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(Research Article)

Impact of water potabilization sludge from the Lukaya plant on the growth of *Amaranthus hybridus*

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Abstract

This study aimed at spreading of water purification sludge from Lukaya and the determination of the optimal proportion improving the growth of market gardening crops. The sludge from the purification of the Lukaya water treatment plant has been analyzed. The results indicate the presence of iron (9.8%), phosphorus (0.5%), nitrogen (0.5%), potassium (1.1%), magnesium (0.99%), carbon (0. 5%), aluminum (18.55%) and organic materials (1.2%).

Its spreading on Amaranthus hybridus cultivation soil has improved productivity. The optimal proportion is at the dose of 40% mud and 60% soil. In excess, this sludge reduces plant growth.

The variances analysis indicated that the F test is significant at the height of the plant due to the presence of iron which plays an important role in photosynthesis and chlorophyll, magnesium and phosphorus and not significant for the number of leaves and the weight of the plant.

Keywords: Impact; Growth; Sludge; Potabilisation-Soil-Water

1. Introduction

The drinking water's production intended for human consumption often generates by products known as hydroxide or clarification sludge. They are generally very low in degradable matter compared to urban sludge (50 to 70% organic material) generated by wastewater treatment plants [1].

Clarification sludge is very voluminous. In addition to aluminum hydroxide ($A1(OH)_3$), they contain other compounds from the earth's crust in varying proportions depending on the season and the geological composition of the area through which the raw water passes (clay, micro -organisms, organic and inorganic materials. The sludge's physicochemical composition varies according to the origin of the water, the time of year, the type of treatment and the packaging [2-3].

In the drinking water production chain by Regideso, it is the coagulation-flocculation stage that leads to the formation of hydroxide sludge [1]. Colloidal particles remain in suspension as a result of their repulsive negative charges. Neutralization occurs by adding cationic coagulants.

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The purged sludge from the settling tank constitutes 85 to 90% of the suspended solids of the flocculated water. On the other hand, the filter washing water, although large in volume, represents a very low mass of suspended solids. [1].

The bad management wastes is the main source of diseases due to a polluted and unsanitary environment. Similarly, settling sludge discharged into the natural environment (sea, rivers, soil) can generate numerous waterborne diseases as well as environmental problems. [4-5].

Regideso also faced this problem of storing used sludge. Their recycling is offered as one of the solutions likely to save natural resources and limit the pressures on the environment.

The purpose of this study aims at analyzing the sewage sludge from the Lukaya plant treatment and to recycle it with a view to propose an appropriate solution to Regideso. To this end, an experiment will be conducted to determine the best soil/sludge ratio likely to improve the physico-chemical properties of the soil and to evaluate the effectiveness on market garden crops.

2. Place, Materials and Methods

2.1. Area of study

2.1.1. Sludge sampling site

The Lukaya water treatment plant under the Kinshasa/Regideso Production Department in the Democratic Republic of Congo is the supplier of the sludge under study. It comes in fourth position in terms of capacity after those of N'djili, Ngaliema and Lukunga.

Scheduled to produce 36,300m ^{3} of water per day, the project took place in 2 phases.

The first phase launched in September 2006 delivered 18,300m ^{3} of water per day. Initially, the plant should treat raw water collected at Tshilombo, about 3 km upstream. The final catchment should concern three rivers: Lukaya, Miwana and Bumuna.

The temporary catchment was built around the treatment line on the banks of the Lukaya River. It is a 2GMP shelter with the capacity of 2000m ^{3} per day. It pumped into the river two suction pipes 400mm in diameter at the end of which were fixed strainers in direct contact with the water without screening, sand trap or dam. This leads to frequent strainer clogging problems in plant operation.

The second phase of the plant dates from 2013. The plant's capacity has increased from 18,300 to 36,300 m ^{3} / day. Following a strong demand, the plant works in overload and reaches up to 40,000 m ^{3} / day. Consequently, it produces an excessive amount of sludge. To limit the damage, a drying bed was built. But its exploitation is far from solving the problem.

2.2. Geographic location

The Lukaya plant is located south of the city of Kinshasa in the Kimwenza valley between the MinoCongo poultry firm and the Kimwenza quarry (CARRIKIM) in the commune of Mont-Ngafula, on the right bank of the Lukaya river. where the raw water is drawn from and which gave its name to the factory. The geographical coordinates measured using a Garmin GPS are:

Latitude: 4° 28' 55.6'' South
Longitude: 15° 16'19.6'' East
Altitude: 318m
It has two seasons: rainy (September to June) and dry (July and August).

