variables and the Discriminant Factor Analysis (DFA) made it possible to discriminate certain variables.

III. Search for endemic plants that hyperaccumulate ETM and phytoremediation

3.1. Presentation of the study area: Gounti There is

Gounti Valley Yena is located in the city of Niamey and covers an area estimated by Tankari Dan Badjo et *al.* (2012) to 38.1 ha on which mainly market gardening is practiced. The number of gardens which was estimated in 2011 at 343 tends today to increase even if on the contrary the surface of the valley tends to decrease. This translates into an increase in the production and yield of the crops grown.

Located in municipal district II, this valley collects wastewater and rainwater from several districts of the city, from Boukoki to the Zongo district before flowing into the Niger River at the convention center (Figure 3). In addition, all around the valley, there are several impurities and sources of pollution, including major roads, open dumps, and small industries.

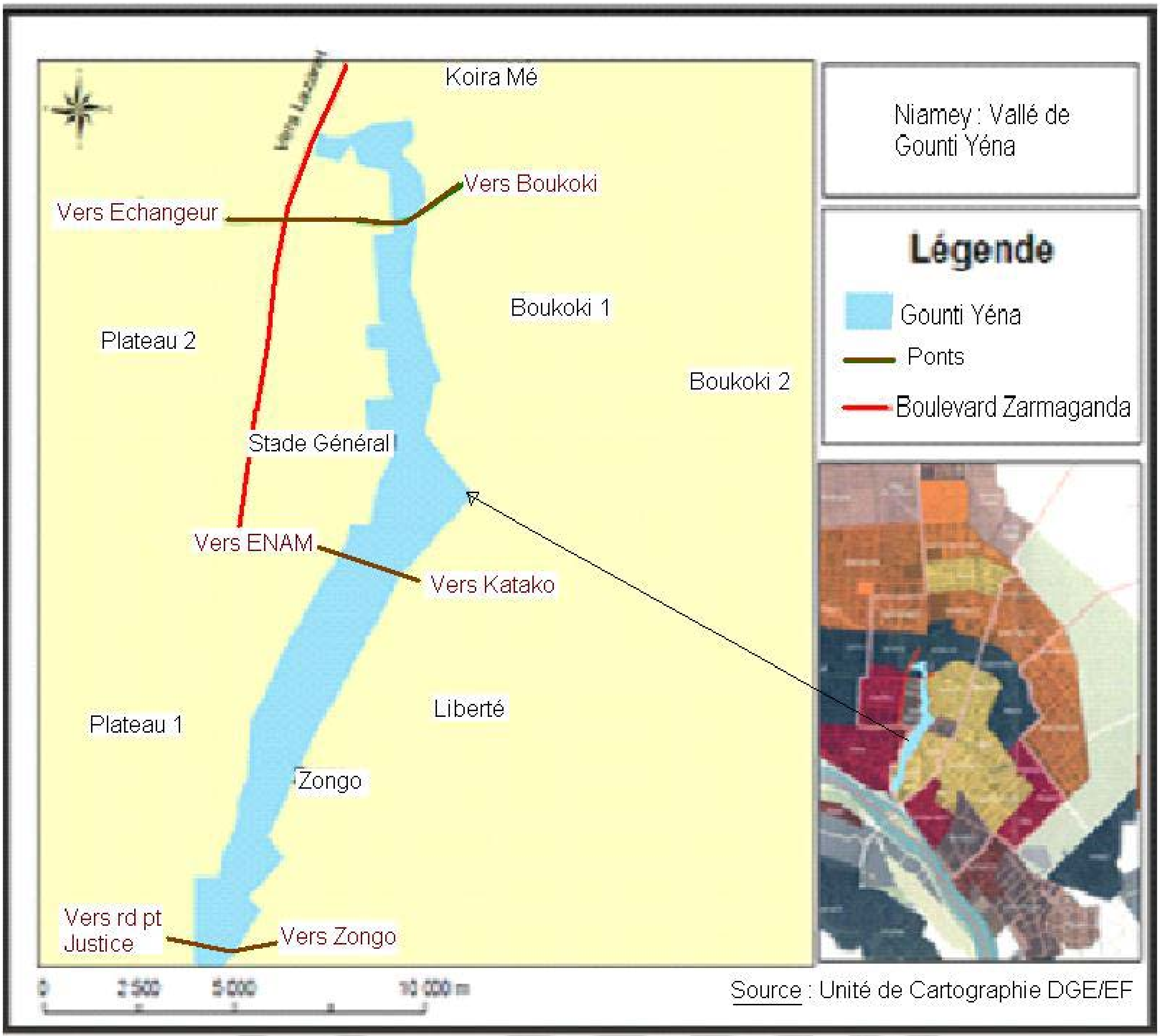

Figure 3: Location of the Gounti-Yéna valley within the urban community of Niamey (Tankari Dan Badjo et *al.*, 2012).

3.2. Valley Segmentation and Field Trip Schedule

The valley was subdivided into three parts taking into account the discontinuity of the roadways. Each portion was the subject of at least two (2) visits on a transect in order to be able to identify all the plant species found there and see the evolution of the plant cover.

3.3. Sampling of plant species

It was necessary to take samples of the plant species present in the valley. These samples were taken in several places, in particular in the wastewater and on the soil of the valley. Most of the plants were picked by hand and/or with pruning shears. Concerning the hydrophyte species, they were sampled using a rake. To protect against possible contamination, gloves, bibs and socks were used.

To confirm that the plant species likely to be hyperaccumulators actually are, the same plant species were sampled at a contaminated site, in particular the Komabangou gold site . The same methodology was used to collect these plants.

3.4. Photo shoots

Each visit to the field is subject to shooting. A large number of plant species were photographed. The shots therefore helped to identify certain species. Photographs also made it possible to follow the evolution of the plant cover, but also illustrations and archives.

