Monitoring and Measuring the biomass of the floating macrophytes by numerical image processing: Case duckweeds (*Lemna minor*) in Waste Stablisation Ponds

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1. Introduction

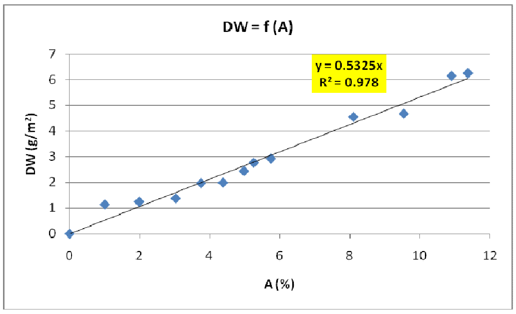
In hot countries temperature conditions allow the use of various WSP technologies, including floating macrophytes. We studied duckweeds and they have been used for industrial or domestic waste water treatment. However, the vegetable carpet formed on the water surface must be managed in order to maintain a good efficiency. The duckweeds must be harvested regularly. Otherwise when the biomass is getting too large there is some overlap, mortality increases, and dead cells sink and degrade at the bottom creating a new pollution. In addition, a hazardous harvest of the lenses can involve the reduction in the capacity of purification and also support the development of algae. We tried to monitor the biomass and the environmental parameters of the system (luminosity, temperature, pH, nitrogen, phosphorus, alkalinity, COD…) as well.
Indeed, the duckweed biomass measurements were carried out by many researchers (Köner and Vermaat, 1998; Caicédo et al., 2000; Rhamani and Sternberg, 1999; Edwards et al., 1992;…) according mainly to two methods, : **the measurement of fresh or dry weight**. It appears that these two methods present disadvantages especially for rather long experiments. If the last one is more reliable but destructive, the first on the other hand is less destructive but less accurate and not very reproducible. In the present work, we considered **numerical image processing by adapted soft wares,** namely: ACDsee® and Image Pro-Plus®. The purpose of this study is thus to establish the surface-biomass relationship for a possible comparison of the resulting biomasses by image and weighing.

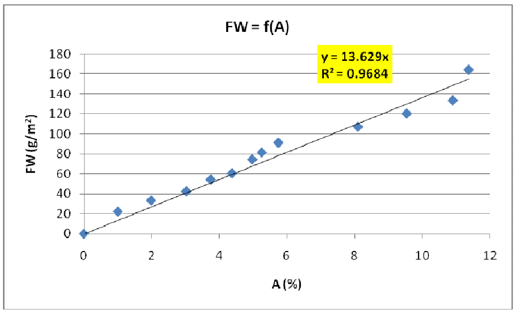
2. Methodology

The duckweeds samples tests were performed in a specially designed pilot located in a phytotron. Photoperiod of 16/8 was adopted. We performed three tests during three weeks at a rate of a test per week. Light intensity was controlled by sodium lamps (310 $\mu mol/m^2/s$). The biomass (± 1g/144 cm^2) *Lemna minor* was placed in six opened Plexiglas transparent parallelipedic tanks of 12x12 cm of side containing 500 ml of water. The water losses caused evapotranspiration were compensated daily by addition of tap water. The follow-up and the measurement of the duckweeds biomass put in culture were made successively by three methods, particularly: the measurement of the fresh weight (FW); the measurement of the dry weight (DW); and processing digital images by ACD-See® and Image Pro-Plus®. The following experimental planning was defined:

Test (Medium)	$[N\text{-}NH_4^+]_i$ (mg/L)	$[P\text{-}PO_4^{3-}]_i$ (mg/L)	Light intensity (µmol/m²/s)	Temperature (°C)
1	From 5 to 15	1	310	27,82
2	10	From 2 to 12	310	28,43
3	From 20 to 40	2	310	27,15

3. Results and Discussion





Good (R^2>0.96) linear relationships are obtained between covered surfaces and weight:
DW (g/m²) = 0.5325*A (%) with R^2 = 0.978 and FW (g/m²) = 13.629*A (%) with R^2 = 0.968 for covered surface not exceeding 15 % on average. In comparison with the relations of former works (H. Richard, 2004), although our values of R^2 are close tight to the unit, the values of the slopes are distinct, respectively **0.2649** and **2.8044** for an average density of 50% for Richard. These differences in slopes can be explained by the type of the image processing software which this author used, namely Image Tools who requires to transform the image into black and white in order to count the objects and to determine other size parameters (surface for example); hat is not of course the case in Image Pro-Plus where the objects are counted and characterized just after the calibration of the image. Thus, to appreciate the correct use of the software, we compared the biomasses obtained by weighing (fresh weight and dry weight) with those obtained by image processing. Most of the results consigned in the tables below show that the differences between the values of dry biomass are not significant, but for fresh biomass, we observed differencies due to less accuracy and lack of reproductibility. .

Test 1	**FW(i) (g)**	**FW(f) (g)**	**FWth (g)**	**DW (g)**	**DWth (g)**
1	**1.6**	1.57	**2.65**	0.06	**0.10**
2	**1.6**	2.53	**3.66**	0.12	**0.14**
3	**1.6**	1.68	**2.53**	0.07	**0.10**
4	**1.6**	2.59	**3.34**	0.13	**0.13**
5	**1.6**	3.09	**4.51**	0.13	**0.18**
6	**1.6**	2.51	**3.85**	0.12	**0.15**

Test 2	**FW(i) (g)**	**FW(f) (g)**	**FWth (g)**	**DW (g)**	**DWth (g)**
1	**0.99**	0.42	**0.92**	0.03	**0.04**
2	**0.98**	2.55	**4.74**	0.16	**0.18**
3	**1.09**	1.54	**1.32**	0.06	**0.05**
4	**1.05**	2.53	**3.91**	0.13	**0.15**
5	**1.08**	3.59	**4.86**	0.17	**0.19**
6	**1.06**	1.55	**2.46**	0.06	**0.10**

With FW(i), FW(f) and DW: fresh (initial and final) and dry biomasses obtained by weighing, and FWth and DWth: fresh and dry biomasses respectively obtained by image processing (theoretical).