Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **5(12),** 1-6, December **(2015)** *Res. J. Chem. Sci.*

Phytoremediation: Investigation and Valorization of purifying power of *Thalia geniculatain* for Domestic Wastewater treatment

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Available online at: www.isca.in, www.isca.me
Received 19th September 2015, revised 13th October 2015, accepted 16th November 2015

Abstract

Thalia geniculata is a widespread plant in the republic of Benin which could be valorized in domestic wastewater purification. It might help to remediate and preserve environmental pollution in Africa. Unfortunately, sufficient information's about this plant, precisely its potential power to absorb pollutants are not available. More investigation on this plant is still needed to feel the gap of knowledge. In the present work, we have investigated Thalia geniculata's absorption and purification power of nutrients including nitrates (NO_3^-), orthophosphates (PO_4^{3-}) and Azote Kejedhal *(NTK) in domestic wastewaters. We have compared it absorption capacity with Eichhornia crassipes (water hyacinth). The physicochemical characterization of the treated domestic wastewater is as follow: pH (~ 8), EC (1596 - 6515 µS/cm), nutrimental elements: NO_3^- (0.3 - 25 mg/L), PO_4^{3-} (72.5 - 152.5 mg/L) and NTK (7.7 - 43.4 mg/L). By the end of 15 days treatment process, nutrients were considerably removed from the wastewater. The optimum removal efficiency of NO_3^- (93.33%) was achieved with the senior shoots (SS); while for PO_4^{3-} (76.16%) and NTK (100%) were achieved with the young shoots (YS). With Eichhornia crassipes, the uptimal removal efficiencies were: NO_3^- (50%), PO_4^{3-} (86.92%) and NTK (77.11%). As a consequence, Thalia geniculata plants possess a strong purifying power and can thus be used to purify polluted water and domestic wastewater. It was also noted that Thalia geniculata was more efficient when treating grey wastewater with high concentration of PO_4^{3-}, compared to water valve with high concentration of NO_3^- and NTK.*

Keywords: *Thalia geniculata*; *Eichhornia crassipes*; wastewaters; phytoremediation; nutrients.

Introduction

Benin, like other tropical countries in Africa, has a rich and diverse flora, estimated to about 65% (FAO) in 2001[1]. Local liable promotes drinking water drilling construction and overshadows the treatment of domestic wastewater which quantity is increasing with population growth and urbanization[2]. Nationally, only 35.4% of people access to basic sanitation. In previous researches chemical measure are important in knowledge of water quality[3]. In a context of widespread poverty, high rates of infants and children mortality mainly caused by malaria, the proliferation of waterborne and diarrheal diseases, lack of hygiene and adequate means for the treatment of sewage; phytoremediation appears as an essential remedy for the treatment of domestic wastewater in the least developed countries as is the case in Benin. Phytoremediation is a set of technologies that use plants to reduce, or degrade natural or anthropogenic contaminants in air, water and soil. Plants like *calendula officinalis* has been used to reduce Cu and Zn in the soil[4]. The use of water hyacinth[5] showed satisfactory results via significant improvement of water quality as the consequence of the diminution of BOD, COD, TDS after the treatment process.

Benin abounds with several aquatic plants not valued because of the deficit in knowledge of their purifying power. It is in this context that we were interested to *Thalia geniculata*. *Thalia geniculata* is a plant belonging to the family of *Marantaceae,* originates from America and tropical Africa. It was used to fight against the strain k of *plasmodium falciparum* through *geranyfarnsesol* extracted from leaves [6]. In Benin, in traditional medicine its aqueous decoction with *Nauclea latifolia* is used to treat paludism[7]. The leaves of *Thalia geniculata* have a potential to produce *provitamin* helpful for children of 6-36 months old[8]. In Benin it is used to protect a kind of food prepared from maize commonly known as "boule d'akassa". Several authors[6-14] have already worked on *Thalia geniculata* relating to the use of its leaves in the food crafts, its use to fight against malaria, their physical and mechanical characterization, and the description of the plant. Although it mainly grows in swamps, few authors were interested in the purifying power of this plant. It is pertinent to mentionne that *Thalia geniculata* was used to reduce the concentration of metals in wastewater. Results showed that this *macrophyte* has the capability of absorbing Hg and Pb and also to reduced Zn, Fe and Cu[15]. Others findings revealed that *Thalia geniculata* reduced more nitrate and phosphate than other macrophytes studies[16].

