left: The “Green Liver System” after planting the macrophytes and filling the tank with water. (Photo: Érika Marques)
right top: View of section containing the macrophyte *Eichhornia crassipes*.
right bottom: Demarcation and planting of macrophyte *Egeria densa* (Photo: Érika Marques)

The “Green Liver System”: eco-friendly water purification

Brazil - *Fitorremediação* (Portuguese)

Water purification using macrophytes to treat effluent from fish farming.

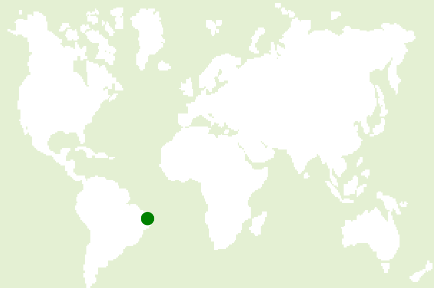
The Itaparica reservoir was completed in 1988 to generate hydropower. About 40,000 people were compulsorily relocated. The construction of the reservoir lead to a shortage of fish, making aquaculture a viable and profitable alternative. However excess feed and excreta of fish add nutrients and pollute water.

The “Green Liver System” uses aquatic plants, established in artificial wetlands, to remove, transfer, stabilize or eliminate pollutants in wastewater from fish farms. The use of large quantities of feed in aquaculture, along with the application of antibiotics, hormones and probiotics, has negative impacts on aquatic ecosystems due to the introduction of nitrogen, phosphorous and drug residues into the system. The Green Liver System is a form of phytoremediation (phyto = plant and remediate = correct) that uses a range of plants to decompose, extract, or hold contaminants present in soils and waters. This technology has been considered as an innovative alternative and a low cost option compared to others used in contaminated sites - like membrane bioreactors, upflow anaerobic sludge blanket (UASB), and others.

The plants selected for use in Green Liver System artificial wetlands depend on the pollutant to be removed. Research shows physiological differences between species, which need to be taken into account when planning wastewater treatments. Ideal plants for phytoremediation need: a) a fast growth rate; b) high biomass production; c) long rooting systems; d) easy maintenance/pruning; e) to be able to persists, and f) to have the ability to store trace metals within specific parts which can be later removed.

The Green Liver System uses aquatic macrophytes, which extract contaminants from the water, store them, or even metabolize them - transforming them into less toxic or harmless products. In the case of *Eichhornia crassipes*, most of the solids in suspension are removed by sedimentation or by adsorption in the root system. The dense coverage of these plants reduces the mixing effect of the wind, as well as minimizing thermal mixture. Shading by the plants restricts algal growth and the root system prevents horizontal movement of particulate material. In this way, particles are removed from the wastewater and microorganisms associated with the plants’ rhizosphere slowly decompose. Many organisms can be used in biodegradation: these include bacteria and fungi as well as plants, and the efficiency of one or the other depend, in many cases, on the molecule structure and of the presence of enzymes that are effective in degrading the pollutant.

The fish farm used as an example here is located on the margins of the Itaparica reservoir in Brazil. There are dozens of excavated tanks used to produce tilapia (*Oreochromis niloticus*) and “tambaqui” (*Colossoma macropomum*) fingerlings and juvenile fish. As well as these tanks, there are many net enclosures installed in the reservoir where the fishes are reared to maturity. Part of the wastewater from the excavated tanks is released into a stabilization lagoon, and the remainder goes to the Green Liver System. The effluent is enriched with spare feed, and excreta from the fish, which includes drug residues. If not treated, this may cause eutrophication because of its mineral richness. The Green Liver System consists of an excavated tank of 100m x 20m x 2m in size. The tank is subdivided into six parts: two planted to *Eichhornia crassipes* and four to *Egeria densa*. A mesh barrier stops fish from being flushed into the tank. Regular monitoring of the physical, chemical and biological parameters is required to control environmental fluctuations.



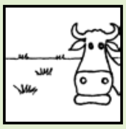
Location: Pernambuco
Region: Vila do Coité, Itacuruba
Technology area: 2 km^2
Conservation measure: vegetative
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago**)**
Land use type: reservoir, ponds, dams; extensive grazing land (before)
Climate: semi-arid, tropics
WOCAT database reference: T_BRA007en
Related approach: none
Compiled by: Érika Alves Tavares Marques, Universidade Federal de Pernambuco; Rua Professor Júlio Ferreira de Melo, n° 756 /apt° 201, Boa Viagem, Recife, PE, Brasil, CEP 51.020-231. erikatmbio@gmail.com
Date: 17 January 2014, updated June 2016

INNOVATE

Classification

Land use problems: The agricultural economy of this semi-arid region is characterized by pastoral activities, as well as the cultivation of crop species resistant to drought, such as cotton, corn (maize), beans, and cassava. Irrigation from the reservoir was potentially possible but investments in aquaculture proved more profitable. In general, the commercial companies involved do not treat effluent, leading to pollution. Even though monitoring is mandatory, almost nobody does it, nor do they make substantial efforts to purify the effluent (expert's point of view).
There are several conflicts over water and related land use in the region. Some people say the water quality in the reservoir is good (and use it directly for drinking), others report ill-health especially during times of low water levels. Commercial aquaculture primarily produces tilapia. The hydroelectric company manages the reservoir according to national needs in electricity – thus sudden water level fluctuations are frequent. Commercial aquaculture and associated land use dominate the shoreline, preventing access for artisanal fishermen to their traditional fishing grounds (land user's point of view).