3.5. Transport and storage

Before their identification, the plants sampled are bagged and transported to the soil science laboratory of the Faculty of Agronomy. To conserve and archive certain species, herbariums have been established.

3.6. Species identification

The identifications were carried out in two phases in order to avoid making mistakes. The first consists of a direct floristic determination in the field with the contribution of market gardeners who were able to identify certain vernacular (mainly) or scientific names. The second phase is the confirmation or invalidation of the first identification. Thus, the determinations issued in the field were adopted when the floristic works, in particular the lexicon of vernacular names of plants from Niger (Volume I: scientific names - vernacular names) confirmed them, and rejected when these invalidated them.

3.7 . Soil preparation, ETM dosage and cultivation

As part of this study, the phytoremediation of two (2) soils polluted by ETM over one (1) month of cultivation was implemented. First, the soils were collected and transported in bags to the Soil Science Laboratory of the Faculty of Agronomy of Abdou Moumouni University in Niamey where they are dried at room temperature. After drying, the soils are crushed and sieved (2 mm) then conditioned for Pb, Cd, Cu and Zn assays at the Geology Laboratory of the Faculty of Sciences of the University of Lomé in Togo by atomic absorption. Then they are distributed in pots at the rate of 1.5 kg per pot and five (5) repetitions per plant species. Finally, the selected plant species were sown: *Datura innoxia* , *Ricinus communist* and *Cyperus esculentus* . The crops are watered daily with tap water (250 ml/pot) for one month.

3.8. Collection, preparation and analysis of samples of plant species

After a month of cultivation, the plants are removed from the pots. They are carefully washed with tap water then with distilled water and all precautions (contact between the different parts of the plant and the substrate) are taken to avoid possible contamination. The roots, stems and leaves are separated.

They are dried at room temperature then in an oven at 60° for 24 hours for complete dehydration. The dry matter produced by each plant species is crushed and well conditioned. The shredded material from each part of the plants is sent to the Geology Laboratory of the Faculty of Sciences of the University of Lomé in Togo in order to determine the concentrations of Pb, Cd, Cu and Zn by atomic absorption.

Results and discussion

I. Concentrations of ETM in the soils of the gounti yena valley

The results show that the values of the concentrations of ETM in the soils of the Gounti valley Yéna are very disparate.

In the control soil, only As, Pb and Zn were detected among the 9 metals sought with concentration values varying respectively from 0.13 to 0.32 mg/kg, from 4.30 to 5.12 mg/kg and 5.40 to 10.10 mg/kg.

In the soils of the Gounti Valley Yéna , the results obtained show that the average concentration values are highly variable and range between 0.01 and 4.23 mg/kg for As, 0.03 and 3.56 mg/kg for Cd, 0, 01 and 50.85 mg/kg for Co, 0.01 and 369.42 mg/kg for Cu, 0.01 and 1.26 mg/kg for Hg, and between 0.01 and 23.05 mg /kg; 0.01 and 725.66 mg/kg and 0.01 and 5546.30 mg/kg respectively for Ni, Pb and Zn.

The highest mean concentration is observed for Zn followed in descending order by those of Pb, Cu, Cr, Co, Ni, As, Cd and Hg. This order found is similar to that of Tankari Dan Badjo et *al.* (2013) in their study of urban and peri-urban soils of the city of Niamey which is: Zn > Pb > Cu > Cr > Ni > Co > As > Cd.

The only difference is at the level of Co and Ni. In our case, it is the concentration of Co which is higher than that of Ni. This difference could be due to the effects of handling.

The average levels of ETM observed in the soils of the Gounti valley Yena are much higher than those detected in the soil of the control site. For Zn for example, the average concentration in the soils of the Gounti Valley Yéna is 38 times greater than that detected in the control soil; which suggests a contamination of the soils of this valley by MTEs in particular Zn coming from road emissions, waste water, fertilizers used and other anthropogenic activities (industry, various cooking) carried out within and around gounti Yena .

In a study evaluating the level of surface soil contamination in the city of Changchun in China (Yang, 2011), the average concentrations of As, Hg, Cd, Cr, Cu, Zn and Pb are respectively equal to : 12.5mg/kg; 0.11mg/kg; 0.13mg/kg; 66.0mg/kg; 29.4mg/kg; 90mg/kg and 35mg/kg. We note that despite the great industrialization of China, the values obtained in the soils of the Gounti Valley Yéna for Hg, Cd and Zn are respectively 2, 3 and 3 times higher than those found in the urban soil of the city of Changchun in China.

Also, the Pb and Zn values detected at certain sampling points in the soils of the Gounti Valley Yéna are respectively 3 and 4 times higher than those found by Ali et *al.* (2006) in the soils of the city of Islamabad in Pakistan (Pb: 202 mg/kg and Zn: 1634 mg/kg against 725 mg/kg and 5546 mg/kg respectively for Pb and Zn in the valley of gounti Yena). As part of a study on the spatial distribution of concentrations of MTEs in urban and suburban areas and in agricultural soils in the Mediterranean city of Annaba in Algeria (Maas, 2010), the average levels obtained for Cd, Pb and Zn are respectively equal to 0.44 mg/kg; 3.1mg/kg and 67.5mg/kg. These average values are much lower than the averages in Cd, Pb and Zn obtained in the soils of the Gounti valley. Yena which are respectively 0.52 mg/kg; 39.51mg/kg; 278.01mg/kg.

In other words, the soils of the Gounti Valley Yéna turn out to be very polluted in MTE (Pb, Zn, Cu, Cr, Co, Ni, As, Cd and Hg) compared to those of Chanchung in China, Islamabad in Pakistan and Annaba in Algeria.

