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Physico-Chemical Properties of Soils from Diguel and Koudalwa Tchad, and Phytoremediation Potentials of Acasia and Kinkeliba Plants in Removing Cr and Cu from These Soils

Dieudonne Caleb Dahaina[1], Jean Claude Doumnang Mbaigane[2], Bobet Ouanmini[3] and Cornelius Tsamo[4,5]

1. Department of Chemistry, Faculty of Exact and Applied Sciences, University of N'Djamena, BP 1027, N'Djamena, Chad

2. Laboratoire de Géologie, Géomorphologie et Télédétection, Faculté des Sciences Exactes et Appliquées, Université de N'Djaména, BP 1027, N'Djamena, Chad

3. Laboratoire de Chimie, Ecole Normale Supérieure de Bongor, BP 13, Bongor, Tchad

4. Department of Chemistry, Higher Teachers' Training College, University of Maroua, P.O. Box 55 Maroua, Cameroon

5. Department of Agricultural and Environmental Engineering, College of Technology, University of Bamenda, P.O. BOX 39, Bambili, Cameroon

Abstract: The aim of this study to investigate the physico-chemical properties of soils from Diguel and Koudalwa Tchad, and phytoremediation potentials of acasia and kinkeliba plants in removing Cr and Cu from these soils. Soil was sampled from the tannery plant in Diguel and agricultural land around crude oil activities in Koudalwa. Soils were characterized by the following properties: pH, (Electrical Conductivity), TDS (Total Dissolved Solids), salinity, bulk density, OM (Organic Matter), nitrate, phosphate, clay, silt, sand, and textural class. The acasia and kinkeliba plants were used to decontaminate Cu and Cr from sample soils for 30 days period. The bulk density of all the soil samples from Kouldawa was higher compared to Diguil, ranging from 1.421 to 1.64 g/cm^3 compared to 1.21 to 1.51 g/cm^3 for Diguel. Most of the soils in Kouldawa are mineral soils, while those of Diguel are mostly mineral soil with some organics. Diguel soils are richer in nitrate (577.9 to 2,687.32 mg/kg in Diguel and 33.64 to 197.64 mg/kg in Kouldawa) and phosphate than soils from Kouldawa. Soils from the studied areas are not saline except for a subsurface soil in Diguel (salinity, 4.21; EC, 4.280 dS/m; TDS, 3,040 mg/L). The highest amount of Cr and Cu removed by acasia is 78% and 53.12% compared to 73.8% and 52.21% by kinkeliba. Diguel soil can be very suitable for agriculture and Kouldawa soils for construction. Acasia and kinkeliba can be effectively used to decontaminate the studied soils from heavy metal pollution.

Key words: Soil, physico-chemical properties, phytoremediation, heavy metals, Tchad.

1. Introduction

Soil is very important component of the environment because it plays several roles such as a medium for growth of all kinds of plants, provides the physical support to the plants, supplies moisture and nutrients for plant growth, serves as a home for a myriad of organisms, acts as a living filter to clean water before it moves into an aquifer, acts as a recycling system for nutrients and organic waste, stores a house of nutrients, modifies the atmosphere by emitting and absorbing gases (carbon dioxide, methane, water vapor, and the like) and dust, and more importantly, the receptor of large quantities of pollutants. The ability of a soil to perform these roles depends on its physico-chemical and biological properties which have been found to

Corresponding author: Cornelius Tsamo, Ph.D., Associate Professor, research fields: applied chemistry.

play significant roles in crop production particularly [1].

Soil is the basic resource for economic development and for maintaining sustainable productive landscapes and people's livelihoods, especially for most developing countries [2]. Unfortunately, soil is seriously exposed to decay and degradation with time, with negative consequences especially with agricultural production. This decay is principally caused by increasing world population accompanied by creation of industries, increased agricultural activities involving overuse of chemical fertilizer, inappropriate land uses, or other management practices on soils causing soil erosion [3, 4]. These activities cause serious deterioration of soil physical, chemical, and biological properties leading to problem of food insecurity, loss of fertile land, effect on human health and ecosystem in general, and contamination of water resources. Some of the soil properties affecting plant growth include soil texture, aggregate size, porosity, aeration, and water holding capacity [5]. One of the group of pollutants that can contaminate the soil and degrade its quality are heavy metals. Although naturally ubiquitous in the soil environment, excessive amounts of heavy metals in soils, resulted from human activities such as mining, smelting, electroplating and other industrial processes, can be harmful to the environment [6]. Heavy metals easily accumulate in the environment, are not degradable, have strong bioavailability, and by entering the environment, they can easily enter the human body through the food chain. Some heavy metals, such as Zn and Cu, are beneficial to human health, are important mineral elements in body organs, and play a vital role, but they may be toxic and even cause mental illness when ingested in excess [7, 8]. Other heavy metals have only serious toxic effects on the human body. For example, As exposure is related to skin cancer, liver cancer, lung cancer, and kidney cancer, it has been listed in the first category of carcinogens by the World Health Organization; Hg may permanently damage the brain, liver, and other organs through oral ingestion, inhalation, or dermal contact. Long-term lowdose exposure to Hg in pregnant women may cause fetal Minamata disease; long-term exposure to Pb may lead to various cardiovascular diseases and even carcinogenesis; Cr intake is closely related to breast cancer death; Cd is one of the causes of chronic kidney disease. A small amount of Cd intake may lead to a decrease in bone density, thereby increasing the risk of osteoporosis and fractures. Long-term Ni exposure may cause skin diseases, and severe cases may cause various respiratory diseases [9].