2.3. Experimentation site

The experimental site is the experimental garden of CREN-K, located next to the University of Kinshasa, Commune of Lemba and District of Mont-Amba. The geographic coordinates are:

Latitude: 4° 19' 42.6'' South
Longitude: 15° 18' 29.4'' East

Altitude: 390m

2.4. Sampling and equipment

The water purification sludge from the Lukaya plant was taken from the decanter and flocculator purge and packaged in the bag which was used to amend the soil. and packaged in hermetically sealed bags.

In addition to sludge, sandy soil was sampled from the first 15 perimeters of the Kimuenza Valley garden (Tsholombo site).

The seedlings of Amaranthus hybridus var. cruentus, with an average height of 5cm, came from the market gardening center of the Mont Amba valley, two weeks after sowing. They were transplanted for experimentation.

The choice of amaranth is justified by its short vegetative cycle. Two experiments were conducted over a period of 42 days (21 days each)

The plastic pots used have favorable characteristics for experimentation, in particular ease of use and transport. (H= 22cm, D=18cm and =2L).

2.5. Experimental protocol

2.5.1. Substrate used.

The substrate consisted of a mixture of mud and sandy soil in different proportions. Table No. 1 gives the composition in % of various substrates.

Table 1 Proportion of mud and soil for each substrate in %

Substrate	Floor (%)	Mud (%)
Witness S_0	100	0 (without mud)
S1 _	90	10
S2 _	80	20
S3 _	70	30
S4 _	60	40
S5 _	50	50
S_6	40	60
S_7	30	70
S8 _	20	80
S_9	10	90
Indicator S_{00}	0	100

The substrates (1.5 kg each) were mixed manually and placed in plastic pots according to the proportion (in g) presented in Table No. 2 below.

For the first test, it was necessary to determine the height of the stem and the number of leaves

At 21 days after transplanting, two seedlings were taken from each pot and the parameters mentioned above were measured.

After harvest, a second test is conducted with 8 seedlings per pot to determine the biomass.

Table 2 Proportion of soil and mud for each substrate in grams

Substrate	**Soil (in g)**	**Mud (g)**
Witness S_0	1500	0g
S1 _	1350	150
S2 _	1200	300
S3 _	1050	450
S4 _	900	600
S5 _	750	750
S_6	600	900
S_7	450	1050
S8 _	300	1200
S_9	150	1350
Indicator S_{00}	0	1500

2.6. Parameter analysis

The following physico-chemical parameters of the water purification sludge were measured in the Laboratory: pH; Humidity; Nitrogen; Phosphorus; Carbon and Organic Matter.

The pH of soil and soil amended with sludge was carried out using a pH meter "with combined pH electrodes". The pH (H_2O) is measured in the proportion 1/2.5, a soil-water suspension, using the CONSORT 532 brand pH meter.

The organic matter is calculated on the basis of the organic carbon values obtained according to the method of Walkley and Black. (%MO=%CO x 1.724). The organic carbon of the sludge is determined by the ISO 14 235 standard. It is an oxidation of the organic carbon of the sludge by potassium bicarbonate ($K_2Cr_2O_7$) in excess, in an acid medium (H_2SO_4) hot.

$^{-1}$ potassium bicarbonate solution and 7.5 mL of concentrated H_2SO_4. After centrifugation (10 min at 3000 – Scientific Bioblock and sigma type 2-15) and filtration at 0.45 µm. the filtrate obtained is assayed at 580 nm using a HACH visible UV spectrophotometer **.** The assay is done using a calibration curve established from glucose, chosen as a reference to the organic component.

The water content was determined in each mud sample which was taken using a split corer, by the oven set at 105°C. The difference in weight before and after parboiling made it possible to determine the water content.

The weight before and after steaming at 105°C made it possible to determine the dryness, the humidity, the dry matter, the consistency of the soil and mud samples. Dryness determines the consistency of each sludge.

The determination of phosphorus by the method of Bray, this happens by the complexation by ammonium fluoride which binds to phosphorus. The dosage of the latter is done by spectrophotometer with molybdenum blue.

Dosage of total nitrogen by Kjeldahl method

The plant parameter was determined using a 30 cm graduated ruler. The height of the plants was measured every three days and the number of leaves was determined at the end of the test as well as the biomass.

2.7. Statistical analysis

The F test of the analysis of variance (at the probability threshold X=0.05) was applied to the results obtained in order to see if there is an influence of the mud of the various treatments on the growth of the plant whose height of the stem, the weight of the plant and the number of leaves.