This work aims to investigate the purifying power of *Thalia geniculata* and compare its performance with *Eichhornia crassipes.* To our knowledge, this is a first investigation on this plant in the republic of Benin.

Material and Methods

Plants species and wastewater: The plant material consisted of macrophyte *Thalia geniculata* collected in coastal Benin specifically in the area of "Agongbomey" and *Eichhornia crassipes* gathered in the neighborhood "Fidjrossè kpota" in southern Benin. Macrophytes were immediately grown in a pot containing tap water after being harvested. *Thalia geniculata* belongs to the family of *Marantaceae*. It is a horizontal and vertical rhizome plant that grows spontaneously in the natural environment (wetlands) and form mono specific fields[6]. It is a very productive species that grows in specific areas and is part of a local operating commercial circuit. The different shoots used were taken from the wild. The *Eichhornia crassipes* used for the comparative study belongs to the family of *Pontederiacea* and it is commonly named water hyacinth[14,17]. *Thalia geniculata* were characterized by their diameters at 10 cm from their lower extremity. Thus, we have: Young shoots (YS) which have a diameter less than 2.5 cm, Senior shoots (SS) with a diameter between 2.5 and 3.5 cm and finally Old shoots (OS) which have a diameter greater than 3.5 cm. The plants of the *Eichhornia crassipes* were not characterized due to fact that their diameters are almost identical.

Experimental wastewaters included: Grey Water (GW) and water valves (WV). GW was collected from shower water and dishwashing detergents' sewer and WV from a septic tank, both located in a neighborhood of the city of Cotonou. This area regularly suffers flooding phenomena and presents an ecological set consisting of marshes and water reservors[15,18].

The experimental pilot consisted of four small pots of about of 10 L each (figure-2). Three of pots contain each 5 different plants shoots of *Thalia geniculata* and the one left contained 5 shoots of *Eichhornia crassipes* taken as the control. The pots were fed only at the beginning of the experiment with gray wastewater collected from a sewer constructed for collecting shower, dishes and laundry water. Samplings were made every morning between 8h30 and 9h30 with a 60 mL syringe (previously washed and rinsed). Collected samples were each kept in 100 mL bottle for physicochemical characterization. The experiment lasted sixteen days from February 25th to March 12th in 2013.The experiments were carried out in Cotonou town which has a sub-equatorial[18].

Throughout the experiment, the operation system was controlled by measuring the physicochemical parameters in the media. Physicochemical parameters included: temperature (T), potential hydrogen (pH), electrical conductivity (EC), total dissolved solid (TDS), turbidity (Turb), dissolved oxygen (DO), the redox potential (EH), orthophosphates (PO_4^{3-}), Nitrate (NO_3^-) and Total Kjeldahl Nitrogen (TKN). The pH was measured with a portable pH meter (waterproof Combo Hanna) according to (NF T 90-008). EC was determined by multi parameters (pH / EC / TDS Combo Hanna Waterproof) according to NF EN 27888. Colorimetric method NF EN 872 was used for determining TDS. The turbidity measurement was determined using a colorimeter (HACH DR/890) as recommended by DIN EN 27027. The dissolved oxygen and redox potential were determined by the potentiometric method (NF EN 25814), a multi parameter WTW pH / O2 340i was used for their measurement. The redox power (R_H) represents the oxidizing or reducing power of a system at a given pH. Knowing the value of the redox potential E_H, the R_H redox power is determined using the formula (equation-1) below. Orthophosphates (PO_4^{3-}) were determined by colorimetric measurement of the formed phosphomolybdic complex using molecular absorption spectrophotometer DR/2800 according to the standard (AFNOR T90-023). TKN was determined following AFNOR NFT90-110 method. TKN was determined via acidimetric process, after being distillated in Buchi Auto distiller Kjeldahl K370. Nitrate (NO_3^-) was determined using the colorimetric method by diazotization according to NF EN ISO 13395; measurement was performed using HACH DR/800[1619] spectrophotometer.

$$RH = [\frac{EH}{0.0992T} + 2pH] \quad where\ EH\ is\ mV\ and\ T\ in\ K^{17} \quad (1)$$