Land use



Extensive grazing land (before);
Reservoir, ponds, dams

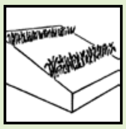
Climate

semi-arid

Degradation

water degradation: decline of surface water quality

Conservation measure



vegetative: macrophytes, different species

Stage of intervention

- Prevention
- ■ Mitigation / Reduction
- Rehabilitation

Origin

- Land user's initiative
- ■ Experiments / research: recent (<10 years ago)
- Externally introduced

Level of technical knowledge

- ■ Agricultural advisor
- ■ Land user

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires), over-exploitation of vegetation for domestic use, overgrazing, urbanization and infrastructure development, discharge (point contamination of water), over-abstraction / excessive withdrawal of water (for irrigation, industry, etc.)
Direct causes - Natural: change in temperature, change of seasonal rainfall, droughts
Indirect causes: poverty / wealth, inputs and infrastructure, education, access to knowledge and support services, war and conflicts, governance / institutional

Main technical functions:
- improvement of water quality, buffering / filtering water

Secondary technical functions:
- nutrient control, ornamental function

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- ▨ 500-750
- ■ 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- ▨ 500-1000
- ■ 100-500
- <100

Landform

- ■ plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- ■ rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- ■ 20-50
- 50-80
- 80-120
- >120

Growing season(s): all year due to tropical climate
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: very low
Ground water table: < 5 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic gradual change and extremes: In tropical areas, macrophytes grow all year. Ideal temperature range for *E. crassipes* (water hyacinth) development is between 25 and 31°C. The water hyacinth is a very fast growing plant, with populations known to double in as little as 12 days.
Sensitive to climatic gradual change and extremes*:* *E. crassipes* (water hyacinth) can tolerate extremes of water level fluctuation and seasonal variations in flow velocity, and extremes of nutrient availability, pH, temperature and toxic substances. *E. densa* is a very resistant plant and grows very fast, but the plant does not tolerate temperatures above 30°C.

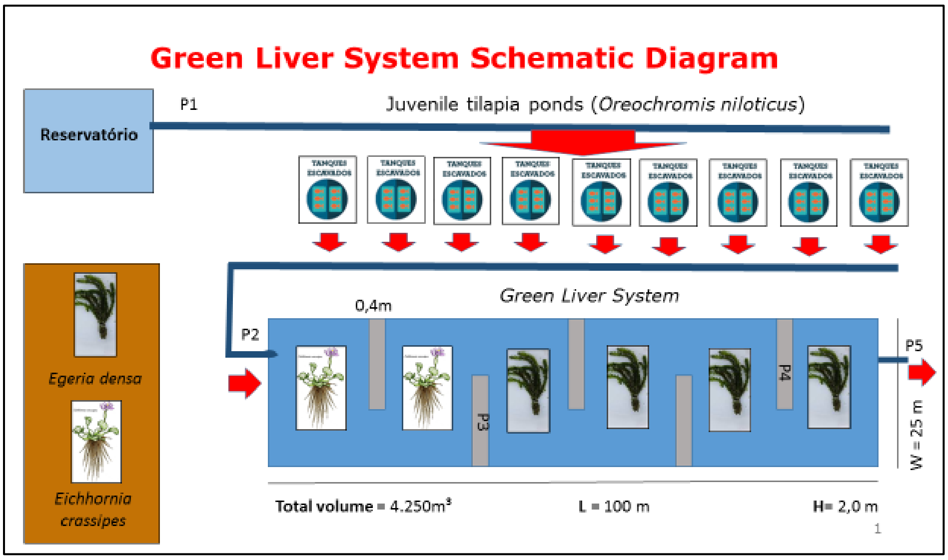
Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
	15-50
■	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual / household, small-scale land users, average land users, mainly men
Population density: < 10 persons/km^2
Annual population growth: 1% - 2%
Land ownership: State
Land use rights: Individual
Water use rights: Needs official registration and permission; heavy water use has a price
Relative level of wealth: Average

Importance of off-farm income: > 50% of all income
Access to service and infrastructure: Low: health, technical assistance, employment (e.g. off-farm), drinking water and sanitation, financial services, extension service; moderate: education, market, roads & transport; high: energy
Market orientation: mixed (subsistence and commercial)
Mechanization: none
Types of other land: Sporadically used by free-grazing livestock (mainly goats)