Due to the toxicity of these metals, there is need to remove them from the soils so as to enhance plant growth and protect human health. Many physical, chemical, and biological approaches have been employed for remediating the environmental pollution, however, their applications are limited due to the cost and labor requirements, safety hazards, and risks to ecosystems [10, 11]. An alternative technique, phytoremediation, can be an effective technique and is gaining popularity, acceptance, and implementation. Phytoremediation technique utilizes plants to remediate the contaminated media including soil and water. Phytoremediation is an economically and environmentally favorable technique as it utilizes green plants to contain, sequester or detoxify contaminants from contaminated soil and water [12]. While several authors [13] have studied physico-chemical properties of soil worldwide, almost no such study exists in Tchad as author [14] studied the "Application of Remote Sensing for Impacts Assessment of Petroleum Activities and Facilities in Bongor Basin, Chad Republic" while Prosper et al. [15] studied the impact of oil installations on groundwater resources in Bongor Basin, Republic of Chad and determined heavy metals in soils of Koudalwa around the oil installations. Dahaina et al. [16] studied heavy metals levels and contamination status in soils of Koudalwa, Tchad without studying the soil properties. Pytoremediation of heavy metals from soils of Tchad is also scarce in literature. This study is therefore aimed at investigating the physico-chemical properties of soils from Diguel and Koudalwa Tchad, and phytoremediation potentials of acasia (genus *Acacia*) and kinkeliba (*Combretum micranthum*) plants in removing Cr and Cu from these soils. The study site, Diguel has a tannery plant while Koudawa sites are agricultural areas around oil wells and left over oil fields. Local acasia and kinkeleba plants will be tested for their Cu and Cr(VI) phytoremediation potentials. The acasia and kinkeliba plants grow very well in the study areas with Sahelian climate.

2. Material and Methods

2.1 Study Area and Soil Sampling

This study was conducted firstly in the Koudalwa (Fig. 1a) situated within the Bongor Basin (which is the capital of the region of East) which is located between longitude 15.15 ° and 17.50 ° E and between latitude 9 ° and 11.25 °N covering approximately 105,767 km^2 [15]. The second site was Diguel (*Latitude 12.13058 ° nord; Longitude 15.07816 ° East*) [17], in Fig. 1b, located in the 8th district of Ndjamena, Tchad's political capital. Koudalwa has a transitional zone between Sahelian and sudanese climates, with vegetation being mainly sudanese shrub savanna supported by sandy textured soils [15] while Diguel has Sahelian climate with very sandy soil.

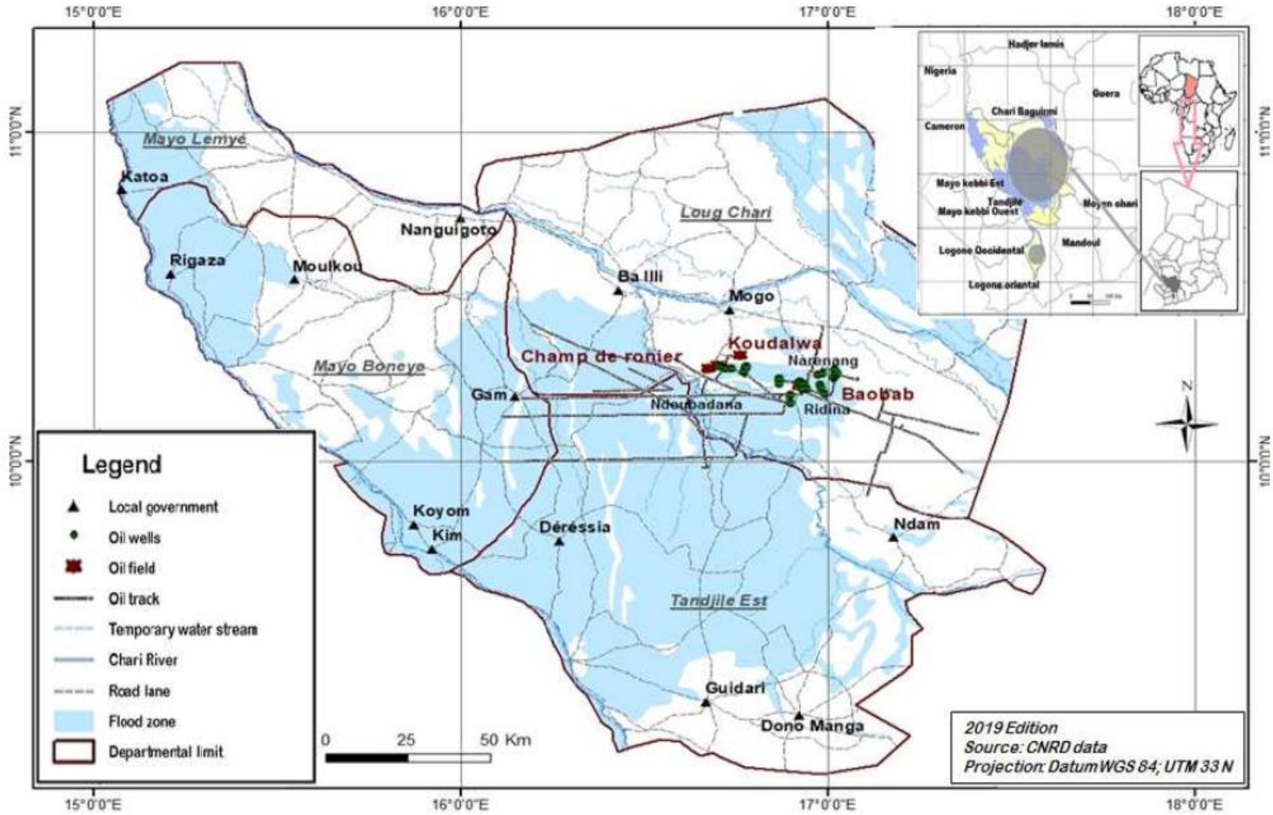
Soil sampling was done on three sites for Koudalwa [16] and two sites for Diguel, each having a control. For each study site, two samples were collected, 0-30 cm depth and 30-60 cm. The samples points, their geographical coordinates and description of activity on each sample site are shown in Table 1 for Koudalwa and Table 2 for Diguel. The corresponding maps of the sampling points in the study areas are shown in Fig. 2a for Koudalwa and Fig. 2b for Diguel. The soil was collected using a hand shovel. For each sub-sample, collected soil was properly mixed for homogenization, parceled in a polyethylene bag and labelled using a tape and marker.