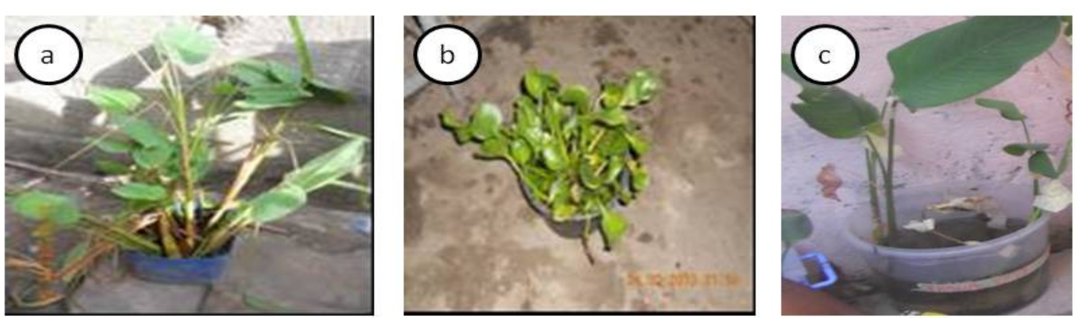

Figure-1
(a)-Macrophytes of *Thalia geniculata*, (b)-Macrophytes of *Eichhornia crassipes* and (c) - young shoot of *Thalia geniculata*

Figure-2
Experimental setup

Results and Discussion

Physicochemical characterizations of drinking water from the distribution network of National Water Company of Benin (SONEB): After being harvested, plants were kept in drinking water from the distribution network of the National Water Company of Benin (SONEB). The dissolved oxygen in the water was 1.59 mg/L (table-1). This value shows that the water provides an aerobic environment that can facilitate the development of certain aquatic species which practice aerobic respiration. The water conductivity was low and equal to 72µS/cm. This reveals low concentration of charged particles[20]. Its turbidity equal to 3 NTU was below the World Health Organization (OMS) standards (4 NTU)[21] and shows that SONEB's water meets certain provisions of this standard. Low concentration of nutrient is in agreement with EC low value.

The physicochemical characterization of the used wastewaters are shown in table-2.

The value of pH equal to 8.12 GW shows that most of the ammonium in GW is in unionized form (NH_3). Discharge of important amount of such water in aquatic environment would be detrimental to aquatic ecosystem[22]. The redox potential E_H of WV and GW is comprised between 15 and 23 mV. Based on these values, it can be stated that the environment is favorable for the oxidation of organic matter and both environments are anoxic. The conductivity values show that the WV is much more loaded with ionic particles[23] compared to the GW. Furthermore, the WV is loaded with suspended matter (1520 mg/L) compared to the GW (137 mg/L). In fact, high level in turbidity were record WV (2300 NTU) against low value in GW (170 NTU). This results show that WV is trouble than GW. The nitrates concentrations in wastewater vary from 0, 3 to 25 mg/L. We note the highest concentrations in WV. This is justified by urine and feces that it contains. Similar results have been reported by Monchalin[24]. The GW exhibits a higher concentration of orthophosphates estimated to (152.5 mg/L). This could be explained by the presence of detergents in this latter[25].

Abatement yields (R) of different *Thalia geniculata* shoots: The purification yields of different shoots ***Thalia geniculata*** during the treatment trials of WV or GW (table-3) reveals that phytoremediation has not a direct significant influence on the pH and temperature of the medium as these two parameters did not significantly change during the course of the treatment. It might be governed by other mechanisms. The pH value (7.79) closer to neutrality in the young is an indicator of quality of treated wastewater which could reuse in aquaculture[26]. The temperature showed same variation profile in all pots and ranged 27.8°C to 29°C during the experiment. This range of the temperature is suitable for nitrifying activity. In contrast (TDS) and nutrients (NO_3^-, $PO_4^{3-}$and TKN) were considerably eliminated. Armstrong et al[27] made the same remark during their investigation. The conductivity decreased by 30.74% and DO concentration increased. This could be explained by the fact that *Thalia geniculata* plants absorbed the excess of nutrients through cell walls of their highly branched stems and roots and produce oxygen needed for decomposition of organic matter, and oxidize NH_3. The table-3 shows that in general *Thalia geniculata* was efficient when purifying wastewater and especially the young shoots was much more efficient compared to the old shoots.