The As concentration fluctuating between 0.93 and 1.66 mg/kg in the Gounti Valley Yéna is mainly due to smoke (Adriano, 2001; Kabata-Pendias and Pendias , 2001). Which, no doubt explains a high concentration of this metal at the level of the Gounti valley Yéna where large quantities of smoke from various cooking, incineration and burning are emitted every day.

Cd concentration in soils at different sampling points along the Gounti Valley Yena varies between 1.43 and 3.56 mg/kg. This Cd content in the soils of the Gounti Valley Yéna would essentially come from the incineration of urban waste, foundry activities, the refining of non-ferrous metals, the combustion of coal, the incineration of household waste and phosphate fertilizers (Kouakou *et al.*, 2005).

The presence of Cr in the Gounti Valley Yena would be due to activities such as metallurgy, waste incineration and coal combustion which are major sources of Cr releases. This explains why at certain sampling points close to the areas where these Cr-generating activities take place, levels varying between 34.7 and 68.49 mg/kg were assayed.

Co contamination of the soils of the Gounti Valley Yena would be due to industrial activities and the incineration of garbage in the surroundings but also by the abundance of Mn and Fe oxides. Its availability increases with increasing acidity (Manda *et al.,* 2010).

The Cu contents come from natural sources such as the transport by the wind of dust from the ground, the incineration of household waste and the manufacture of fertilizers (Kouakou *et al.,* 2005).

The presence of Hg in the Gounti Valley Yena would be due to hospital waste, batteries and fluorescent bulbs. Certain industrial activities can also be the source of Hg contamination in the soil: mining activities, wastewater, and the use of fungicides also lead to Hg pollution.

The presence of Ni in the soils of the Gounti Valley Yena would come from wastewater. Ni is indeed generally found in wastewater and is absorbed into sediments, soil particles and subsequently becomes immobile.

As for Pb, the high levels detected in the Gounti valley Yena would be mainly due to the constant presence of smoke, solid industrial waste, recycling of electric batteries and road traffic.

Zn contamination in the Gounti Valley Yena would come from wild dumps and industrial activities. Zn is considered easily soluble, compared to other metals in soils (Baize , 2000).

Soil pollution in the Gounti Valley Yena by ETM can be represented by the level of ETM contamination for different places in the valley. Thus, the map below (figure 4) represents the pollution zones of the Gounti valley Yena by level of predominance.

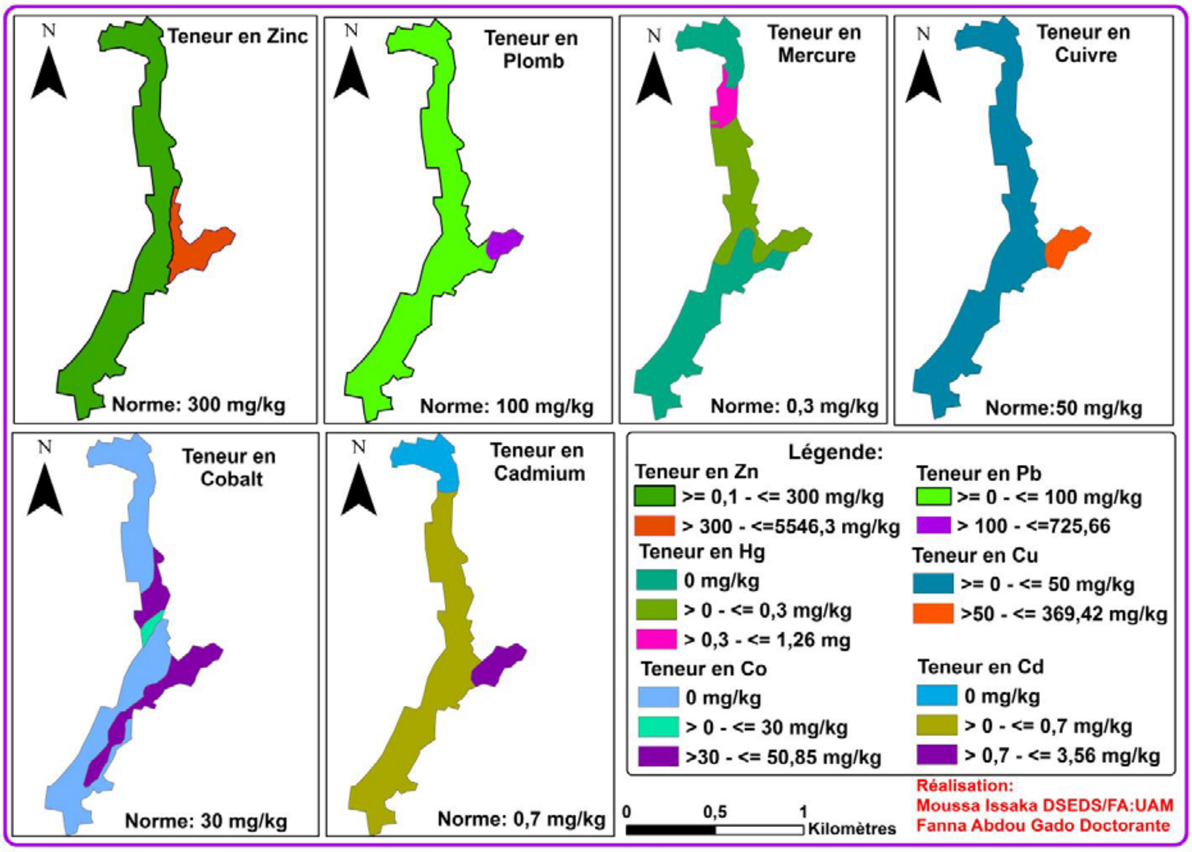

Figure 4: Spatialization of MTE pollution in the Gounti Valley Yena.

