Layman's report

This report concerns the project designed to **demonstrate** that lumbri-filtration, an **innovative wastewater processing method** remains both **reliable** and **viable after industrial scale-up**, with a view to its inclusion in the range of technical wastewater disposal solutions proposed for small and medium sized communities.

Lumbri-filtration is a novel method that uses earthworms to treat Organically Polluted Water (OPW). The method was first advocated by Professor José TOHA of the University of Chile, Santiago, and was further researched and developed through a partnership formed between the French department of the Hérault and Chile.

1. Context and aims

Wastewater, and more generally organically polluted water, is treated by decomposing the organic matter it contains under aerobic or anaerobic conditions. This type of fermentation almost always takes place in a **liquid medium** (activated sludge, bacteria beds, lagooning, etc.). This requires **extremely large surface areas or volumes** (extensive lagooning ~ 10 m^2/inhabitant equivalent) or the construction of costly plants with complex systems that accelerate decomposition and produce an undecomposed « mass » or sewage sludge to be digested in fields or incinerators.

These treatment systems are problematic, both in terms of the space they occupy and of the high investment, running (energy, sludge disposal, etc.) and maintenance costs associated with the frequently complex technology used. This particularly applies to small rural communities such as **Combaillaux**, which has, like the rest of the Languedoc-Roussillon region, an ever expanding population **(1400 inhabitants in 2003 ; projected 2200 in 2020)**, and is already densely constructed **(13 % -114 hectares**

– of urbanisable area), but has a strong attachment to the preservation of its local economy (58% of the land is worked, including 300 hectares of vines and 30 hectares of olive trees) and the surrounding countryside (29% of the land is protected, of which 120 hectares is protected forest).

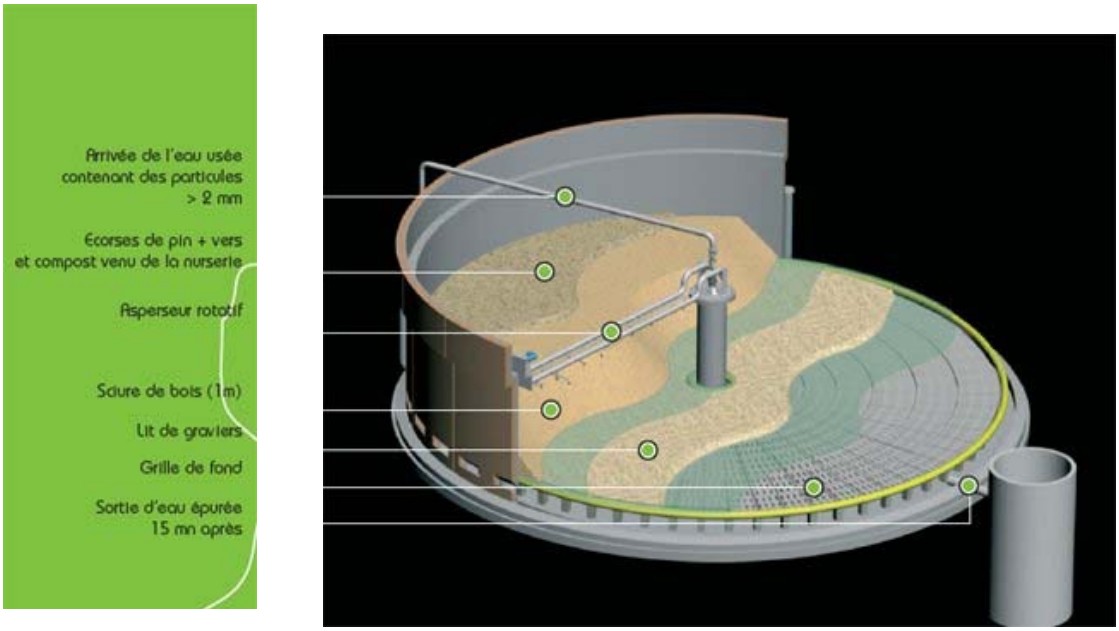
A novel wastewater treatment procedure known as lumbri-filtration which has been researched and developed (R&D) in France by the Soil Zooecology lab at the INRA (National Institute for Agronomic Research, Montpellier) in partnership with the University of Montpellier 2 (UM2/Water Sciences Unit) dispenses with most of these major inconveniences.