Table-1
Drinkable water physicochemical characterization

pH (-)	EC (µS/cm)	TDS (mg/L)	NO_3^- (mg/L)	NTK (mg/L)	PO_4^{3-} (mg/L)	Turb (NTU)	DO (mg/L)
7,08	72	00	0.9	-	1.5	3	1.59

Table-2
Physicochemical characterization of valve water (WV) and grey water (GW)

Parameters	Valve water (WV)	Grey water (GW)	EU standard
NO_3^- (mg/L)	25	0.3	< 45[e]
PO_4^{3-} (mg/L)	72.5	152.5	5[f]
EC (µs/cm)	6515	1596	250[f]
pH	7.93	8.12	6 – 9[e]
Temp (°C)	27.8	30.0	> 1[e]
Turb (NTU)	2300	170	< 4[f]
DO (mg/L)	0.1	0.45	-
TDS (mg/L)	1520	137	35[e]
NTK (mg/L)	43.4	7.7	10 - 15[e]
R_H (mV)	15.55	15.96	-
E_H (mV)	-92	-83	-

Table-3
Purifying yields of different shoots of *Thalia geniculata*

Parameters	Young Shout (YS)			Senior shoot (SS)			Old Shoot (OS)		
	In come	Exit	R (%)	In come	Exit	R (%)	In come	Exit	R (%)
EC (µs/cm)	1851	1282	30.74	1909	1464	23.32	1812	1665	8.11
pH	8.19	7.79	4.83	8.14	8.05	1.16	8.17	7.92	3.04
Temp (°C)	28.9	27.8	3.80	29	27.8	4.13	28.9	27,8	3.80
Turb (NTU)	1434	24	83.21	1354	39	70.89	142	60	57.74
DO (mg/L)	0.47	3.6	-86.94	0.49	2.4	-79.58	0.53	4.3	-87.67
NO_3^- (mg/L)	2	0.2	90	3	0.2	93.33	2.2	0.2	90.90
PO_4^{3-} (mg/L)	31.47	7.5	76.16	35.05	12	5.76	34.31	14.5	57.73
TDS (mg/L)	110	15	86.36	104	30	91.15	109	46	57.79
NTK (mg/L)	81.9	00	100	73.5	00	100	110.6	9.8	97.13

R = abatement percentage

Figure-3 shows the profile of the electrical conductivity and turbidity in YS, SS and OS pots. Data showed that from the 1st to the 8th day, the macrophytes showed similar activity. Indeed, almost the same amounts of charged particles were removed in all cases. From the 8th day, the young shoots consumption of particles was four times greater than senior and old shoots. It can thus be stated that YS are more efficient in the assimilation of charged particles. Turbidity's curve drops till 22 NTU in the case of the YS; which confirmed the above-statement made. Comparing the purifying capacity of the different shoots, it can be said that the young shoots better abate or remove charged particles and suspended particles in Grey water.

Dissolved oxygen slowly increased in all pots the first three days to reach around 2 mg/L and then fluctuates around this value until the ninth day. The increase of DO could be related to its participation in the reactions of degradation and mineralization of organic matter to provide essential nutrients to the development of macrophytes. A drastic increase of DO was noted from the 10th and 14th day with a maximum value equal to YS (5.8 mg/L), SS (5.4 mg/L) and OS (6.1 mg/L) respectively reached on the day 11, 13 and 10. This increase could be explained by a decrease in oxidized material in the water.