II. Chemical and physical characteristics of soils for the study of ETM transfer

2.1. ETM concentrations in the three soils

The concentrations of metallic trace elements in the three soils as well as the AFNOR regulatory standards.

From the analysis of the table, we note that the concentrations of ETM vary according to the type of soil, but also according to the element concerned. They are generally higher in the soil of the katako landfill followed by the soil of the boulevard and finally that of the green belt, considered as a control.

In the soil of the landfill, the high concentrations of ETM can be explained by the various sources of ETM to which this site is exposed (uncontrolled dumps, road traffic, waste water, incineration and burns, etc.). The concentration of Co dosed in the soil of the landfill (58.36 mg/kg) is almost double the regulatory standards for Co (30 mg/kg). That of Mn, 1615.83 mg/kg, is much higher than the regulatory standard which is 270 mg/kg. For the other MTEs, even if the concentrations are high, they do not exceed the AFNOR standards.

In the control soil, none of the MTEs detected exceeded the regulatory value of the AFNOR NFU 44-04 standards and the concentrations measured were much lower than those measured in the soil of the katako landfill and still much lower than the regulatory standards. However, this low presence of ETM at the level of the green belt control ground would be due to the wind.

In the soil of boulevard Mali Béro, even if some values are high, none exceeds the AFNOR standard. Nevertheless, they are much higher than those recorded in the control soil of the green belt.

All the concentrations that we obtained are lower than those detected by Tankari Dan Badjo et *al.,* (2013) at the treatment plant of the National Hospital of Niamey. Much higher levels than those we recorded were obtained in Algerian soil (Baba Ahmed, 2012). For example, he obtained 9.49 mg/kg for Cd, 121.49 mg/kg for Ni and 127.4 mg/kg for Co. This shows that the soils of the Gounti valley Yéna are little contaminated with ETM compared to those of Algeria and this would be explained by the low industrialization of the city of Niamey.

It should also be noted that the ETM contents in the soil of the Katako landfill are high with the following decreasing order: Al > Mn > Pb > Co > Ni > Cd. These high contents of Al, Mn, Pb, Co, Ni and Cd represent a danger for the population in the sense that these ETMs are toxic to health.

2.2. Determination of ETM levels in each plant grown on the three soils used

The concentrations of ETM recorded in the soil led to the study of their accumulation by plants. Thus, the six metallic trace elements (aluminum, cadmium, cobalt, manganese, lead and nickel) were searched for in the leaves, stems and roots of the four plants grown on these soils (amaranth, sorrel, okra and tomato). In this section the results are presented.

2.3. Balance sheet of ETMs transferred

2.3.1. From the soil of the Green Belt to the plants

The total concentrations of ETM accumulated by the different plants grown on the soil of the landfill are calculated from the concentrations assayed in each of their vegetative parts. The results are shown in Figure 5.

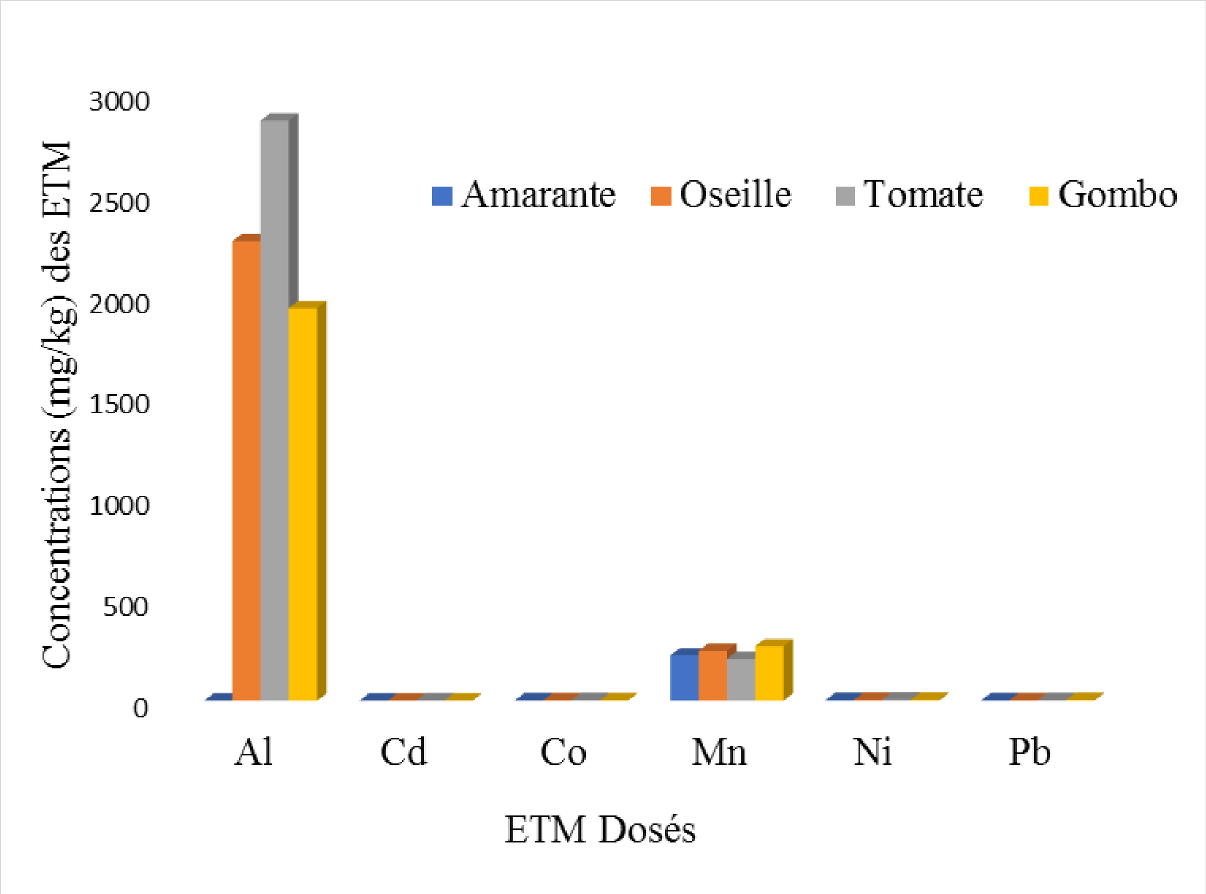

Figure 5: Balance sheet of ETM transferred from the soil of the green belt to amaranth, sorrel, tomato and okra.