The aim of the Recyclaqua project is therefore to demonstrate this new sewage treatment method on an industrial scale for a community of 2000 inhabitant equivalents ; the project provides conclusions regarding the feasibility, economic and environmental advantages, and social benefits of the process in a concrete setting allowing it to be validated. In the setting of the wider water network, i.e. the tributary basin, it can be evaluated both upstream in terms of the wastewater produced and downstream in terms of the wastewater processed and its re-use. In addition, the project includes a public education and popularisation phase, on a local and European level.

1.2. Technical solution

The lumbri-filter consists of a 10 cm-thick active organic substrate layer (mixture of wood chips and pine sawdust and bark) in which the earthworms live, placed over a 1 m substrate which itself is on top of a gravel bed.

The wastewater is sieved on its arrival at the plant to remove any large particles and is sprinkled over the surface of the substrate through which it filters, leaving behind any organic particles in suspension which the earthworms then transform into mineral matter by digestion. The earthworms also ensure that the surface layer remains loose, allowing water to circulate freely.



The wastewater is treated in an Active Layer (AL) consisting of an initial mixture of 1/3 pine bark (25 to 40 mm in size) and 2/3 untreated pine sawdust, 100 cm thick. The sawdust contains approximately 10% pine chips (maximum 0.5 mm thick). Earthworms (*Eisenia andrei*, Bouché, 1972) are inoculated into the upper layer together with a 10 cm layer of vermi-compost (a mixture of blonde peat and pine bark vermi-composted for at least six months). Earthworms are inoculated after the lumbri-filter has been « watered » for the first time.

Sieved wastewater is regularly sprinkled over the circular lumbri-filter (which in the case of Combaillaux is 12 m in diameter) by a revolving sprinkler arm fitted with nozzles (1 m above the active layer).

The fine sprinkling ensures that wastewater is spread evenly over the whole surface of the lumbri-filter before percolating into the active layer. Finally, the lumbri-filtered wastewater is drained towards the outlet through a bed of silica gravel (20 to 30 mm in diameter and 10 cm thick) placed on duckboards.

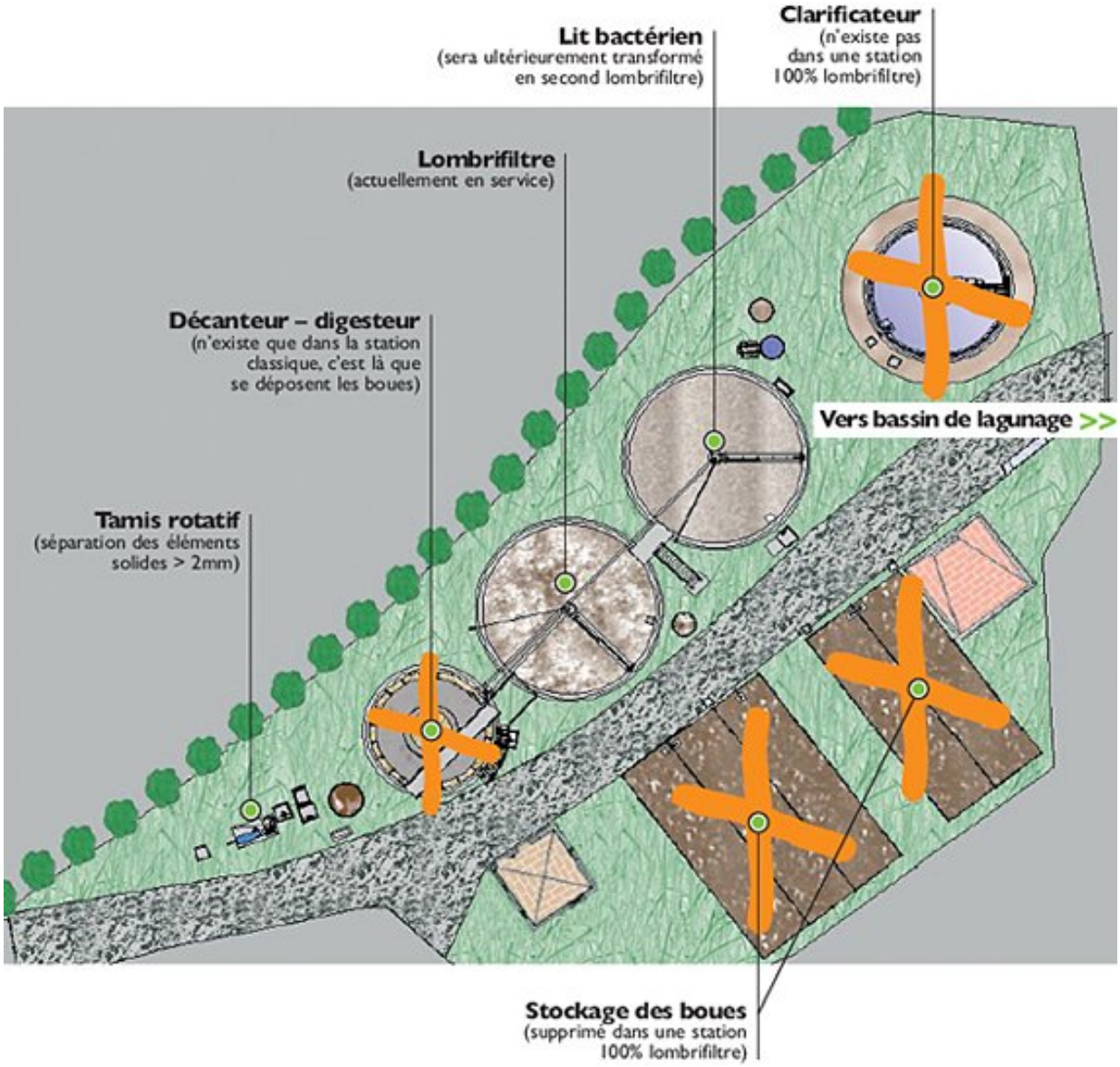
The proposed treatment differs from other extensive systems in the following ways:

a) there is no de-oiling-degreasing, as fats are processed in the lumbri-filter;

b) an anaerobic decanter-digester is not used before filtration, and therefore there is no anaerobic sludge,

c) no decanter or clarifier is required after lumbri-filtration, since all organic pollution is removed during the process. Lumbri-filtration is not therefore simply a filtration process, it also acts as a solid phase fermenter dispensing with the problem of sludge.

In environmental terms, the main advantage of this process resides in the minimal amount of sludge it produces, which almost entirely consists of the matter removed during pretreatment (sieving < 2mm), and transformed on site into vermi-compost.


Clarificateur
(n'existe pas dans une station 100% lombrifiltre)
Lit bactérien
(sera ultérieurement transformé en second lombrifiltre)
Lombrifiltre
(actuellement en service)
Décanteur – digesteur
(n'existe que dans la station classique, c'est là que se déposent les boues)
Tamis rotatif
(séparation des éléments solides > 2mm)
Vers bassin de lagunage >>
Stockage des boues
(supprimé dans une station 100% lombrifiltre)

2. Description of the system, monitoring/evaluation methods and results obtained

2.1. The system

2.1.1 Active layer (AL)

The active layer can be considered variously to be an artificial soil with earthworms, a solid-phase microbiological reactor or a physical filter, etc ; the behaviour of the substrate (potent Van der Walls forces) clearly distinguishes it from the mineral or synthetic materials used in filtration-percolation (sand, plastic filling elements, etc).

The porosity of the solid elements is such that there is room for both liquids and gases (water and air) : damp organic matter has a high water-retention capacity. The circulation of water (infiltration-percolation) and air (aeration) depends on this porosity, here created by **earthworm galleries**, and how the pores are organised.

These galleries also prevent water outlets becoming blocked subsequent to the filter materials subsiding (loss of almost 10% volume in 4 weeks).

2.1.2. Earthworm activity

Earthworms perform the « groundwork » via two concomitant mechanisms : burrowing and ingestion-digestion-defecation.

- **Burrowing** : leaves linear pores through which fluids and air can circulate.
- **Ingestion** : earthworms selectively feed on organic substrates rich in assimilable molecules which include the most polluting micro-organisms and organic matter, which are also the most completely decomposable; earthworms therefore mainly ingest the putrid substances on the surface of the active layer.
- **Digestion** : during this process, organic matter, including the most assimilable micro-organisms, is broken down. However, this matter also contains substances more difficult to digest such as cellulose and the keratin found in hairs, etc. The digestive process does, however, crush and blend non assimilable matter by mixing it with microbial inocula.
- Finally, the **casts**, or faeces are composed of this relatively indigestible organic matter in a new form and with a renewed microbial population in which antibiosis has ceased. This causes intense post-digestion decomposition of faeces (Cortez *et al*. 2000).