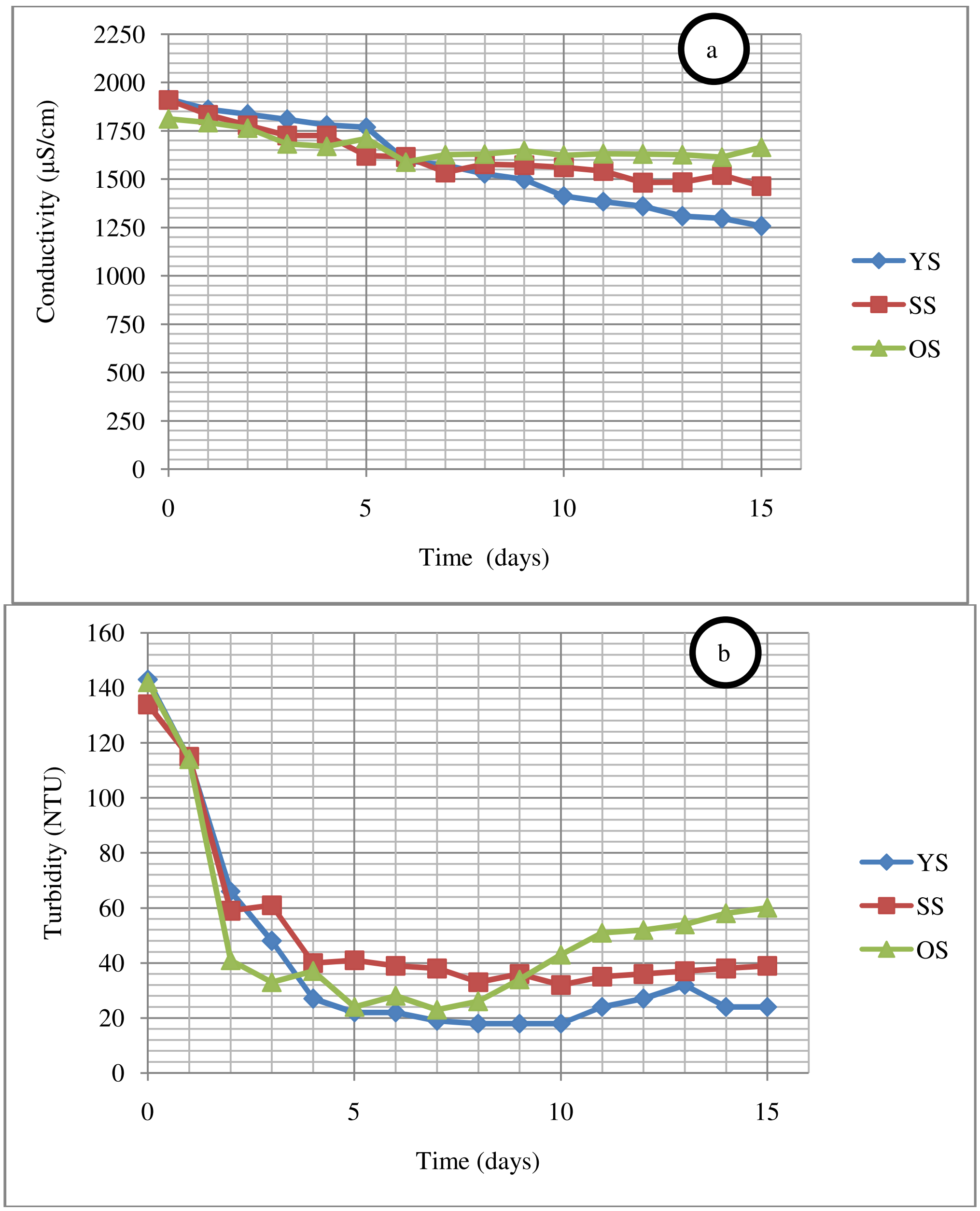

Figure-3
Electrical conductivity (a), turbidity (b) in YS, SS and OS pots of *Thalia geniculata* during the treatment

For easier and better discussion, pollutants removal efficiency is represented in the figure-5 for different types of macrophytes *Thalia geniculata*. Data shows that the performances of all shoots in removing pollutants exceed 50%. The minimum yield ranged 58% and was achieved by the old shoots when removing suspended matter and orthophosphates. This could be justified by the fact that rate for old shoot decreased comparing to others shoots. The YS pot owns the best removal efficiencies: 86.36% for TDS and 76.16% for PO_4^{3-}. Otherwise, the young shoots completely removed NTK (100%) as well as the senior shoot. Unlikely, the senior shoots exhibit a slightly greater performance (93.33%) in NO_3^- removal compared to 90% for young shoot. In summary, the young shoots of *Thalia geniculata* show very good performance in the removal of TDS, NTK, NO_3^- and PO_4^{3-}.