Analysis of this figure shows that for all plants, the most transferred metallic element is Al with concentrations of 2024.65; 2,276.47; 2874.64 and 1945.34 mg/kg respectively in amaranth, sorrel, tomato and okra. It is closely followed by Mn, Ni, Pb, Co and Cd.

Of the four plants, tomato is the most contaminated with Al followed by sorrel, amaranth and okra.

In the soil of the green belt, the tomato is the plant species towards which there is more transfer of ETM with a total concentration of ETM in tomato of 3095.28 mg/kg.

These results indicate that Al is the most phytoavailable and the tomato the most contaminated.

2.3.2. From the soil of Boulevard Mali Béro to the plants

The total concentrations of ETM accumulated by the different plants grown on the ground of Boulevard Mali Béro are calculated from the concentrations measured in each of their vegetative parts. The results are shown in Figure 6.

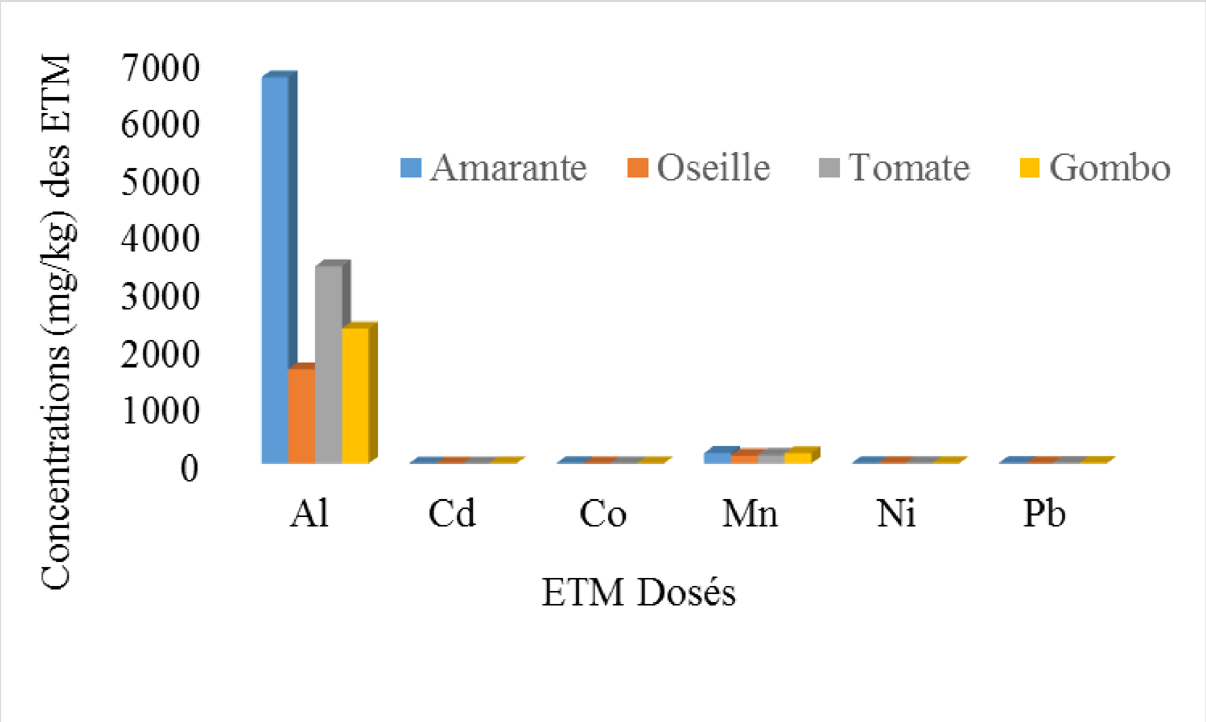

Figure 6: Balance sheet of ETM transferred from the soil of Boulevard Mali Béro to amaranth, sorrel, tomato and okra.

Analysis of this figure shows that for all plants, the most transferred metallic element is Al with concentrations of 6,721.4; 1,638.91; 3431.52 and 2346.36 mg/kg respectively in amaranth, sorrel, tomato and okra. It is closely followed by Mn, Pb, Co, Ni and Cd.

Of the four plants, amaranth is the most Al contaminated followed by tomato, okra and sorrel.

In the soil of boulevard Mali Béro, amaranth is the plant species towards which there is more transfer of ETM with a total concentration of ETM of 6,926 mg/kg of ETM transferred.

These results therefore indicate that Al is the most phytoavailable and the most contaminated amaranth.

2.3.4. From the soil of the Landfill to the plants

The total concentrations of TMs accumulated by the different plants grown on the ground of the katako landfill in the Gounti valley Yena are calculated from the concentrations measured in each of their vegetative parts. The results are shown in Figure 7.