Table 1 Sampling points for Koudalwa [16].

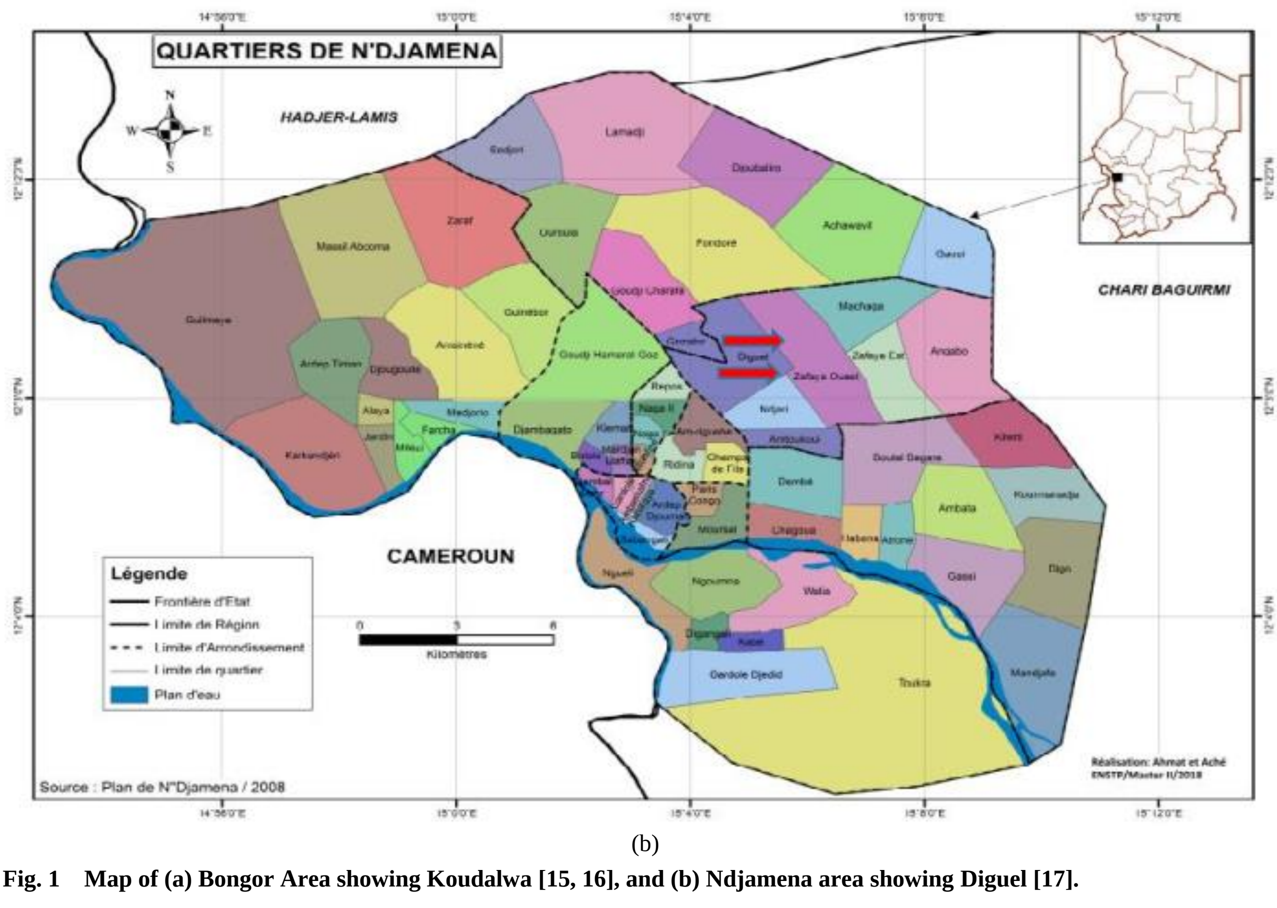
Site	Sub samples	Geographical Coordinates	Description
Control		9 °59′2.34″ N, 17 °31′18.72″ E	It is a point away from oil wells with little agriculture activities.
AA	AA1 0-30 cm	10 °11′15.84″ N, 17 °6′15.144″ E	This is the end of the drilling where drilling holes underwent treatment using chemicals. This site is also characterized by oil fields which were left fallow. There is no agricultural activity on these sites
	AA2 30-60 cm	10 °11′15.84″ N, 17 °6′15.144″ E	
BB	BB1 0-30 cm	9 °59′2.226″ N, 17 °31′18.612″ E	Sampling at these sites was carried out next to a well platform in the surrounding area. Pipelines (crude oil pipes) traverse these areas. There are agricultural farms around these wells from where samples were collected
	BB2 30-60 cm	9 °59′2.226″ N, 17 °31′18.612″ E	
CC	CC1 0-30 cm	10 °1′22.134″ N, 17 °27′51.384″ E	
	CC2 30-60 cm	10 °1′22.134″ N, 17 °27′51.384″ E	

Table 2 Sampling points for Diguel.