The electrical conductivity of wastewater containing the YS of *Thalia geniculata* and the WH (*Eichhornia crassipes*) vary differently during the first 6 days. Indeed, during the first 6 days, the YS of *Thalia geniculata* fixed much more charged particles compared to the water hyacinth. Charged particles absorption rate is three times greater than that of WH. Beyond the sixth day, the EC showed similar profiles in all the pots. Charged particles absorption rate decreased significantly with YS; while the WH still continued to absorb particles. The effectiveness of both macrophytes in abating ions is comparable. At the end of the treatment, on the 15th day, the EC values were 1282 and 1257 µS/cm respectively in *Thalia geniculata* YS pot and WH pot. These two values are close to the average (1150.46 µS/cm) reported by Abissy for a bed planted network[28]. Our result shows that the macrophytes reduce charged. Turbidity drops dramatically to about 20 NTU in both systems on the fifth days and then fluctuates around this value until the fifteenth day. On the fifth, the turbidity already decreased for about 86%. The curve shows that both macrophytes have similar behavior toward dissolved solid.

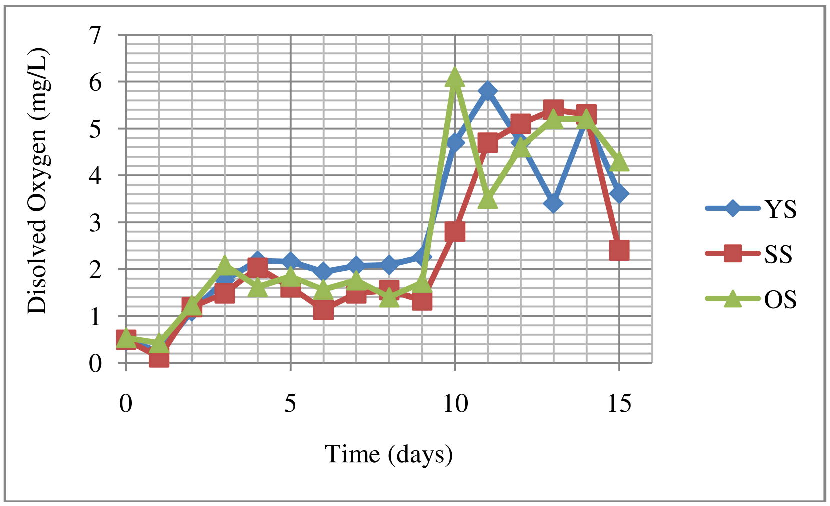

Figure-4
Dissolve oxygen profile during the treatment in Thalia *geniculata* YS, SS and OS pots

