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Study of the Purification Efficiencies of three Floating Macrophytes in Wastewater Treatment

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Abstract

In Benin, wastewater treatment remains a recurrent problem. While new technologies are in use around the world, sewage treatment process, adapted to the contexts of developing countries is almost inexistent. To overcome these deficiencies and provide practical experience for domestic wastewater treatment, phyto-purification tests on domestic wastewater has been conducted on the Campus of the University of Abomey-Calavi (CUAC). The work focused on three floating species which are Eichhornia crassipes Mart. Solms-Laub. (Water hyacinth), Pistia stratiotes L. (Water lettuce) and Lemna minor L. (Duckweed). A mini system was installed and consisted of an anaerobic lagoon and three different floating macrophyte ponds. The parallel position of the floating macrophyte ponds allowed, during the first phase, to assess the wastewater purification efficiency of individual floating macrophytes.; this was achieved by monitoring the pollution level of the wastewater in terms of its : SS, COD, BOD_5, TKN, $N\text{-}NO_3^-$,$P – PO_4^{3-}$, fecal coliforms and fecal streptococci and monitoring operational parameters such as T, pH, E_H , turbidity, electrical conductivity. The results of the first phase showed that water hyacinth has been effective in the removal of carbon and nitrogen for COD 70%, 52.8% BOD_5, TKN 78.3% while water lettuce achieved nitrogen ($N\text{-}NO_3^-$) and $P –PO_4^{3-}$, forms abatement at 20.0%, and 92.6% respectively. Duckweed was successful in reducing 35.6% of TKN, and 100% of coliform and fecal streptococci. The complementary effect of the potential of the studied species in a mixed system of floating lagoon gives even better returns, provide that the limit of the salinity content to 1.126 µS / cm in wastewater tolerable by the macrophytes is observed.

Keywords: Domestic sewage, treatment, floating macrophytes, purification efficiency.

Introduction

Beninese - suffer a profound lack of sanitation and hygienic facilities due to the non existence of master plans for wastewater management in the 77 municipalities of the country. Instead of real and concrete sanitary measures to improve the living conditions of the populations, only non lasting decisions are taken. The adopted sanitary strategies that are developed throughout the country are limited to the construction of individual septic faucets or tanks and latrines adapted to rural areas but this turns out to be precarious in large cities, while exemption systems or sewer systems and purification stations of waste water are almost nonexistent[1]. This creates enough contrast, in the sense that according to the Ministry of Energy and Water[2], Benin urban population has been growing steadily because migration from villages to the main cities. Thus, urban population is projected to be over 53.5% in 2015. It is therefore imperative that large cities be endowed with appropriate and cost effective sewage system. To attain this goal, the choice of effective tools for treatment of domestic sewage produced in the municipalities where extensive processes are adapted to environmental conditions is crucial in order to initiate the improvement of the living conditions of the populations and therefore partly meet the Millennium Development Goals (MDGs) for 2015. Several processes are operated worldwide. Anaerobic-aerobic systems are remarkably used on an industrial scale for the treatment for several years of very high COD loads municipal wastewater. But an examination of different types of anaerobic-aerobic showed the limits of these methods for the high flow rates[3]. Meanwhile, other rustic techniques, known as environmental technologies have been developed and are based on the self-purification ability of natural aquatic ecosystems[4]. Those technologies put in use specific diversity of plant resources, set up emergent macrophytes, floating and submerged macrophytes. Senegal, Burkina Faso, Niger, Ivory Coast and Cameroon have put this in use over a decade, constantly seeking more efficient treatment processes. Fixed macrophytes are often used to treat very loaded wastewater with very good yields. However, the clogging risk and the difficulties in maintaining the fixed macrophyte lagoon limit its spread use[5,6]. In West Africa, treatment of waste water by floating macrophytes are acclaimed as innovative technologies, decentralizing, with better prospects of sanitation for developing countries[7]. The floating lagooning started in Benin few years ago, can turn out to be very opportune, if systematic research on several floating plant resources settled preferentially in polluted aquatic ecosystems are undertaken and demonstrated the effectiveness of the technology.