Site	Sub-samples	Geographical coordinates	Description
Control		Longitude: 15.03724 Latitude: 12.17802	It is located 10 m away from the leather manufacturing activities site.
A	A1 0-30 cm A2 30-60 cm	Longitude: 15.04471 Latitude: 12.18782	Site for leather manufacturing (or tanning activities) activities using artisanal methods. The tanning operations here consist of removing the flesh from cattle, then allowing them to be soften by applying natron, carbide and mixture of acacia grains and water.
B	B1 0-30 cm B2 30-60 cm	Longitude: 15.05657 Latitude: 12.17679	Exit point of the liquid waste from the tanning activities.



(a)



(b)

Fig. 1 Map of (a) Bongor Area showing Koudalwa [15, 16], and (b) Ndjamena area showing Diguel [17].

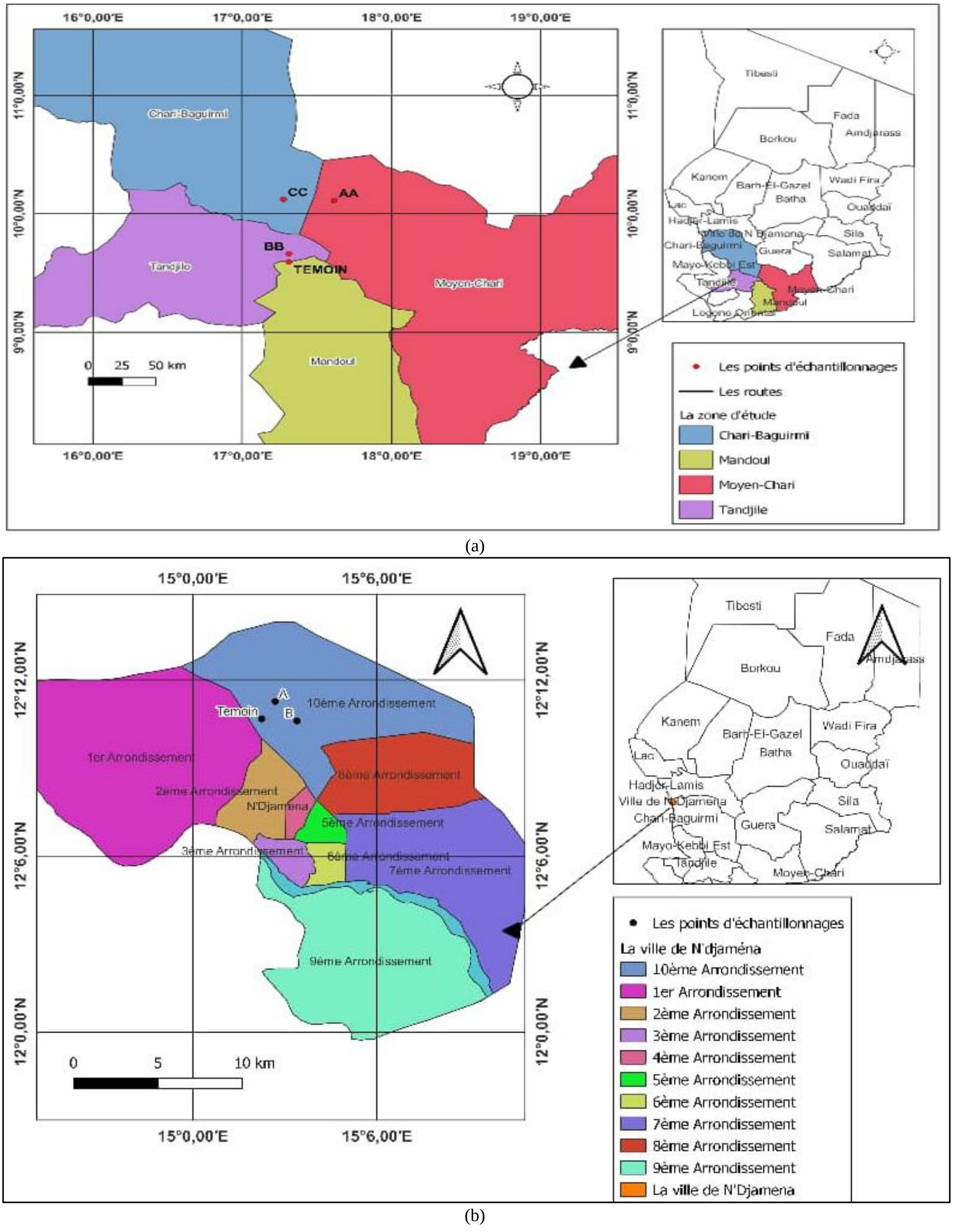


Fig. 2 Map of sampling points in (a) Koudalwa and (b) Diguel, the study areas.