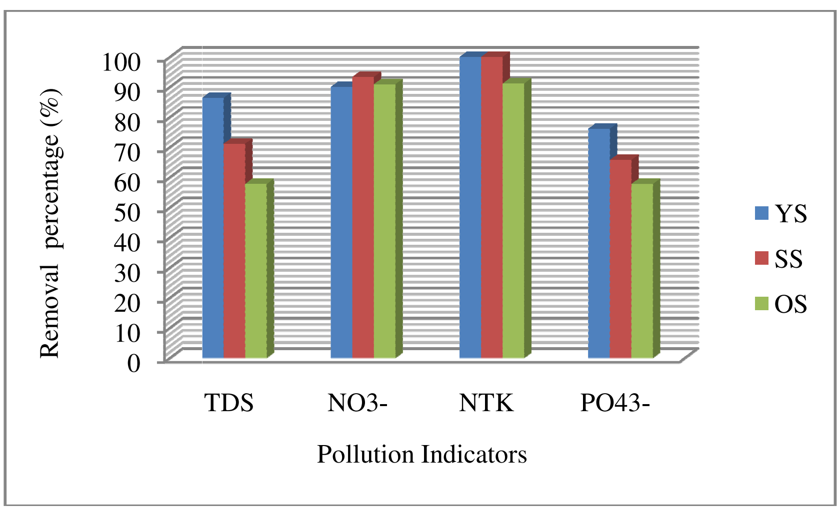

Figure-5
Macrophytes purifying yields over pollution parameters

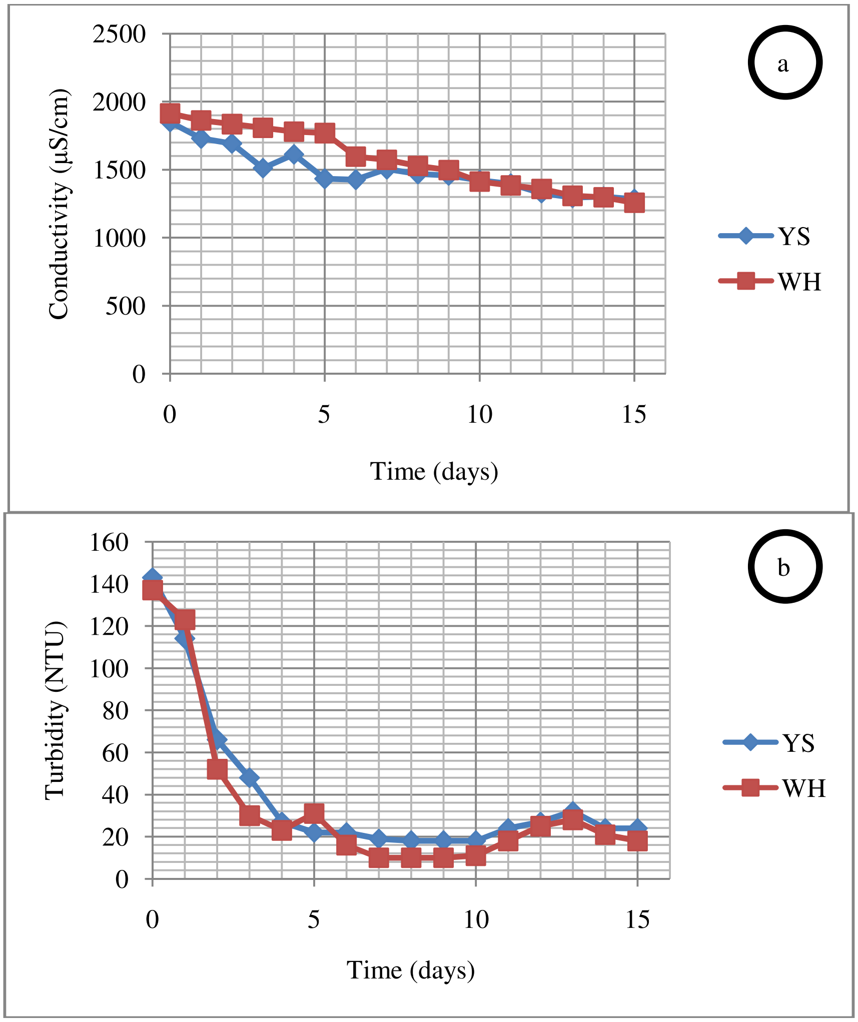

Figure-6

Electrical conductivity (a), turbidity (b) in *Thalia geniculata* young shout (YS) and water hyacinth (WH) pots during the treatment

Dissolved oxygen profile was quick similar in both pots although the experiment process. The highest concentrations of dissolved oxygen were 5.4 and 7.8 mg/L, in YS and WH pots; both were recorded on the eleventh day of the experiments. Data allow pointing out that although between 5^{th} and 10^{th} day, both pots showed similar DO concentration; WH produces more dissolved oxygen than YS. This may stimulate the growth of nitrifying bacteria in the rhizosphere. A similar result has been reported by Armstrong[27].

Figure-8 shows the results of comparative study between YS and WH. Results show that compared to the YS of *Thalia geniculata*, WH better eliminated TDS (90.90%) and PO_4^{3-} (86.92%). TDS dropped from 104 to 15 mg/L (YS) and 110 to 10 mg/L (WH). Removal of TDS and organic matters which trouble the raw water was possible via sedimentation and by microbial degradation[29]. The treated waste water obtain is clear at the end of the experiment. This confirms the results of Aïna[30]. Orthophosphate generally undergo reduction with purifying yield depending on the residence time. Orthophosphates removal yield achieved did not exceed 90% at the end of the experiment. The yield was 76.16% and 86.92%, respectively for the YS and WH. Unlikely to TDS, the YS of *Thalia geniculata* achieved better yield when removing NO_3^-. There is a wide variation in the concentration of NTK and NO_3^- in the wastewater between the 1^{st} and 5^{th} day. Their concentrations respectively dropped from 82.6 to 0 mg/L (NTK) and 6 to 0.2 mg/L (NO_3^-). NTK was completely removed (100%) by the YS; while 77.11% was achieved with WH. Concerning NO_3^-, 90% and 50% were removed, respectively by YS and WH. This suggests that the YS system is more effective in removing nutrients from wastewater. By the end of the treatment, the nutrients concentrations in the treated wastewater met some recommended values (table-2) for pourable domestic wastewater in the natural receptors in the republic of Benin. At the end of the experiments, only new shoots *Thalia geniculata* which represent a so-called neoformation charge[28] were found in the YS treated wastewater.