It is in this context and in order to give incentive for a drastic consolidation of appropriate solutions that it has been initiated on the University Campus of Abomey- Calavi (UCAC), an experimental study on the phyto-purification of domestic wastewater with three floating species : *Eichhornia crassipes Mart. Solms-Laub.* (Water hyacinth), *Pistia stratiotes L.* (Water lettuce) and *Lemna minor L.* (Duckweed). This study specifically aims to: i) evaluate the effect of three floating macrophytes put in parallel tanks to purify the same quality of household waste water ; ii) propose a mixed system of optimal floating lagooning.

Material and Methods

Experimental site: Purification trials were conducted on the UAC located in the town of Abomey-Calavi figure-1. The experimental site is characterized by a Guinean climate type composed of two wet seasons and two dry seasons[8]. The average annual rainfall is around 1200 mm[9]. The monthly average temperature varied between 27°C and 31°C with a deviation of ± 3.2°C between the warmest month (March) and the coolest (August); relative humidity varied from 76.84% in January to 84.55% in July.

Methodological approach: at the Technology Center for Practical Water Supply and Sanitation Laboratory of Science and Technology of Water at the Ecole Polytechnique d'Abomey-Calavi (EPAC), it was simulated a mini waste water treatment plant that is consisted of four basins. The first pool put at the head of the system is an anaerobic pond whose role was the pretreatment of influents, with considerable reduction of solid by sedimentation and partial digestion. The other three basins were connected in parallel and to the anaerobic pond by PVC pipes figure 2. Household wastewater from a septic faucet system of the university was retained for 11 days in the anaerobic pond prior to sending it to the floating macrophyte ponds called secondary basins. The operation of these secondary basins is based on a symbiotic action of plants and microorganisms that are living free in the water or attached to plant roots. The retention time of wastewater in the secondary basins was 15 days, which differed from the time of contact of the influents with floating plants.

To monitor the pollution level of wastewater in the system, daily sampling campaigns of global parameters of pollution such as T, pH, E_H, O_2, conductivity, turbidity, were performed. While for the purification efficiency parameters, measurements were periodically done before, during and after the introduction of plants in the basins. The analytical methods used for all parameters were in line with AFNOR and European standards. COD was measured by the volumetric method NF T 90-101, based on chemical oxidation of oxidizable molecules of wastewater by potassium dichromate. BOD_5 was determined using the manometric method NF T 90-103. For kjeldhal nitrogen, the assay method was the mineralization with selenium, following the procedure NF EN 25663 (January 1994). In the presence of concentrated sulfuric acid and heat (440°C), all forms of nitrogen are converted to ammonium. Finally, with regard to microbiological analyzes, counting on solid medium by the agar incorporation method was used. Fecal coliforms were counted according to the NF-08-05 with the mid-Rapid E. coli (24 h at 44°C). Fecal streptococci were determined according to NFT-90416 with the environment Slanetz (24 h - 48 h at 37°C). After laboratory measurements, yields were determined for the treatment efficiencies.

Results and Discussion

Characterization of anaerobic basin: Global pollution parameters sought in raw water for their contents match the composition of the influent from household origin. The determined COD/BOD_5 ratio is 2.7 a value < 3 indicating the biodegradability of household sewage. The parameters presented in table-1 have varied throughout the treatment, notably for turbidity, electrical conductivity, redox potential. The pH ranging from 6 to 8 is favorable for the activity of microorganisms involved in the elimination of nearly half of the pollutants[10,11].

The pretreated waste water, once in the floating macrophyte ponds are modified, by the levels of global parameters table-2. Parameters vary with time. Lower turbidity values begin to be observed at the cultivation and after harvest. It was recorded for the pond with water hyacinth a value of 4.66 NTU indicating an efficient trapping of suspended solids. Nonetheless, the conductivity values fluctuates very little figure-3: 3a and 3b.