Technical drawing

The constructed wetland termed a "Green Liver System" is 100m x 25m x 2.0m in size. It is divided into six parts (one third of the tank planted with *Eichhornia crassipes* the remainder with *Egeria densa*). The average outflow during the period was 1,800 m³/h. Point P1 is the catchment from the reservoir. Point P2 is the inlet that receives the discharge of effluent from 10 ponds with juvenile tilapia (*Oreochromis niloticus*). Point P3 is the stage after the treatment with *Eichhornia crassipes*. Point P4 is the stage of the treatment with *Egeria densa*. Point P5 is the outlet into a containment basin. (Stephan Pflugmacher-Lima)

Implementation activities, inputs and costs

Establishment activities

1. Digging the pit (truck), stabilizing the walls
2. Building separation walls (construction costs: USD 3000 / unit
3. Fencing (cutting fence posts: USD 160 / unit)
4. Planting macrophytes in place (costs: USD 1900 / unit)

Establishment inputs and costs per unit

Inputs	Costs (US$)	% met by land user
Labour	5060.00	0 %
Supervision	1000.00	0 %
Equipment:		
– truck	125.00	0 %
Construction material		
– walls/baffles (cement)	475.00	0 %
– barbed wire	315.00	0 %
– earthwork	250.00	0 %
– tubular elements	30.00	0 %
TOTAL	**7255.00**	**0 %**

Maintenance/recurrent activities

1. Exchange macrophytes

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	3000.00	0 %
Equipment:		
– nylon fabric	38.41	0 %
TOTAL	**3015.00**	**0 %**

Remarks: Because of the tropical climate in the northeast of Brazil there is a need to remove *Eichhornia crassipes* periodically because it grows very fast (plenty of nutrients and warm temperatures all year). The cost of removal of the macrophytes is permanent and must be made monthly as the plant reaches adulthood it loses its capability of removing nutrients and gives it back to the water.

Assessment

Impacts of the Technology

Production and socio-economic benefits

++ increased drinking water availability
++ increased water availability / quality
++ increased irrigation water availability quality

Production and socio-economic disadvantages

−− increase of maintenance costs as manual labour is required for management of macrophytes.

Socio-cultural benefits

Socio-cultural disadvantages

Ecological benefits

++ increased water quality

Ecological disadvantages

−− nylon mesh (prevent the macrophytes from occasionally breaking loose into the reservoir).

Off-site benefits

Off-site disadvantages

Contribution to human well-being/livelihoods and support to decrease eutrophication in reservoir and channels.

\+ the technology contributed to improved water quality, which is directly related to people's health.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	positive
Maintenance/recurrent	positive	positive

Acceptance/adoption: There is little trend towards (growing) spontaneous adoption of the technology. Broad adoption is not yet expected at this stage of experimental analysis and testing. However a few people have already expressed interest.

Concluding statements

Strengths and → how to sustain/improve

Water purification is achieved by using natural processes → If the related tilapia fish production unit could be awarded a “green” or “ecological” brand, this would be beneficial and maybe trigger the adoption of the technology.

Among the advantages of adopting the Green Liver System are the low costs, the speed of construction and its relatively easy operation → Easily accessible and comprehensive information is needed, as well as the possibility of exchanging experience among users or future users.

If the environmental authority increases controls of how effluent from aquaculture ponds is handled (checking pollution and nutrient loads in the effluent which is usually returned to the reservoir without any treatment), the technology would help compliance with existing rules → Enhancing control and penalties would favour the adoption of such a green technology. Currently controls are rare or non-existent.

The technology can be constructed using locally available material. → As long as cheap labour is available and rural shops exist, the availability of inputs is adequate.

Weaknesses and → how to overcome

From time to time the macrophytes have to be removed, tubes may need cleaning and the system needs to be set up again. Sometimes, the removal of almost all water may be indicated. Major maintenance can cause peak labour needs. Manual labour required to monitor the system on a regular basis, and perform maintenance according to needs. Depending on the number and size of Green Liver Systems in action, caring for them can be a full-time job → The maintenance costs have to be well budgeted in the overall planning of costs and benefits of the related productive units.

Additional manual labour increases costs (and hinders adoption) → The more people use such techniques, for instance due to improved environmental monitoring and fines imposed, the more such extra expenditure will be accepted as regular running costs .

The disposal of the removed macrophytes is still a problem to be solved. If the macrophytes have accumulated high levels of toxins, the biomass cannot be used for compost making or livestock feeding → The removed macrophytes should be analysed for their pollutant content. A biodigester could be the solution to the disposal of contaminated biomass, generating energy for the productive unit and possibly for the local population too.

The management of the system is not simple. Many different and unexpected disturbances can occur. Experience and close, constant watch out is needed → Exchange of experience among users would facilitate its management. An updated list of threats could be helpful.

Key reference(s): Pflugmacher, S. et al. (2015) Green Liver Systems® for water purification: Using the phytoremediation potential of aquatic macrophytes for the removal of different cyanobacterial toxins from water. AJPS 06 (09), 1607–1618. doi:10.4236/ajps.2015.69161.• Nimptsch, J.et al. (2008) Cyanobacterial toxin elimination via bioaccumulation of MC-LR in aquatic macrophytes: An application of the “Green Liver Concept”. Environ. Sci. Technol. 42 (22), 8552-8557. doi:10.1021/es8010404
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