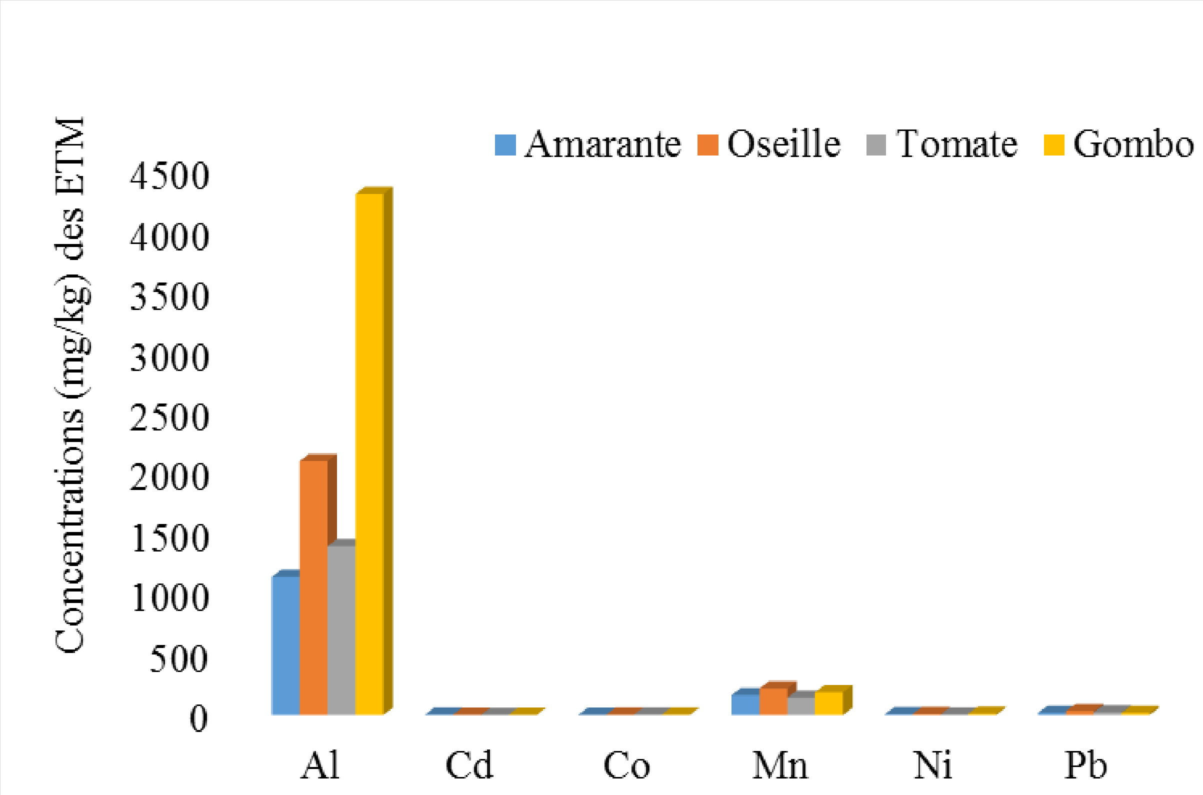

Figure 7: Balance of TMs transferred from the soil of the Katako landfill in the Gounti Valley Yéna towards amaranth, sorrel, tomato and okra.

Analysis of this figure shows that for all plants, the most transferred metallic element is Al with concentrations of 1,140.17; 2,096.22; 1394.29 and 4302.49 mg/kg respectively in amaranth, sorrel, tomato and okra. It is closely followed by Mn, Pb, Co, Ni and Cd.

Of the four plants, okra is the most contaminated with Al followed by sorrel, tomato and amaranth.

The plant species found in the valley are classified by family and according to whether they are lignified or not, but with their relative abundance. Thus, two tables have been established, the first of which presents the herbaceous and the second the woody ones.

III. Presentation of species by family

3.1. herbaceous vegetation

Table I presents the herbaceous plants of Gounti Yéna classified by family with the relative abundance of each species.

Table I: Gounti herbaceous plants Yena classified by families.

Family/Number of species	**Scientific names**	**Plenty**
Cyperaceae (4 species)	*Round cyperus*	++
	Cyperus bulbosus	+++
	Cyperus esculentus	+++
	Cyperus articulatus	++
Euphorbiaceae (4 species)	*Chrozophora senegalensis*	++
	Chrozophora brocchia	+
	Phyllanthus pentandrus	+
	Manihot esculenta	+
Gramineae (7 species)	*Eragrostis pilosa*	++++
	Pennisetum glaucum	+
	Sorghum bicolor	+
	Digitaria gayana	++
	Dactyloctenium aegyptium	+++
	Cenchrus biflora	+
	Zea mays	++
Liliaceae (1 species)	*Eichornia crassipes*	++
Malvaceae (1 species)	*Hibiscus sabdariffa*	++
Musaceae (1 species)	*Musa acuminata*	++
Umbelliferae (2 species)	*Dacus carrot*	++
	Petroselinum sativa	+
Papilionaceae (2 species)	*Vigna unguiculata*	+
	Sesbania leptocarpa	+
Pedaliaceae (1 species)	*Ceratotheca sesamoids*	+
	Lycopersicon esculentum	+

Solanaceae (5 species)	*capsicum grossum*	+
	capsicum annum	+
	Datura innoxia	+++
	D.stramonium	++
Tiliaceae (3 species)	*Corchorus tridens*	+
	Corchorus fascicularis	+
	Corchorus olitorius	++
Zygophyllaceae (1 species)	*Tribulus terrestrial*	+++
24	**59**	**Total**

+: very sparse; ++: scarce; +++: abundant; ++++: very abundant.

According to Table I, the valley of Gounti Yena contains twenty-four (24) families of herbaceous represented by fifty-nine (59) species. Moreover, it appears that:

✓ The Cucurbitaceae, Euphorbiaceae, Solanaceae and Gramineae families are the most represented with more than four (4) species each.

✓ Some families such as Malvaceae and Liliaceae are represented by only one species.

✓ *Eragrostis pilosa* is the most abundant herb.