2.2 Determination of Soil Physicochemical Properties

The < 2 mm soil fraction was analyzed for physical and chemical properties. pH, EC (Electrical Conductivity), TDS (Total Dissolved Solids), and salinity were determined using APERA PC60 pH/cond./sal pH Meter. Test. Particle size distribution analysis was determined by hydrometer method using sodium hexametaphosphate and sodium carbonate as dispersant while the textural class was obtained using the USDA (U.S. Department of Agriculture) textural triangle [18]. The percentage of gravel, sand, silt and clay was therefore obtained from the particle size analysis. SOC (Soil Organic Carbon) content was determined by the Walkley-Black wet combustion method by oxidation with potassium dichromate and titration with iron (II) sulphate. The percentage of OM (Organic Matter) was obtained using the equation OM (%) = SOC (%) × 1.724 [19, 20]. Total N was determined by the Kjeldahl wet digestion by dissolving 2 g of sample in nitric acid, followed by steam distillation to obtain ammonia and then titration with sulfuric acid to get total nitrogen [19, 20]. Total available phosphorous was determined by the Bray II. This method combines the extraction of phosphorus in an acidic medium (HCl 0.1 N) followed by complexation with ammonium fluoride (NH_4F 0.03 N) and aluminum linked to phosphorus. The measurement of the extracted phosphorus was then carried out by spectrophotometry with molybdenum blue using AAS (Atomic Absorption Spectrophotometer, RAYLEIGH WFX-130B) at a wavelength of 665 nm [19, 20]. Bulk density measurement was determined according to the method of ASABE standard [18]. Accordingly, a cylinder with a 500 mL volume was weighed (M_5). A soil sample was filled to the 500 mL volume mark in the cylinder and the mass of the cylinder and its content weighed (M_6). The bulk density measurement was repeated five times and the average value and range were reported. The bulk density was calculated from the relationship:

$$Bulkdensity(B_d) = \frac{M_6 - M_5}{V} \quad (1)$$

where M_5 = mass of empty cylinder, M_6 = mass of sample and cylinder, V = volume occupied by soil.

2.3 Evaluating the Potentials of Acasia and Kinkeliba Plants in Removing Cr and Cu from the Soil

A synthetic stock solution of Cu(II) and Cr(VI) each was prepared by dissolving respective amounts of $CuSO_4$ $5H_2O$ and $K_2Cr_2O_7$ powder (all AR grade) in distilled water. The stock solution for each metal was then diluted with distilled water to obtain desired concentrations 100 mg/L and 500 mg/L. The acasia and kinkeliba plants used were uprooted from non-usable land, roots and stems washed properly to eliminate soil particles. The experiment was conducted in plastic pots filled with soil from site A for Diguel and from site AA for Kouldawa. Four pots were used per plant for soil from each site, as each metal had two concentrations (100 and 500 mg/L) (Fig. 3). For Diguel the different pots designation and heavy metal concentration added are as follow: pot A3 (100 mg/L Cu), pot A5 (500 mg/L Cu); pot A4 (100 mg/L Cr), pot A6 (500 mg/L Cr) (Fig. 3). For Koudalwa, B3 (100 mg/L Cu), B5 (500 mg/L Cu), B4 (100 mg/L Cr); B6 (500 mg/L, Cr) (Fig. 3). These soils were initially contaminated by these metal solutions for seven days, after which portion of the soil was sampled for total initial metal concentration analysis and the plants planted immediately. The experiment was conducted for thirty days, after which soil samples were collected and analyzed for remaining heavy metal concentrations in the soil. The percentage of heavy metal removed by each plant was calculated using Eq. (2).

$$\%\ \text{removed} = \frac{(Ci - Cf)}{Cf} \times 100 \quad (2)$$

where, C_i and C_f (mg/L) are respectively the initial and final concentrations of Cu and Cr in the soil.

Cr and Cu analysis in the soils was done as described by Dahainaet al. [16], where fresh soil samples from different experiments were air dried in the laboratory,

(a)

(b)

Fig. 3 Field experiment for removal of Cu and Cr by (a) acasia and (b) kinkeliba plants in soils of Kouldawa and Diguel.

then ground in a porcelain mortar using a pestle and sieved through a 2 mm sieve. Then 2 g of each 2 mm sieved soil sample was digested in a mixture of HCl and HNO_3 in the ratio 1:3 and the concentrations of Cr and Cu in the digested solution were determined by atomic absorption spectroscopy (AAS (Atomic Absorption Spectrophotometer) RAYLEIGH WFX-130B).

3. Results and Discussion

3.1 Soil Physicochemical Properties of Diguel and Kouldawa, Tchad

The pH, EC, TDS, salinity and bulk density of soils sampled from Diguel and Kouldawa, in Tchad are presented in Table 3 while corresponding OM, nitrate and phosphate, particle size distribution and textural class are presented in Table 4. The results show that the soils from Diguel are basic with pH ranging from 8.33 to 9.17. According to McKenzie et al. [21], soils with large quantities of negative charge are more fertile because they retain more cations. However, Oliver et al. [13] cautioned that at pH < 5, Al and Mn compounds become increasingly soluble; Al^{3+} and $AlOH^{2+}$ are phytotoxic. As the soil pH increases the cations, Fe^{3+}, Mn^{2+}, Zn^{2+} and $Cu^{2+,}$ form insoluble hydroxides and become less available to plants, and at pH > 8 B decreases in availability as the borate anion is adsorbed. This increase may be detrimental to plants because iron is important for chlorophyll function, and