3. Results

3.1. Chemical composition of mud

For a mass of sludge from drinking water treatment at the Lukaya plant, the useful nutrient content for the plant is given in table 3 below:

Table 3 Chemical composition of the sludge

No.	Parameters analyzed	% got	Standard (AFNOR)
1	Nitrogen	0.4%	2%
2	Phosphorus	1.1%	0.43%
3	Potassium	0.5%	0.16%
4	Iron	9,8%	
5	Aluminium	18,5%	
4	Carbon	0.6%	-
5	Organic materials	1.2%	40%

The results obtained show that the sludge has levels of nitrogen and organic matter below the standards. On the other hand, they are beyond the standards for Phosphorus and Potassium.

3.2. Physico-chemical parameters of substrates

3.2.1. pH of substrates

The figure above shows the pH values obtained for each treatment.

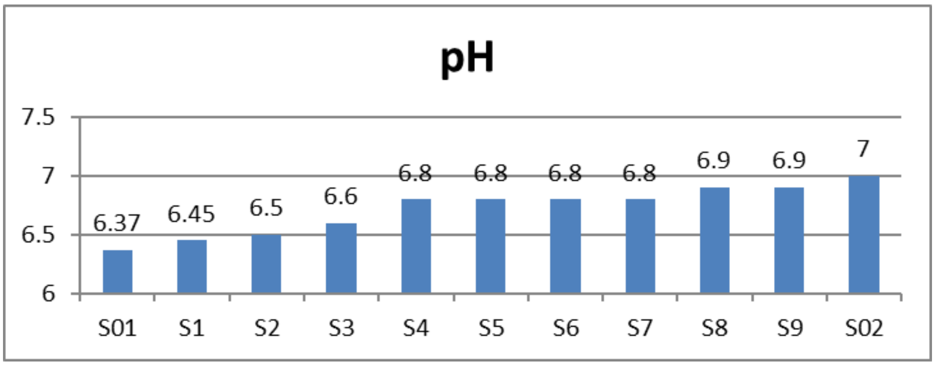

Figure 1 Substrate pH variation

This graph indicates that the pH of the soil and mud mixture in the proportions mentioned varies between 6.37 and 7.0. Sandy soil has a pH of 6.37, while water purification sludge has a pH of 7.0. The S4, S5, S6 and S7 mixtures have a pH equal to 6.8.

3.2.2. Water content of substrates

The figure below gives the water content values for each treatment in the proportions mentioned.

This figure reveals that the water content increases in proportion to the amount of sludge in the mix. It goes from 13% (Cf. S0) to 30% (S7-9-00).

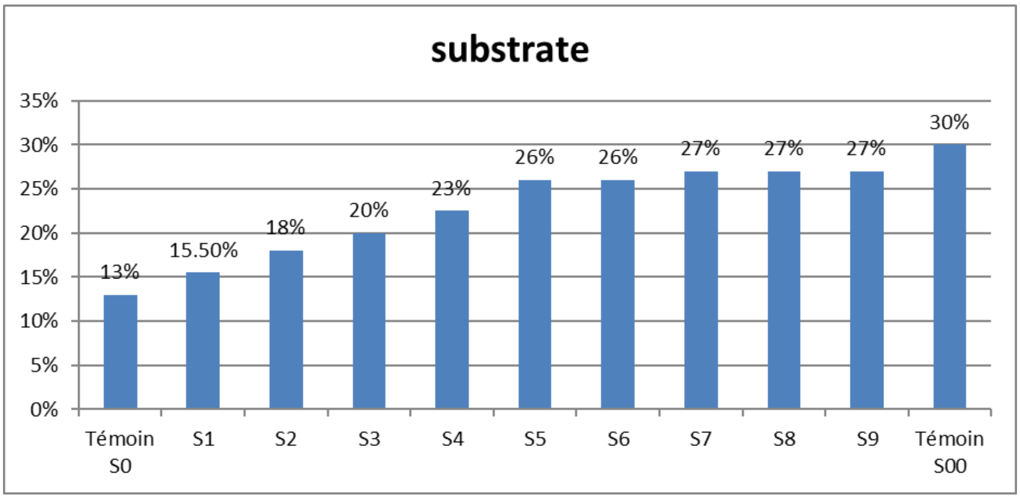

Figure 2 Variation of the water content according to substrate

3.3. Influence of mud on plant growth

3.3.1. Variation in the height of the stem according to the substrates.

The figure below shows the heights of the plants according to the treatments.