Purifying efficiencies of floating macrophytes: The best removal efficiencies of organic, nitrous and phosphorous pollution are shared by purifying plants used. Water hyacinth turns out to be the better organic pollution reducing plant with respectively 70%, 52.8%, and 78.3% for COD, BOD_5 and TKN; water lettuce makes a greater contribution in reducing nitrogenous forms with 20.0%, and 92.6% respectively for N-NO_3^- and P-PO_4^{3-} of allowances respectively of however, duckweed weakly follows. Quickly forming an opaque screen, thinner, it can be used to reduce TSS, as are the dead material of algae, which grow at the expense of floating macrophytes. An important part of the scrubber role of water hyacinth and water lettuce is the trapping of these materials, by processes of filtration-adsorption by their root system. But compared to their yields, water hyacinth stands out. Overall, P –PO_4^{3-} are similar to those found for macrophytes[12]. Efficiencies related to pollution of nitrogenous and phosphorous are provided by the three species say 92.6% and 91.7% for orthophosphate; Kjeldahl nitrogen (TKN) being the best eliminated in the basin B hyacinth of . For nitrate nitrogen, water lettuce only influences the reduction of its content, with an efficiency of 27.0%. The improved removal of fecal coliforms and fecal streptococci is provided by the duckweed. This elimination can be understood by sedimentation but also by the effect of repeated harvesting of duckweed, which removes environmental pathogens, however, the water hyacinth has achieved efficient TSS, COD and BOD_5 removal comparable to[13], who found in Marrakech abatements of 62% and 82% of COD and TSS respectively in winter (November, February). These results are in contrast, slightly below those reported for a system with water hyacinth with an anaerobic lagoon at the head of the treatment in Niger[14].

Of all the above and depending on the priority given to the elimination of organic nitrogenous, phosphate and microbial pollution, water hyacinth is proven to be the best purifying species, followed by water lettuce and finally, the duckweed that polishes water treatment by the reduction of pathogens. It therefore appears a certain complementarity between these species, which can be usefully exploited. As it were, a mixed system of lagooning with subwatersheds in series significantly t will contribute to improved water treatment.

Table-1
Physicochemical characteristics of the global anaerobic pond

Parameters	T (°C)	pH	E_H (mV)	χ (µS/cm)	Turbidity (NTU)	O_2 (mg/L)
Mean ± SD	31,4 ± 1,2	6,32 ± 0,32	54,5 ± 19,4	516 ± 35	45,15 ± 33,00	1,5 ± 0, 9
Min	29,6	5,84	21,7	428	6,31	0,5
Max	33,0	6,87	83,6	552	95,83	3,3

Table-2
Characteristics of monitoring parameters of the operation

Basins	Physico-chemical variables	Min	Max	Average	Ecart type
Basin (*Water hyacinth)*	T (°C)	28,3	31,9	30,4	0,9
	pH	6,44	9,80	8,41	1,43
	E_H (mV)	-154,4	49,5	-70,9	86,4
	χ (µS/cm)	473	505	485	9
	Turb (NTU)	3,96	20,82	13,60	6,04
	O_2 (mg/L)	5,2	16,0	9,8	3,7
Basin *(Water lettuce)*	T (°C)	29,0	31,4	30,4	0,7
	pH	6,45	9,81	8,95	1,27
	E_H (mV)	-155,6	149,2	-81,3	100,7
	χ (µS/cm)	479	513	491	9
	Turb (NTU)	9,85	23,10	17,04	4,08
	O_2 (mg/L)	3,8	17,3	10,5	3,8
Basin *(Duckweed)*	T (°C)	28,7	31,6	30,4	0,7
	pH	8,00	9,81	9,57	0,46
	E_H (mV)	-155,2	149,3	-101, 9	105,3
	χ (µS/cm)	492	507	499	5
	Turb (NTU)	16,04	22,01	18,89	1,84
	O_2 (mg/L)	4,5	17,3	10,4	3,5