Zn and B are important for good fruits. The main activity on soils from Diguel is tanning which is traditional and using mainly plant materials which are all organic. Meanwhile for Kouldawa soils, sites CC and BB which are agricultural soils showed acidic pH with values ranging from 4.54 in subsurface to 5.57 in the surface for site CC and 5.97 in the surface sample to 6.83 in the subsurface sample for site BB. According to Oliver et al. [13], severe acidification of the soil, is due to much use of urea or ammonium-based fertilizer. However, site AA has a basic pH while the control has a neutral pH. Generally, soil pH between 6.0 and 7.0, with a target pH of 6.4, should be optimal for micronutrient availability [22]. EC which is the standard measure of salinity for the soil was all ≤ 2 dS/m for Kouldawa, indicating a non-saline soil [23]. This trend was also observed for TDS (Total Dissolve Solids) as values were between 13.7 and 846 mg/L for Kouldawa soil. The total amount of TDS levels between 700 and 1,750 mg/L are considered possibly safe, while levels above these are considered hazardous to any crop [24]. While values of EC and TDS for soils of Duguel were also between acceptable ranges, the subsurface soil (A2), has EC value of 4.280 dS/m, TDS value of 3,040 mg/L and salinity value of 4.21 dS/m. All these values are above standard for soil, particularly agricultural soils [23, 24]. The fact that these values are high in subsurface soil (30-60 cm), suggests the soil from this site has high porosity, and contaminants can be easily moved beneath the soil with the risk of contaminating the ground water. The bulk density of the all the soil samples from Kouldawa was higher compared to Diguil and ranged from 1.421 g/cm^3 in CC2 to 1.64 g/cm^3 in AA1 (Table 3). For Diguel values ranged from 1.21 g/cm^3 in BB2 to 1.51 g/cm^3 in the control. With the exception of site AA1, all the bulk density values were within range as it is generally desirable to have soil with a low bulk density (<1.5 g/cm^3) for optimum movement of air and water through the soil. Soils with a bulk density higher than 1.6 g/cm^3 tend to restrict root growth [18]. All the studied soils have bulk density less than 1.6 g/cm^3 which means their compactness cannot not restrict root growth.

The organic composition of soils from Kouldawa were all less than 3% except AA1 with OM of 3.7% (Table 4). Similarly, only soil from the control and site B1 in Diguel had OM less than 3%, all other sites in Diguel had OM between 3.08 and 5.22 (Table 4). So soils from Kouldawa (control, AA2, BB1, BB2, CC1 and CC2) and from Diguel (control and B1) are classified as mineral soil (OM content < 3%) while soils from Kouldawa (AA1) and Diguel (A1, A2, B2) are classified as mineral soil with some organics (3% < OM content < 15%) [21]. Soil OM is key for sorbing phase for metals. OM improves the stability of soil aggregates resulting in better aeration of the soil and better water retention. It also improves the hydraulic conductivity as a result of the increasing percentage of soil macropores [21]. The higher values of OM in soils of Diguel show that soils from Diguel have more aeration and easy flow and this is also confirmed with bulk density values for soils from Diguel which are smaller than those of Kouldawa (Table 3). OM is important for the retention of nutrients by soil solids, thus decreasing mobility and bioavailability. However, because of the complexation of metals by soluble OM, the addition of OM can result in release of metals from solids to the soil solution [21]. The trend in OM is also observed with nitrate and phosphate. Soils from Diguel are richer in nitrate and phosphate than soils from Kouldawa (Table 4). The nitrate content ranges from 577.9 in the control to 2,687.32 mg/kg in B2, of Diguel soils and from 33.64 in AA1 to 197.64 in BB2 of soils of Kouldawa. This is to be expected as the site studied in Diguel is tannery site using organic materials from plants for their processes. The rich organic content in Diguel soil can held and keep the nitrate and phosphate nutrients in the soil. The low nitrate concentrations in soils of Kouldawa could be due to increased pollution of soils from the petroleum activities and used chemicals that created unfavorable conditions for

Table 3 pH, EC, TDS, salinity and bulk density of soils of Diguel and Kouldawa, Tchad.

Area of study	Site	pH	EC (dS/m)	TDS (mg/L)	Salinity (dS/m)	Bulk density (g/cm^3)
	Control	7.2	0.027	19.3	0.02	1.529
	AA1	8.3	1.192	846	1.181	1.64
	AA2	8.87	0.214	152	0.216	1.564
Koudalwa	BB1	5.97	0.030	20.2	0.02	1.569
	BB2	6.83	0.019	13.7	0.02	1.521
	CC1	5.57	0	0	0	1.535
	CC2	4.54	0.015	10.6	0.02	1.421
	Control	9.02	0.627	461	0.62	1.51
	A1	9.15	1.687	1,100	1.53	1.28
Diguel	A2	9.17	4.280	3,040	4.21	1.45
	B1	9.07	1.426	1,010	1.41	1.39
	B2	8.33	0.938	664	0.9	1.21

Table 4 OM, nitrate and phosphate, particle size distribution and textural class of soils of Diguel and Kouldawa, Tchad.