✓ *Dactyloctenium Aegyptium, Datura innoxia ; Datura stramonium, Luffa cylindrica, Eragrostis pilosa , Cyperus bulbosus, Amaranthus spinosus, Amaranthus hybridus* are present and fairly abundant throughout the valley.

✓ *Sesbania leptocarpa, Sorghum bicolor, Manihot esculenta, Gynandropsis gynandra, Pennisetum glaucum* are poorly represented everywhere.

3.2. woody vegetation

As in the case of herbaceous plants, the woody species of the valley are classified by family while notifying their relative abundance (table II):

<u>Table I:</u> Gounti trees Yena classified by families.

Family/Number of species	**Scientific names**	**Plenty**
Anacardiaceae (2 species)	*Manguifera indica*	++
	Sclerocarya birrea	+
Bombacaceae (1 species)	*Adansonia digitata*	+
Caesalpiniaceae (2 species)	*Cassia sieberana*	+++
	Tamarindus indica	+
Caricaceae (1 species)	*carica papaya*	+
Combretaceae (2 species)	*Combretum glutinosum*	+
	Terminalia mantaly	++
Euphorbiaceae (1 species)	*Ricinus communist*	+
Meliaceae (1 species)	*Azadirecta indica*	++
Mimosaceae (4 species)	*Acacia albida*	+
	Acacia nilotica	+
	Acacia polyacantha	+
	Prosopis juliflora	++++
Moraceae (1 species)	*Ficus platyphylla*	++
Moringaceae (1 species)	*Moringa oleifera*	++
Myrtaceae (1 species)	*Eucaliptus*	++
Palmaceae (3 species)	*Borassus aethiopum*	++
	Hyphaene thebaica	+++
	Phoenix dactylifera	+++
Rosaceae (1 species)	*Papinari macrophylla*	+
Storculiaceae (1 species)	*Cola lauriflora*	+
Verbenaceae (1 species)	*Vitex doniana*	+
Zygophyllaceae (1 species)	*Balanites aegyptiaca*	+

16	**24**	**Total**

+: very sparse; ++: scarce; +++: abundant; ++++: very abundant.

Based on the analysis of Table II, twenty-four (24) ligneous species distributed in sixteen (16) families were counted in the Gounti Yena . Unlike herbaceous plants, the different woody families are generally represented by one or two species, with the exception of the Palmaceae (3 plant species) and Mimosaceae (4 plant species) families.

The number of herbaceous species (59) is higher than that of woody species (24). This could be explained by the fact that ligneous plants have a longer development cycle than herbaceous plants, hence their low number.

Most species have low abundance. But plant species *: Phoenix dactylifera , Hyphaenethebaica , Cassia sieberiana* all have average relative abundances. *Prosopis juliflora* is the most abundant woody species with an almost homogeneous distribution.

Gounti Valley Yéna has a well marked floristic richness. Although the soils are known to be polluted and contaminated, they abound in a diversity of plant species which are developing well. These species belong to twenty-two (22) families for herbaceous and seventeen (17) families for ligneous. The number of ligneous plants is very small compared to that of herbaceous plants.

Some plants are relatively very abundant over the extent of the valley while others are very poorly represented.

This is in line with the thesis put forward by several authors according to which most ligneous plants do not tolerate large quantities of metals well. Contrary to these ligneous plants, herbaceous plants are numerous and develop very quickly, sometimes more than those which live in a normal environment.

Most of the species identified have unfortunately never been studied in Niger or tested in terms of depollution, although they grow and emerge well in the polluted environment. Ten (10) herbaceous species and four (4) ligneous species (a total of 14 plant species) are presented as hyper accumulators of metals and would be good test subjects for phytoremediation.

The high number of herbaceous plants could be explained by the fact that they support the presence of MTEs more than woody plants and therefore obviously are more accumulative. They are easier to handle and harvest. Unlike herbaceous plants, lignified plants have a very long development cycle, the walls of their roots are more rigid, making the assimilation of

ETM more difficult. As a result, herbaceous plants are more suitable for phytoremediation than woody ones.

IV. Phytoremediation test

The phytoremediation test performed with *Cyperus esculentus* , *Datura innoxia* showed that these plants do indeed tolerate pollution since they developed well both in the polluted soil and in the control soil with the exception of *Ricinus communis* . Plants used in this phytoremediation study accumulated TEs in their roots, stems and leaves. The extraction depends on the metal, its concentration and the species.

These results show that *Cyperus esculentus* , *Datura innoxia* and *Ricinus communist* are good species that could decontaminate soil polluted by several metals. Indeed, at the end of this study, we propose *Cyperus esculentus* for the depollution of soils contaminated by Cd and Zn which are very toxic metals. *Datura innoxia* and *Ricinus communist* for the remediation of soils contaminated by Cu and Zn. However, the most suitable plant species that we propose to extract Zn is *Ricinus communist* (260.53%) followed by *Datura innoxia* (232.71%) and finally *Cyperus esculentus* (110.96%). Zn can be recovered (in just 4 weeks) from the vegetative parts of these plants and be used for other purposes such as its use as a trace element in very small quantities. For the extraction of Pb, we indicate the plant species *Cyperus esculentus* .

After four weeks of treatment of the polluted soils, the plants were able to extract up to 60.8% of metal, in particular Cu. If we make an estimate from metal extraction rates, it would take *Cyperus esculentus 9 months on average* to “completely” extract the Pb; 15 months on average for *Datura innoxia* to “completely” extract the Pb and 40 months on average at *Ricinus communist* to "completely" extract the Pb. This confirms that phytoremediation is a long technique that extends over several years (generally between 2 and 3 years to "completely" decontaminate a soil).