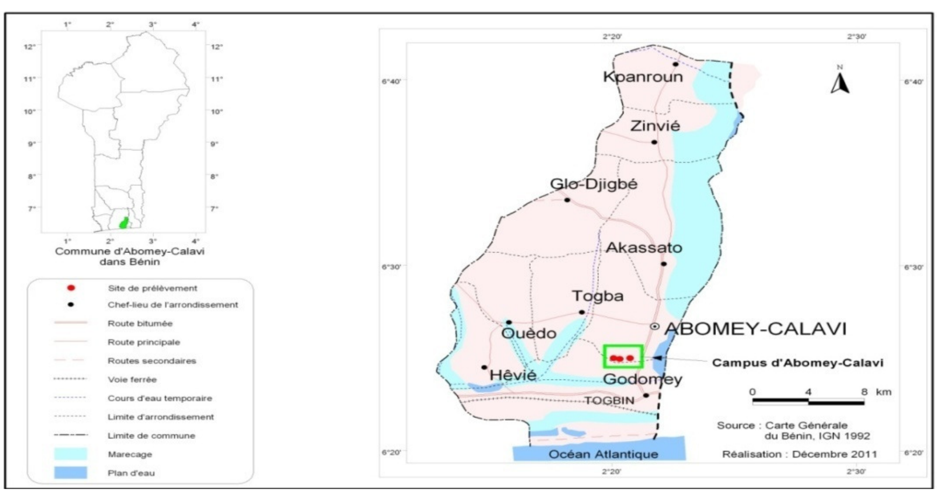

Figure-1

Location of UCAC in Benin and in the town of Abomey-Calavi

Figure-2
Experimental device installed

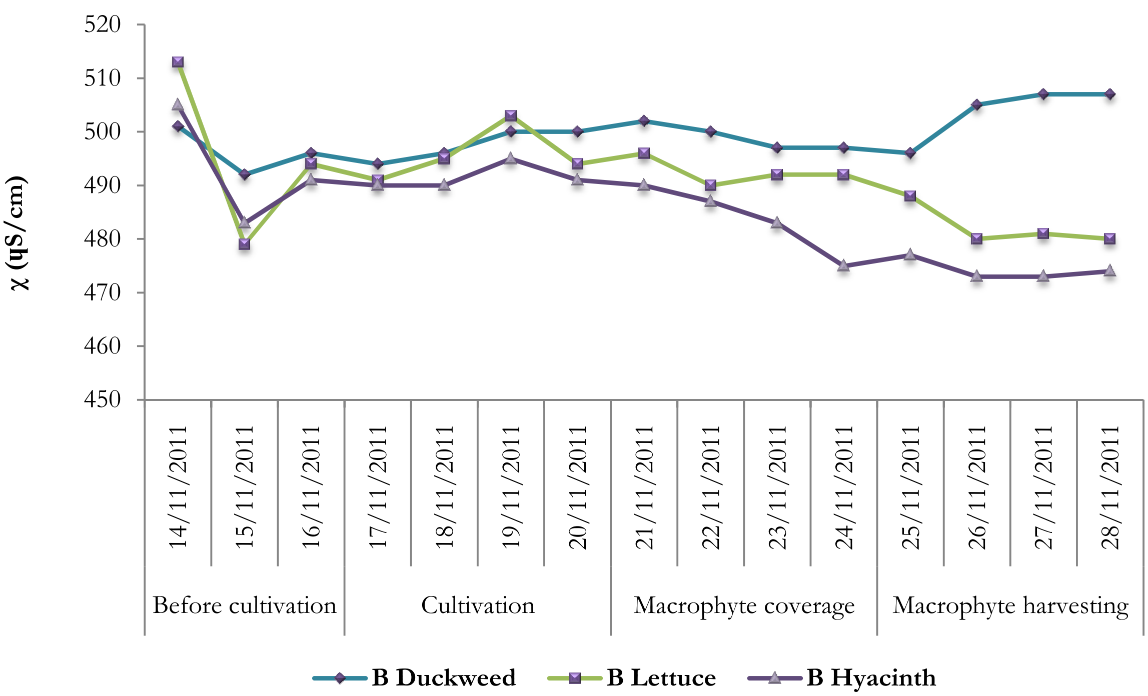

Figure-3a