Area of study	Site	OM (%)	Nitrate (mg/kg)	Phosphate (mg/kg)	Clay (%)	Silt (%)	Sand (%)	Textural class
	Control	2.35	58.87	19.15	41	8	51	Sandy clay
	AA1	3.7	33.64	17.32	29	20	51	Sandy clay loam
	AA2	2.13	71.49	16.29	3	10	88	Sandy
Koudalwa	BB1	2.02	147.18	7.82	47	3	51	Sandy clay
	BB2	1.46	197.64	10.68	49	3	50	Sandy clay
	CC1	2.58	13.03	10	30	10	58	Sandy clay loam
	CC2	2.24	49.66	15.83	40	10	47	Sandy clay
	Control	1.47	577.9	287.48	30	12	57.5	Sandy clay loam
	A1	4.69	1,841.8	76.94	15	14.5	70.5	Sandy loam
Diguel	A2	3.08	2,301.17	66.67	14	16	70	Sandy loam
	B1	1.61	2,687.32	121.32	24.5	9.5	66	Sandy clay loam
	B2	5.22	2,414.22	151.77	25.5	6	68.5	Sandy clay loam

the growth of nitrogen-fixing bacteria, which are responsible for the conversion of nitrogen to ammonia and then to soluble nitrate in the soils [25]. Also, nitrate is the secondary form of nitrogen that is available for plant uptake and might have been taken up by the plants, especially on the surface soils, particularly in Kouldawa with agricultural activities and those not taken up by plants were washed off by runoffs into streams [25]. The higher nutrient content of soils from Diguel is also due to their mostly loamy properties (Table 4) as they have good water retention and nutrient holding capacity, and are generally easy to work. Soils with high amount of clay are compact nature, and can limit root aeration. Plant roots may struggle to penetrate the dense soil, leading to shallow root systems. The soils from Kouldawa are rich in clay and this probably explains why they have higher densities than soils from Diguel, due to their compact nature.

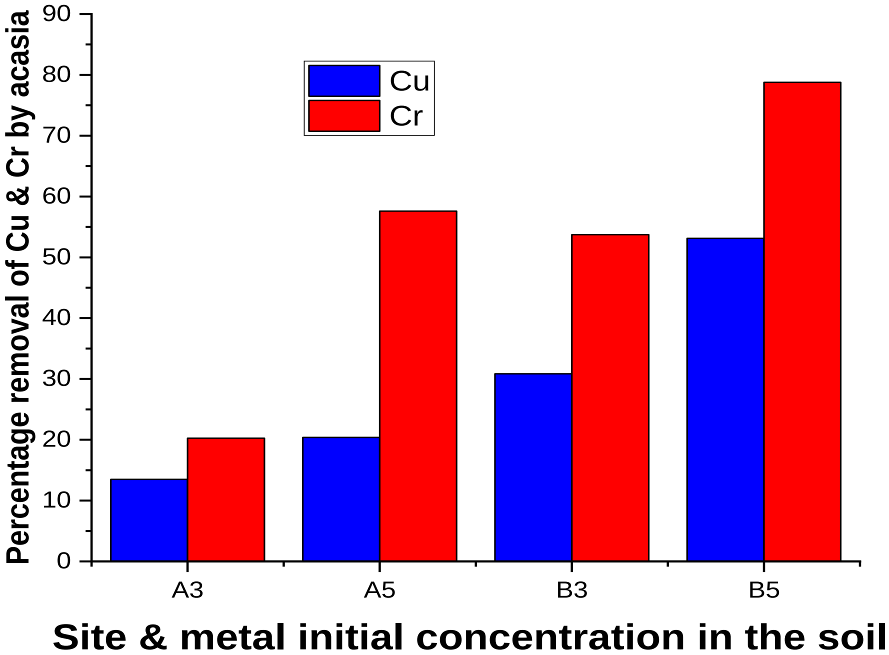
3.2 Removal of Cr and Cu from the Soil by Acasia and Kinkeliba Plants

Results the efficiency of acasia and kinkeliba plants in removing Cu(II) and Cr(VI) from soils of Diguel and Koudalwa are plotted in Fig. 3 while the characteristics of the field experiment is summarized in Table 5. For this study, the soils were initially contaminated by metal solutions (100 and 500 mg/L) for seven days, after which portion of the soil was sampled from each pot and total initial metal concentration determined before planting. As observed from Table 5, total initial concentration of all the metals increased more than the amounts added. Equally, the initial concentration of Cu in all the soils was more than that of Cr. These results are consistent with those of Dahaina et al. [16] who reported that Cu is more dominant in the soils of Koudalwa than Cr. Though same amounts of Cu and Cr (100 and 500 mg/L) were added to same soils, the total initial amount determined shows variations. This occurrence was more for soil from Diguel. For example, 100 mg/L of Cu was added to pot A3 and pot A4 but their determined initial concentrations are 437.6 and 526.36 mg/kg respectively. This is the same behavior with Cr in similar pots. This may be due to the fact that the soil from Diguel was richer in OM than soils of Koudalwa (Table 4). The soils from Diguel have lower bulk density and contain more sand (Table 4) than those of Kouldawa allowing easy speciation of the metals.