Of these three plant species, the decontamination capacity of *Cyperus esculentus* appears superior to the decontamination capacity of the other two (*Datura innoxia* and *Ricinus communis*) because having allowed the extraction of 10.629% of Pb, 120% of Cd 34.67% of Cu and 44.27% of Zn. *Cyperus esculentus* is a plant species that adapts to all types of soil and all types of stress.

Conclusion

The study of soil contamination in the Gounti Valley Yena highlighted the presence of nine TEs, the majority of whose concentrations exceed the regulatory standards. Which confirms our hypothesis 1, the valley of Gounti Yena is polluted by ETM. Among these levels which exceed the standards are those of ETM such as Pb, Hg, Cu, Cd which are particularly toxic. These nine (9) ETMs sought in the soils of the Gounti Valley Yena , namely As, Pb, Zn, Cu, Cr, Co, Ni, Cd and Hg, were measured on all the sampling transects. The concentrations at certain points were much higher than the regulatory standards.

This is how the study of the transfer of ETM from soils to plants. It was noted during this study, that the transfer of the ETM is generally done from the roots to the leaves and that the stems seem to be intermediate. The rate of accumulation of ETM is higher in okra and lower in amaranth, but it has been observed for this species that the leaves accumulate more than the roots, which represents a danger for consumers. It is the same observation for sorrel. Gounti Valley Yena is an area of market gardening par excellence. The results of the study of the transfer of ETM from the soil to four (4) species (amaranth, sorrel, okra and tomato) showed that there is indeed a transfer taking place. This confirms our initial hypothesis 2. This transfer follows the root-stem-leaf gradient. This study also showed that the transfer could continue to seeds and fruits.

One of the main objectives of this study was to set up a phytoremediation test of the Gounti Valley Yena . Indeed, field visits revealed that some plant species were developing well despite the presence of metal pollution in the valley. On this basis, all plant species in the Gounti Valley Yéna were first inventoried and thanks to the literature those likely to be hyperaccumulators were retained. The results showed the presence of 24 herbaceous families and 16 woody families. Following this inventory, 14 plant species are deemed to be hyper-accumulators. This result is in perfect agreement with our hypothesis 3 according to which the endemic plants of the Gounti valley Yena would be hyper-accumulators. Among these, 5 plant species were retained as being hyperaccumulative , of which 3 plant species were the subject of phytoremediation tests.

Also, this study meets the objectives set but also raises several points that would need to be investigated in order to better assess the mobility of ETMs and the risk to human health.

Bibliographic references

Kirpichtchikova T., Manceau A., Spadini L., Panfili F., Marcus M. A., Jacquet T., 2006. Phytoremediation par Jardins Filtrants d'un sol pollué par des métaux lourds : Approche de la phytoremediation dans des casiers végétalises par des plantes de milieux humides et étude des mécanismes de remobilisation/immobilisation du zinc et du cuivre. Géochimie. Université Joseph-Fourier - Grenoble I, 2009.

Kjeldsen P., Barlaz M.A., Rooker A.P., Baun A., Ledin A., Christensen T.H., 2002. Present and long-term composition of msw landfill leachate: a review. Critical Reviews in Environmental Science and Technology 32(4):297-336.

Kodama H., Nelson S., Yang A. F., Kohyama N., 1994. Mineralogy of rhizospheric and non-rhizospheric soils in corn fields. *Clays Clay Miner.* 42, 755-763.

Koechlin J., 1989. Les gombos africains (*Abelmoschus ssp*) : Etude de la diversité en vue de l'amélioration. Thèse Doctorat, Institut National Agronomique. Paris-Grignon, France. 180P.

Koopal L.K., Willem H., Van Riemsdijk D.G., Kinniburgh., 2001. Humic matter and contaminants. General aspects and modeling metal ion binding, Pure Appl. Chem., Vol. 73, No. 12, pp.

Kouakou K.J., Bekro Y.A., Sika A.E., Baize D., Dogbo D.O., Bounakhla M., Macaigne P., 2005. Diagnostic D'une Contamination Par les Éléments Traces Métalliques de L'épinard (Spinacia Oleracea) Cultivé Sur des Sols Maraîchers de la Ville D'abidjan (Côte D'ivoire) Amendés Avec de la Fiente de Volaille. *Editorial Advisory Board e*, *21*(3), 471-487.

Lanson B., Marcus M. A., Fakra S., Panfili F., Geoffroy N., Manceau A., 2008. Formation of Zn-Ca phyllomanganate nanoparticles in grass roots. Geochim. Cosmochim. Acta 72, 2478 2490.

Laperche V., Logan T. J., Gaddam P., and Triana S. J., 1997. Effects of apatite amendment on plant uptake of lead from contaminated soil. Environ. Sci. Technol. 31, 2745-2753.

Tabatabai M.A., 1982. Soil enzymes. In: Page, A.L., Miller, E.M., Keeney, D.R. (Eds.), Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties. America Society of Agronomy, Madison, pp 903–947.

Tankari Dan Badjo A., Guéro Y., Dan Lamso N, Baragé M., Balla A., Sterckeman T., Echevarria. G., Feidt C., 2013. Évaluation des niveaux de contamination en éléments traces métalliques de laitue et de chou cultivés dans la vallée de GountiYena à Niamey, Niger. Journal of Applied Biosciences 67 :5326 – 5335.

Tankari Dan Badjo A., Guéro Y., Dan Lamso N., Moussa Taweye O., 2012. Risque d'exposition de la population de Niamey (Niger) aux métaux lourds à travers la consommation des produits maraichers. Revue des Bioressouces 2 : 88-99.

Tankari Dan Badjo., Y Guéro., N Dan Lamso., D Tidjani., K Ambouta, C Feidt, T., Sterckeman et Echevarria G., 2013. Evaluation de la contamination des sols par les éléments traces métalliques dans les zones urbaines et périurbaines de la ville de Niamey (Niger). Revue des BioRessources 3, 82-95.