Profiles of the electrical conductivity before and after the cultivation of plants of the species

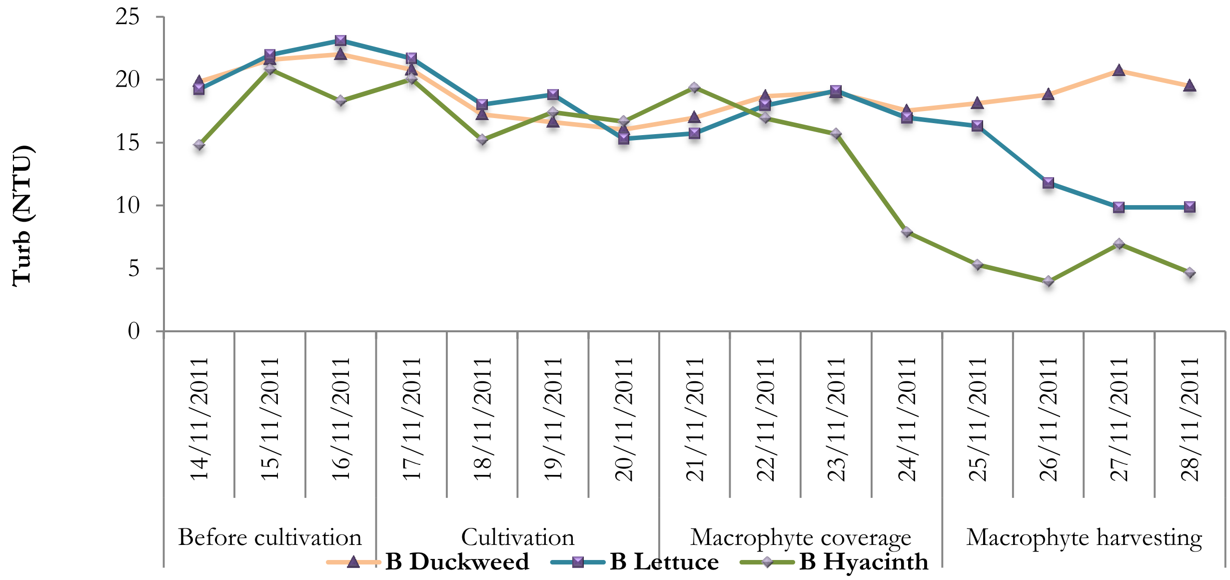

Figure-3b
Profiles of the turbidity before and after the cultivation of plants of the species