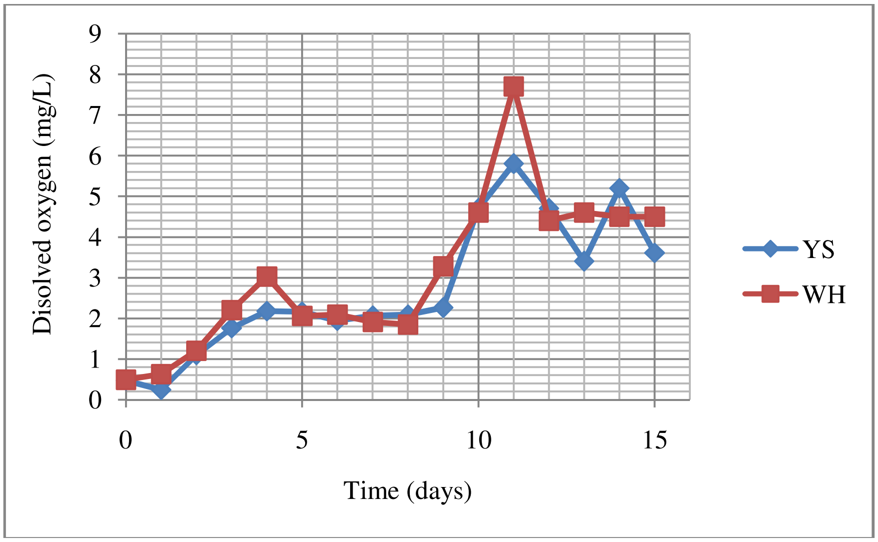

Figure-7
Dissolve oxygen profile in *Thalia geniculata* YS and WH pots

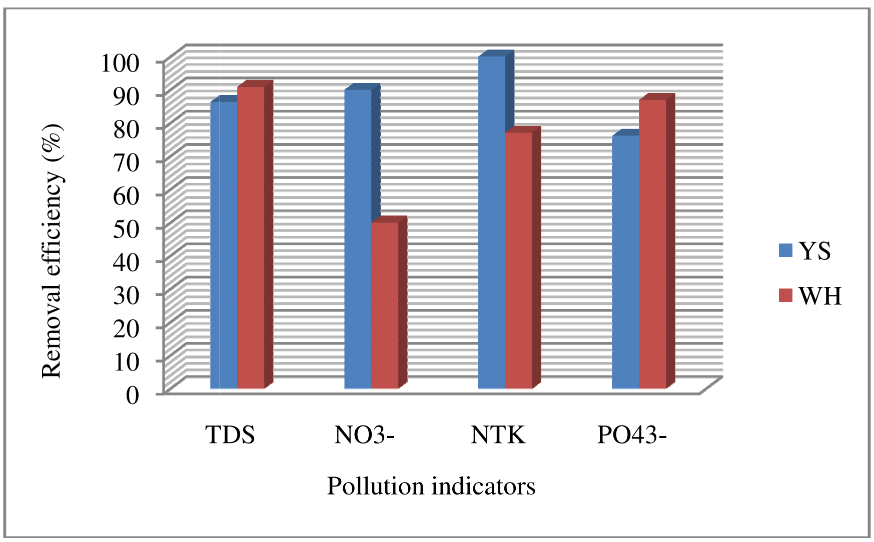

Figure-8
Macrophytes purifying yields over pollution parameters in YS and WH pots

Conclusion

The purifying power of *Thalia geniculata* plant and it comparative studies with *Eichhornia crassipes* (water hyacinth) have been investigated. *Thalia geniculata* was found effective in removing pollutants such as NO_3^-, TKN, PO_4^{3-} and TDS from domestic wastewater. Precisely the young shoots have the best ability of removing pollutants up to 80% from polluted water. Results also revealed that *Thalia geniculata* purifying capacity is comparable to the one of *Eichhornia crassipes*. As a consequence, we suggest and encourage the use of this plant, *Thalia geniculata*, in phytoremediation to improve the performance of sewage and domestic wastewater treatment systems.

Acknowledgement

Thank for Beninese Center for Scientifics Research and Technologies (CBRST), Cotonou, Benin for it financial contribution which help us to acquire some laboratory material in way to make this research.

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