Like a brewer mixes his brew or as in microorganism reactors, the lumbri-filter is mixed through the digestive processes of the earthworms and the consequent displacement of the substrates, since the worms do not defecate where they eat.

2.1.3 Parameters affecting the system

- Temperature : optimal function is obtained at temperatures of between 0 and 30°C
- Waste type : the lumbri-filter is not designed to treat industrial waste

2.2 Demonstration protocol

2.2.1 Context and problems encountered

Lumbri-filtration is only one of the four phases involved in this novel wastewater processing system which can be broken down as follows:

1) earthworm breeding
2) sieving to prepare the wastewater for lumbi-filtration and more specifically to remove small diameter solid matter (sieving residue) that might block the spray nozzles
3) lumbri-filtration itself which treats the sieved wastewater by spraying it evenly over the AL
4) vermi-composting of sieving residues.

Process validation/optimisation took place in the period between February and November 2005.
As a precautionary measure and following the incidents described below, the lumbri-filter was loaded gradually. These incidents were :

- Two incidents involving the massive inflow of highly organically loaded wastewater after septic tanks were voided into the network, probably when new users were linked into the mains drainage system : the overload blocked the lumbri-filter and caused the death of the earthworms by suffocation (March and June 2005)
- Inflow of stagnant water, i.e. non oxygenated water which had stagnated in the different collection points; this problem was solved by placing aerators to inject air bubbles into organically polluted wastewaters before their injection into the lumbri-filter.
- After new earthworms were introduced into the filter in September 2005 to replace those killed by suffocation, the lumbri-filter became compacted once more as the substrate supplied with the earthworms was too highly charged in organic matter. The upper layer had to be turned over periodically, until such time as the substrate had been completely mineralised.

2.2. Monitoring/ evaluation and description of the method

During the monitoring/evaluation phase, the volume delivered to the lumbri-filter varied from 6 to 46 m^3, with a daily average of 15 m^3.
The system was monitored via water sampling and analyses conducted as follows:

- On a monthly basis, at the plant inlet and outlet points, as per French legislation (self-monitoring measures)
- At the same dates but also in the event of exceptional circumstances, before and after lumbri-filtration.

In total, twelve (12) sets of results were obtained.

2.2.3 The results obtained

Under French law, any waste released after processing must not adversely affect the environment : D4 is the most stringent quality requirement for processed wastewater leaving a plant.
Level D4 is attained in all our results (BOD* : 25 mg/l ; COD* : 125 mg/l or 75 % ; TSM* : 35 mg/l or 90 %). Purification yield objectives were consistently reached and TSM and BOD abatements were of excellent quality with mean yields of 94 and 97 % and concentrations always below level D4 thresholds.

* TSM : Totally Suspended Matter; BOD : Biological Oxygen Demand;
COD : Chemical Oxygen Demand

At the end of the LIFE project, the Steering Committee considered that the validation was incomplete since, for a variety of technical reasons, the incoming volumes never reached and were sustained at the standard operating levels defined for the Combaillaux community. With the assistance of the Hérault General Council, it was therefore decided pursue the validation for a further 6 months under the following conditions:
- incoming volume of 30 m^3/ day for the first 3 months,
- incoming volume of 60 m^3/day for the following 3 months. Given the current surface area of the lumbri-filter, this would validate the process for 4 IE/ m^2 by June 2006.

3. Evaluation of the environmental impact of the project

The primary advantage of the system resides in the minimal amounts of sludge produced ; this sludge in fact consists almost entirely of pretreatment residue (sieving < 2mm), and is vermi-composted at the plant. After auto-compacting, a volume of solid waste equivalent to one litre of primary waste per 30m^3 of water is fed into the vermi-composter.

The system also has the advantage of requiring little surface area (0.25 to 0.5 m^2/IE) at this stage in the validation and uses little energy. It has a real capacity to absorb major fluctuations in hydraulic load which was demonstrated in exceptional circumstances. It is virtually odourless and noiseless and allows waste to be monitored from an eco-toxicological standpoint.