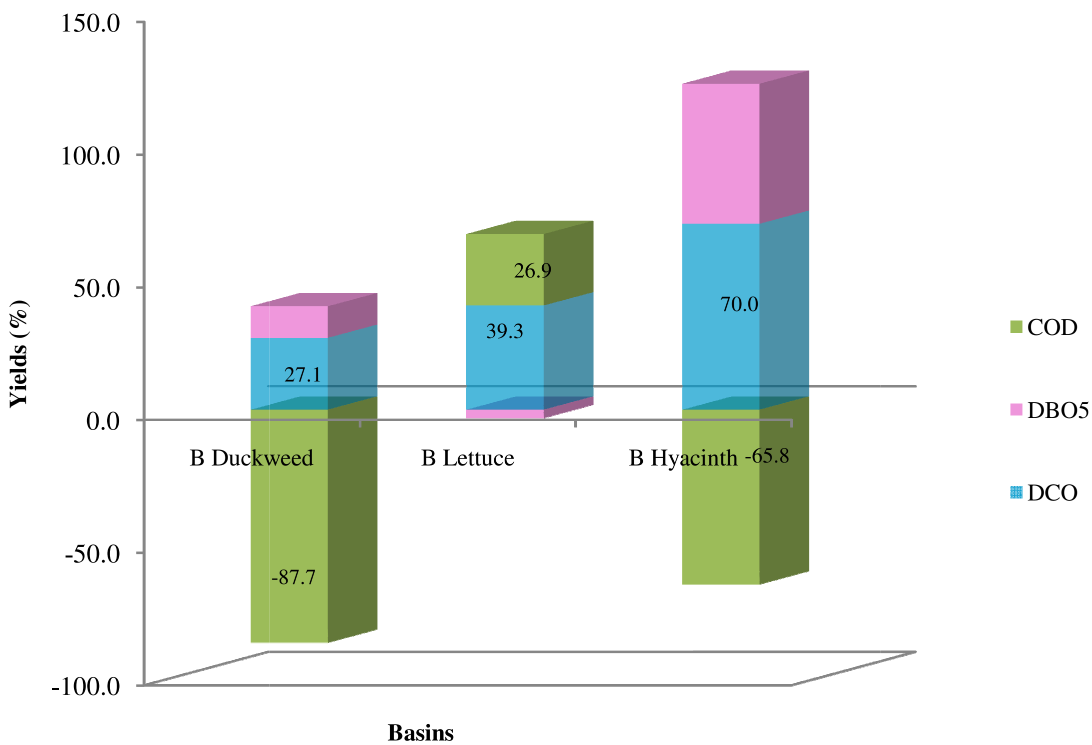

Figure-4
Purification yields in COD, COD and BOD5 of floating macrophyte ponds

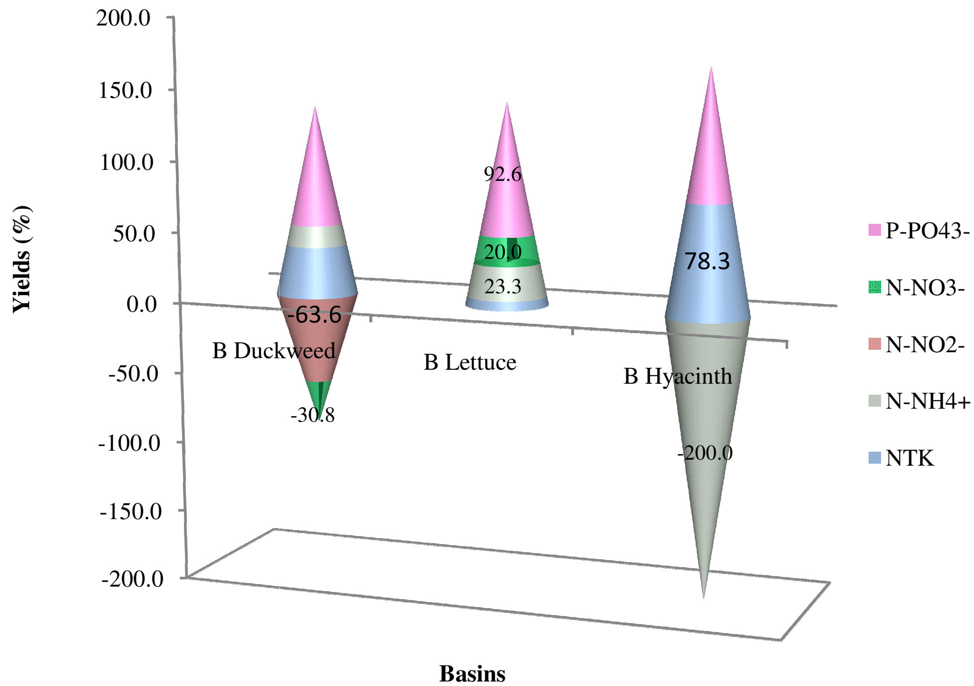

Figure-5
Purification yields in nitrogen and phosphorus compounds on river floating macrophyte