Figure 3 Variation in the height of the stem depending on the substrate

It is apparent from Figure 4 that the substrates S_4; S_5 and S_7 recorded the best stem height growth after 21 days of experimentation. On the other hand, the witness S_{00} is the worst of the substrates. It induced the lowest seedling growth.

Table 4 Analysis of variance: Stem height

	sum of squares	dof	medium square	F calculated	F tabbed
treatment	59	10	6.5333333	2.96969697	2.392814108

The value of calculated F being higher than F of the table, the test is significant, therefore the mud has a significant influence on the height of the rod.

3.3.2. Plant weight variation by pots (substrates)

The figure below shows the weight of the plants after 21 days of each treatment.

This figure indicates the average weight of the plant according to substrate. Substrates S_4 and S_6 have a higher weight than the others and control S_0 is weak.

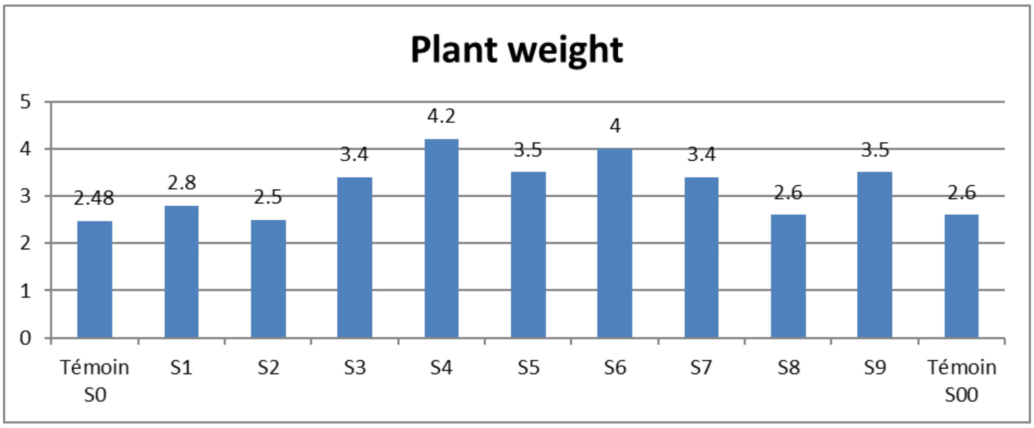

Figure 4 Variation of the weight of the plant according to substrate

Table 5 Analysis of variance: Plant weight

	sum of squares	dof	medium square	F calculated	F tabbed
treatment	6.84140333	10	0.760155926	1.83420556	2.392814108

The value of calculated F being lower than that of the table, the test is not significant, therefore, the mud does not have a significant influence on the weight of the plant.

3.3.3. Variation in number of sheets according to the substrates

The figure below shows the variation in the number of plant leaves for each treatment.

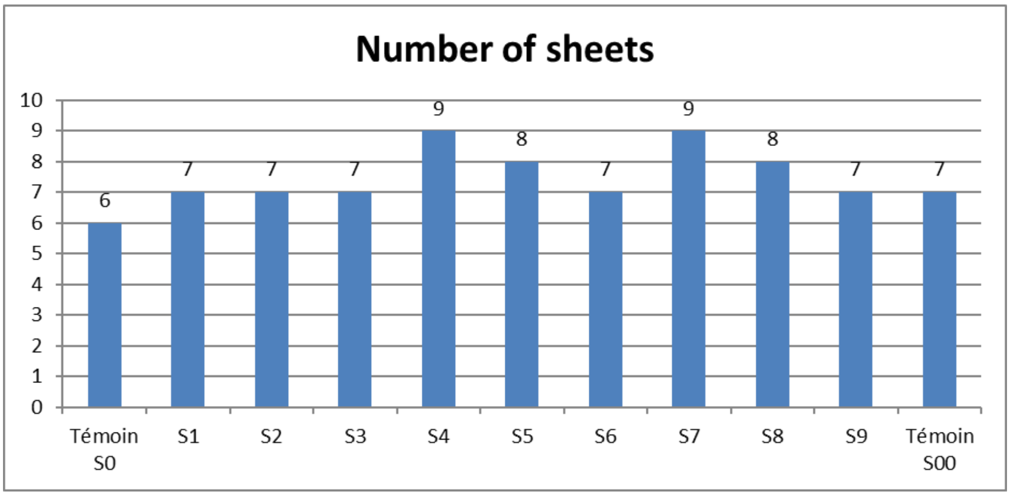

Figure 5 Variation in the number of plant leaves depending on the substrate

The figure reveals the average number of leaves per amaranth plant for the different treatments. This figure also shows that although the treatment with 40% (S_4) and 70% (S_7) of mud had more leaf, all the other treatments gave appreciable results compared to the control (S_0), because that the water retention capacity of the substrates has been improved.