4. Cost/benefit comparison of results

The system presents advantages both in economical and ecological terms. A comparison of different filters is provided below :

Comparative Table

Criteria		Activated sludge	Bacterial bed	Decanter-digester	Biological discs	Natural lagooning	Infiltration - percolation ponds	Planted reed filters	Lumbri-filter
Treatment level		D4	D2 ; D4 if proportions approp.	D1 if used (rarely)	D2 ; D4 if proportions approp.	D3	D4	D4	D4
Transient hydraulic overload									
Global capacity for 1000 IE		800 m^2	1500 m^2			15 000 m^2	12 000 m^2		400 m^2
Landscape integration									
No odour									
No noise									
Suitable for cold climates					Needs cover				
Suitable for major seasonal population fluctuations									
Investment costs (Euros Bef Tax/IE)	Mains for 50-200 pers	-	-		-	-	700	750	To be evaluated under standard conditions
	Mains for 200-1000 pers	500 Eur bef tax for 1000-2000 IH	550		500	450	600	650	
Running costs (Euros Bef Tax/IE)	Mains for 50-200 pers		Needs pre-trt						
	Mains for 200-1000 pers								
Maintenance interval									
Simplicity of maintenance									
Energy consumption									
Preferred application zone (IE)		> 1000	200-1500	100-1000	300-1000	300-1500	100-1500	0-1500	100-2000
Sludge production			Pre-trt in decant.-digester	Sludge mass reduc. 15-20%	Pre-trt in decant.-digester	H_2O type : sediment Slu. Type :scrape ev. 10-15 yr	Septic tank : Anaero. Digest. of sludge	V.mineral earth (can be used for agric.)	Very little sludge (inert)
Abatement (fecal coliforms)			-1ULog	0	- 1ULog	-3 to –4 ULog	-2 to –4 ULog	-2 to –4 ULog	-2 to –3 ULog

Very positive	Rather positive	Neutral	Rather negative	Quite negative

In very rural areas, an additional 15% must be added to the cost of the plant.

5. Transferability of the project results

At the end of the study, it appears that the lumbri-filtration process can indeed be effectively validated for 4 IE/m^2 ; it is therefore best suited to small communities, unless several lumbri-filter beds, which are space-consuming, are built.

The **conditions for transfer** are as follows :

- Control of incoming wastewater to prevent organic overload;
- Regular monitoring to detect any signs of substrate compaction caused by organic matter;
- It should be noted that a lumbri-filter should only be installed where a mains network already exists, the filter can be blocked by gravel released during connection to the mains drainage of inhabitants previously relying on individual septic tanks.

Compliance with legislation

The results obtained show that lumbri-filtration complies with French legislation (decree dated December 22, 1994), which is stricter than the European legislation covering this field.

7. Public education and communication activities

This was identified as a specific task in the project. The aim is to provide regular information throughout the duration of the project, together with the intermediate and final results and an explanation of the process itself. The Steering Committee chose to divide this task into five sub tasks depending on the public concerned and the means required:

- Information for the general public

The media, both national and international (Chile, Spain, Germany, etc.), have shown great interest in the project. In total over thirty interviews have been given (TV, the press) and a press file has been compiled and widely distributed (1000 copies).

- Communication to elected representatives

Representatives from all over France have visited the plant and have shown interest in exporting the system to their own wastewater treatment plants. The project has been presented to the Senate and has been awarded first prize in the Eco-Action Trophy, Infrastructure Category, presented by the President of the National Assembly in December 2005.

- Educational communication;

Several educational activities have taken place at the treatment plant itself

- educational visit of the plant : explanatory information panels describing each stage of the process with a mural painted on to the shell of the lumbri-filter;
- educational workshop : the aim is to raise consciousness about the pollutant nature of the wastewater we produce and to demonstrate the advantages of lumbi-filtration using explanatory panels and activities.

- Scientific and technical communications;

Certain members of the Steering Committee have taken part in a number of international seminars and/or meetings (Spain, Chile and Italy) with the aim of making the process known to the international community.

- Project web-site, for all audiences

The web site of the project can be found at the following address: http://lombristation.iamm.fr. (in French) and at www.laap.it (Italian version). The site includes a educational virtual exploration of the plant.

Legends :

Arrival of wastewater containing particles > 2 mm

Pine bark + worms and compost from nursery

Rotating spray arm

Pine sawdust (1m)

Gravel bed

Bottom grid

Purified water released 15 min later

Spray arm

Bags of worms and breeding compost from nursery

Sawdust and bark substrate

Clarifier (does not exist in a 100% lumbri-filter plant)

Bacteria bed (to be transformed into a second lumbri-filter)

Lumbri-filter (currently in use)

Decanter-digester (only exists in a traditional plant, this is where sludge is stored)

Rotating sieve (separation of solid matter > 2 mm)

To lagooning pond

Sludge storage (not required in a 100% lumbri-filter plant)