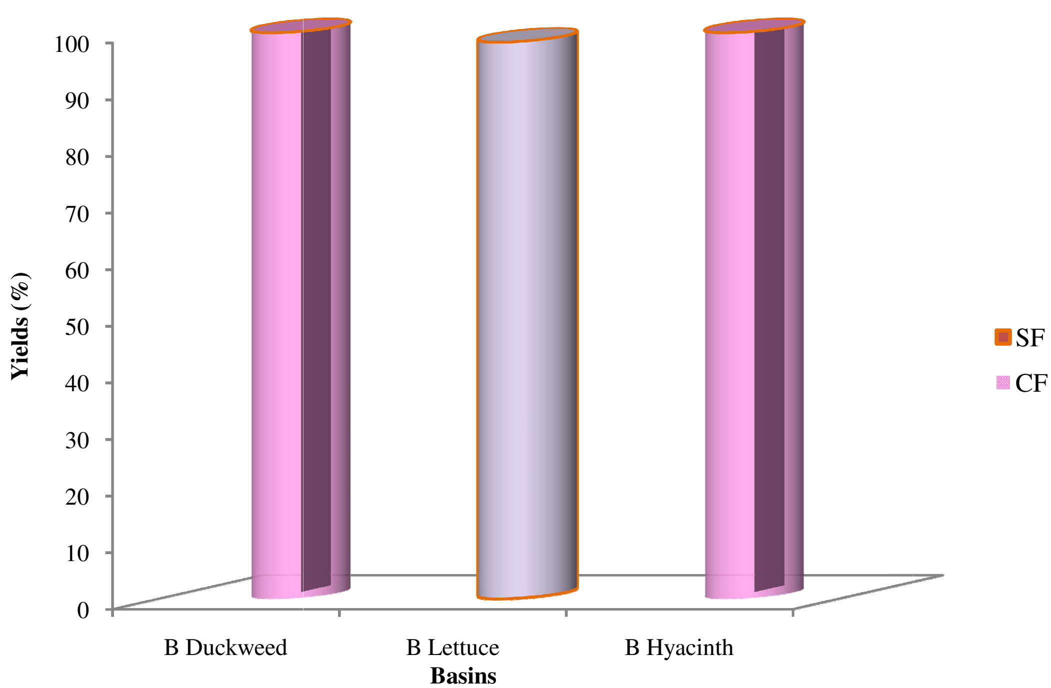

Figure-6
Yield purification of bio-indicators of floating macrophyte ponds

Conclusion

In Benin, wastewater treatment sector is at earlier stage of development, embryonic, with only few influents purification trials in urban and suburban areas. On the campus of the University Campus of Abomey-Calavi (CUAC), household wastewater produced in the residence halls meets the reference values for wastewater from domestic sources. At the end of the study, it is worth remembering that: the anaerobic tank ensures the removal of large suspended solids, dissolved organic carbon, the chemical oxygen demand and biochemical oxygen demand for 5 days three floating macrophytes induce physico-chemical processes in the sub-basins.

The dissolved oxygen of the medium increases with the presence of plants. However, the redox potential of the medium decreases immediately after their introduction.

Water hyacinth is better to increase and decrease the redox potential and turbidity of household wastewater; Organic, nitrogenous, phosphorous and microbial pollution removal efficiency vary from one species to another. The effect of water hyacinth (*E. crassipes*) is predominant compared to that of water lettuce (*P. stratiotes*) and duckweed (*L. minor*).

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