Table 6 Analysis of variance: Number of leaves per plant

	sum of squares	dof	medium square	F calculated	F tabbed
treatment	21.36666667	10	2.37407407029	1.3189300	2.392814108

The value of calculated F being lower than that of the table, the test is not significant, therefore, the mud does not have a significant influence on the production of number of the plant.

4. Discussions

Having analyzed the sludge of Andred (1982) [6] estimated the nitrogen content between 0.1 and 2%. Compared to the standards (2%) [7], the purification sludge from the Lukaya plant has a low nitrogen content (0.4%).

Available phosphorus is within the acceptable range for plant growth. These results confirm those of [5] Fabre (2008) cited by Amir (2008) who mentions the range of 0.1 to 2% of phosphorus in the sewage sludge and higher than those of Grenier Y. (1989) whose phosphorus is 0.12%. These results are beyond the norms (0.43%) [7] cited by Ayers et al (1988).

According to Fabre's studies, the carbon content of drinking water treatment sludge is between 1 and 3%, which is not the case for the sludge from the Lukaya station, which has a low carbon content (0.5%). This is explained by the fact that the sludge from the Lukaya station contains fewer biodegradable compounds, which justifies the low percentage of organic matter.

Organic matter is an important element that qualifies the value of sludge and its agricultural destination [9]. The standards quoted by Ayers require 40% organic matter in sludge intended for agriculture. The organic matter found in the Lukaya sludge is far below Azzabi's standards and results (61.95%). This is explained by the presence of minimal quantities of biodegradable materials in the Lukaya sludge.

Regarding the potassium content of the Lukaya mud, it is lower compared to the standards set by Lacée (1985) because potassium is weakly retained by the mud during the treatment process and is found in small quantities. in the sludge [6]. The potassium found in the sewage sludge from Lukaya (0.5%) is far superior to that of the sludge from Algiers (0.066%) and the standards (0.16%) [7]. These results confirm the work of Brame et al. (1977) and Mese, (2013) [9-10], who confirmed that potassium inputs through sewage sludge are negligible.

Substrates are weakly acidic. However, they can be favorable to the development of plants provided they are mixed with sludge. According to Samira et al. (2008), the mixture of mud and soil whose pH oscillates between 5 and 6, does not inhibit the development of plants due to the mobility of the mineral elements of the soil [11].

The mud improves water retention in the soil and refines the particles by forming solid aggregates like clays or organic matter. The substrate used is the sandy soil of the Kimuenza Valley and whose water retention capacity is very low. It was improved by mixing it with sewage sludge from the Lukaya plant.

certain doses of the mud stimulate stem growth more than others. The presence of phosphorus in acceptable quantities and iron promotes plant growth [12] (Kanda, 2015). These results support Samira (2008) who argues that above 60% mud, plant growth is slowed down. This slowdown is due to excess iron. Iron toxicity often appears on soil with K, P, Ca Mg deficiency and becomes excess uptake. This is the case of the market garden soil used [13].

In the case of Lukaya, the presence of aluminum from aluminum sulphate, the basic element of the coagulant used, could also be blamed.

The number of leaves is the index of a supply of water and mineral salts and a good production of biomass by the plant [14]. Treatments S_4 (40% mud) and S7 (70% mud) induced more leaves than all the other treatments.

Reported on the scale of one hectare of land, the quantity of 1800kg of sludge would be the quantity necessary to improve the physical and chemical properties of the soil studied as an amendment and not an elemental contribution.

5. Conclusion

The chemical composition of sludge from Lukaya river water purification is 0.4% nitrogen, 0.6% potassium, 0.6% carbon, 1.2% organic matter 1.1 % phosphorus. These values, although low compared to the values found by other authors, give an indication of the quality of this sludge to be used for agricultural and market gardening purposes in order to improve the quality of cultivable soils.

As for the tests carried out on the mixture of sludge with the market garden soil of Kimuenza, the optimal dose of 40% mud and 60% soil gave better results by improving the growth of amaranths (height of the stem, number of leaves and plant weight). However, statistically significant differences were found only in stem height.

This is why Regideso must support in-depth research on sludge with a view to identifying the toxic elements that hinder the growth of the plant and to valorize them for use in large and small-scale agriculture. This is how Regideso will participate in the protection of the environment and the waterways used to capture water, the raw material, for the production of water for human consumption.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

There is no conflict of interest either between the authors or with third parties in this study

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