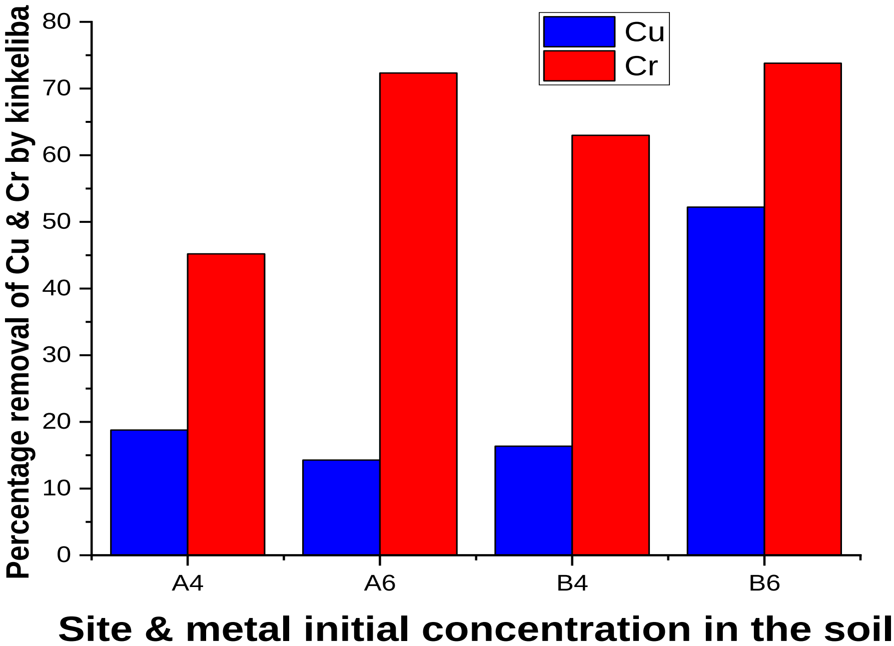
The percentage removal of metals from soil was calculated using Eq. (1) and using the final and initial metal concentrations shown in Table 5. The results show that for the tested plants, Cr removal was higher than for Cu on both plants. The highest amount of Cr removed by acasia is 78% (Fig. 4a) for 697.98 mg/kg initial Cr concentration compared to 73.8% by kinkeliba (Fig. 4b) for the same initial Cr concentration all in the soils of Koudalwa. Meanwhile the highest Cu removed by acasia is 53.12% (Fig. 3a) for 720.19 mg/kg initial Cu concentration compared to 52.21% by kinkeliba (Fig. 3b) for the same initial Cu concentration all in the soils of Koudalwa. Other authors [26, 27] have reported Acacia can be used as a phtyoremediator for Cd, Cu, Cr and Zn contaminated soils and to mitigate soil pollution.

Table 5 Characteristics of experimental pots for Cu and Cr removal from soils of Diguel and Koudalwa by acasia and kinkeliba plants.

Plant	Experimental pot code	Soil site name	Metal concentration added to the soil (mg/L)	Total initial Cu concentration in soil (mg/kg)/pot	Final Cu concentration in soil (mg/kg)	Total initial Cr concentration in soil (mg/kg)/pot	Final Cr concentration in soil (mg/kg)
Acasis	A3	Diguel	100	437.62	378.63	262.73	209.5
	A5	Diguel	500	652.16	519.21	527.73	223.82
	B3	Koudalwa	100	320.17	221.42	297.98	137.89
	B5	Koudalwa	500	720.19	337.62	697.98	148.12
Kenkeliba	A4	Diguel	100	526.36	427.46	246.07	134.82
	A6	Diguel	500	652.36	559.28	527.73	146.07
	B4	Koudalwa	100	320.77	268.29	297.98	110.26
	B6	Koudalwa	500	720.77	344.46	697.98	182.9



(a)



(b)

Fig. 4 Efficiency of Cu and Cr removal from soils of Diguel and Koudalwa, Tchad by (a) acasia and (b) kinkeliba plants.

4. Conclusions

This study investigated the physico-chemical properties of soils from Diguel and Koudalwa Tchad, and phytoremediation potentials of acasia (genus *Acacia*) and kinkeliba (*Combretum micranthum*) plants in removing Cr and Cu from these soils. The study site, Diguel has a tannery plant while Koudawa sites are agricultural areas around oil wells and left over oil fields. Soils were characterized for the following properties: pH, EC, TDS, salinity, bulk density, OM, nitrate, phosphate, clay, silt, sand, and textural class using standard methods. Using plastic pots experiments filled with soils, acasia and kinkeliba plants were tested for their potentials to decontaminate Cu and Cr from these sample soils for a period of 30 days. Results obtained show that the soils from Diguel are basic with pH ranging from 8.33 to 9.17, meanwhile for Kouldawa soils, sites CC and BB which are agricultural soils showed acidic pH with values ranging from 4.54 in subsurface to 5.57 in the surface for site CC and 5.97 in the surface sample to 6.83 in the subsurface sample for site BB. EC which is the standard measure of salinity for the soil was all ≤ 2 dS/m for Kouldawa, indicating a non-saline soils. While values of EC and TDS for soils of Duguel were also between acceptable ranges, the subsurface soil (A2), has EC value of 4.280 dS/m, TDS value of 3,040 mg/L and salinity value of 4.21 dS/m which are above standard for soil, particularly agricultural soils. The bulk density of the all the soil samples from Kouldawa was higher compared to Diguil. The organic composition of soils from Kouldawa was all less than 3% except AA1 with OM of 3.7%. Similarly, only soil from the control and site B1 in Diguel had OM less than 3%, all other sites in Diguel had OM between 3.08% and 5.22%. Soils from Diguel are richer in nitrate and phosphate than soils from Kouldawa. The soils from Kouldawa are rich in clay while those from Diguel, are rich in sand and silt. The soils from all the sites contain high amounts of Cu and Cr. Acasia and kinkeliba plants can remove Cu and Cr from tested soils with each plant showing higher removal potential for Cr than Cu. Though significant amount of each metal was removed from the tested soils, a huge amount was still remaining, hence the decontamination should involve planting many of the tested plants per unit area to better eliminate these metals from the soils. It is recommended that further studies should determine the accumulation of the studied heavy metals in the different parts of the plants.

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