Design criteria and performances of reed bed filters for the treatment of washing parlour effluents

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DESIGN CRITERIA AND PERFORMANCES OF REED BED FILTERS FOR THE TREATMENT OF WASHING PARLOUR EFFLUENTS

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ABSTRACT
Initially designed for the treatment of domestic wastewater, Vertical Flow Reed Bed Filters [VFRBF] have been adapted for washing parlour effluents to study the feasibility of the treatment of such effluents instead of their storage and land spreading.
It was necessary to adapt the design of VFRBF to minimise the investment costs. Several experimental sites have been built, monitored and progressively adapted.
Following a septic tank of 3 to 9 m^3, the best design was considered to be: 2 stages of VFRBF in series each composed of 2 filters which are alternately fed on a weekly rhythm. The total active area is approximately equivalent to 0.25 m^2 per milking cow for the washing effluent of the milking machine and milk-storage tank and 0.4 m^2 per milking cow when the washing effluents from the floor and walls of the milking parlour are added to the previous ones. The 1st stage filters takes up 65 % of the total area.
Based on a survey done in 3 farms, the concentrations achieved a range of 50 to 180 mgL^{-1} in COD, 5 to 75 mgL^{-1} in BOD_5, 10 to 60 mgL^{-1} in SS. The nitrification, which can be considered as a good indicator of the redox potential within the filter media, was not complete but much more effective than in sand filters studied for the same purpose but some of them have clogged.

KEYWORDS
Milking parlour, reed-bed filters, vertical flow systems, wastewater treatment plants.

INTRODUCTION

The effluent generated by the washing processes of the milking machine and the refrigerated milk storage tank is called "white water" [ww]. The washing of the floor and walls of the milking parlour spattered with manures of which the major part of the solids must be scraped before washing generates a more concentrated effluent called "green water" [gw].
However, considering that the daily polluting load is rather low, compared with the domestic wastewater loads of several tens or hundreds of inhabitants, and that building cost must be minimised, treatment system design has been simplified.
After a first trial in Frolois [1] (Burgundy) where the low difference in level led to build a plant composed of a first stage with vertical flow and a second one with horizontal flow, 3 other plants were built with 2 vertical flow stages containing only 2 filters at each level. This choice allows respectively:

i) to decrease the necessary surface thanks to a better oxygen transfer through the interstices of the drained filtering material, not saturated, used as media for the purifying biomass,
ii) to simplify the operation of the system by alternating one working week for one filter while the other one is in rest week, and vice versa,
iii) to reduce construction costs by using a geomembrane and not breezeblocks like in Frolois.

This poster sums up the main objectives of the national program concerning the treatment of effluents coming from bovine milking parlours. It's focussed on the treatment of this type of wastewater treatment by a septic tank and reed bed filters. It explains and justifies the adaptations of the "French model" of VRFBF which were initially designed for small communities wastewater treatment. Then it gives the purifying performances of 3 sites built and monitored in the scope of a national program. Finally it examines a possible joint treatment for washing parlour effluents and the domestic wastewater of the farming house.

THE NATIONAL PROGRAM FOR WASHING PARLOUR EFFLUENTS TREATMENT

Because of their low fertilizing potential versus the one of liquid manure, the cattle breeders are not favourable to white water and green water land spreading which obliges them to build costly equipments for storage capacities, pending on which region, of a 4 to 6 months volume (for example: 200 m^3/6 months storage/60 dairy cows). When the storage capacities for liquid manure exceed requirements, a common storage leads to a reduced fertilizing potential of the mixture and extends strongly the land spreading time. This latter is estimated at 2.5 or 3 minutes/m^3 pending on whether the parcel is respectively 500 m or 1 km far from the storage area.
A dilution should only be done for too much viscous bovine liquid manure. But such a situation is seldom in France. So it is obviously interesting to create specific treatment plants for white and green water. A study allowed to prove that some treatment devices, derived from solutions which were designed for domestic wastewater, are inadequate. The concentrations and the loads induced by the washing parlour effluents were not enough known, that's why underground irrigations made on grown soil were quickly clogged.
The program begun with the characterization of the water to be treated and an experiment of 3 processes supposed to fit 3 principal criteria:
i) low building costs
ii) easy operation
iii) reliable performances even if they don't reach the same quality level than the one achieved for domestic wastewater.
So investigations concerned:
i) oxidation ponds similar to waste stabilisation ponds but initially adapted in New Zeeland [2],
ii) the sand filters (2 buried filters alternately fed) of which distribution system and infiltration area are covered by coarse gravel,
iii) VFRBF, started in France in 1992 – 1993, for small rural communities wastewater treatment [1].
This article focuses on this last process. At the end of the experimentation program (2001), sand filters have not been accepted because of fast clogging. The oxidation ponds process is not yet clearly defined because of an insufficient number of plants built according to the new guidelines adopted during the program. This latter recommends to come back to aerobic conditions in the second basin onwards just after an anaerobic process in the first one which is at least 2 meters deep.

MAIN DIFFERENCES BETWEEN DOMESTIC WASTEWATER AND WASHING PARLOUR EFFLUENTS

Septic tank implementation. Raw wastewater can be treated by VFRBF without preliminary clarification. This point is one of the reason of the success of this process in France for the treatment of domestic wastewater coming from small communities. Therefore it isn't necessary to build any clarification tank and correlatively no primary sludge is produced. The disposal of this latter is actually problematic.
A septic tank placed before the filters is necessary for washing parlour effluents for many reasons. The reasons are listed in the order they were studied for the adaptation of the treatment process.

1. Batch feeding implementation difficulties: Because of low daily treated volumes (485 to 680 l in average for 3 surveyed farms) it wasn't possible to miniaturize a self-priming siphon for the batch feeding without frequent clogging risks.
2. The necessary reduction of the superficial permeability: To obtain a satisfactory repartition on the first stage filters, it is necessary to add a sand layer on the surface in order to limit fine gravel [2 to 6 mm] permeability. These are normally the operating filtering layer of domestic wastewater filters.
3. SS flow reduction: When a superficial sand layer has been added, it is necessary to reduce the wastewater SS to minimise the clogging risks.
4. Buffer action on washing water pH: The successive washings with alkaline products for disinfections, then acids for the dissolving of the precipitates in the piping are giving a water pH between 2 and 12. The ST, with residence time between 6 and 9 days, for the ww and the mixture [ww+gw] respectively, gives the sufficient buffer action to get a pH closer to 7.

On the hydraulic point of view, in spite of a normal trend of the pond to level out the throughput peaks when the liquid level increases by a few cm inside the system, the equipments emptying done by automatic washing programs (about 70 l for each 3 cycles: pre-washing, washing, rinsing) nevertheless are sufficient to suitably spread the effluent if the filter unit surface at the 2nd level is lower than 15 m². For a larger surface, a dumping pan (voir photo de l'auget de Grammond si place nécessaire) or a pump, activated by quick levelling instruments, is required to be able to get, within 1 or 2 mn, a unit volume equivalent to a water height of 10 mm on one of the 1st stage filters.

2 filters series alternating every week. For domestic wastewater, the mineralization of organic deposits on the 1st stage filters and, together, the re oxygenation of the filters by diffusion require a rest period which has to be double from feeding period. In order to achieve that, 3 filters are needed with a feeding alternating twice a week, so that there are 7 days rest period for 3 to 4 feeding days. For ww or gw, in order to simplify the operation and the follow-up, decision has been made for a treatment process with only 2 filters in series (see Figure 1).

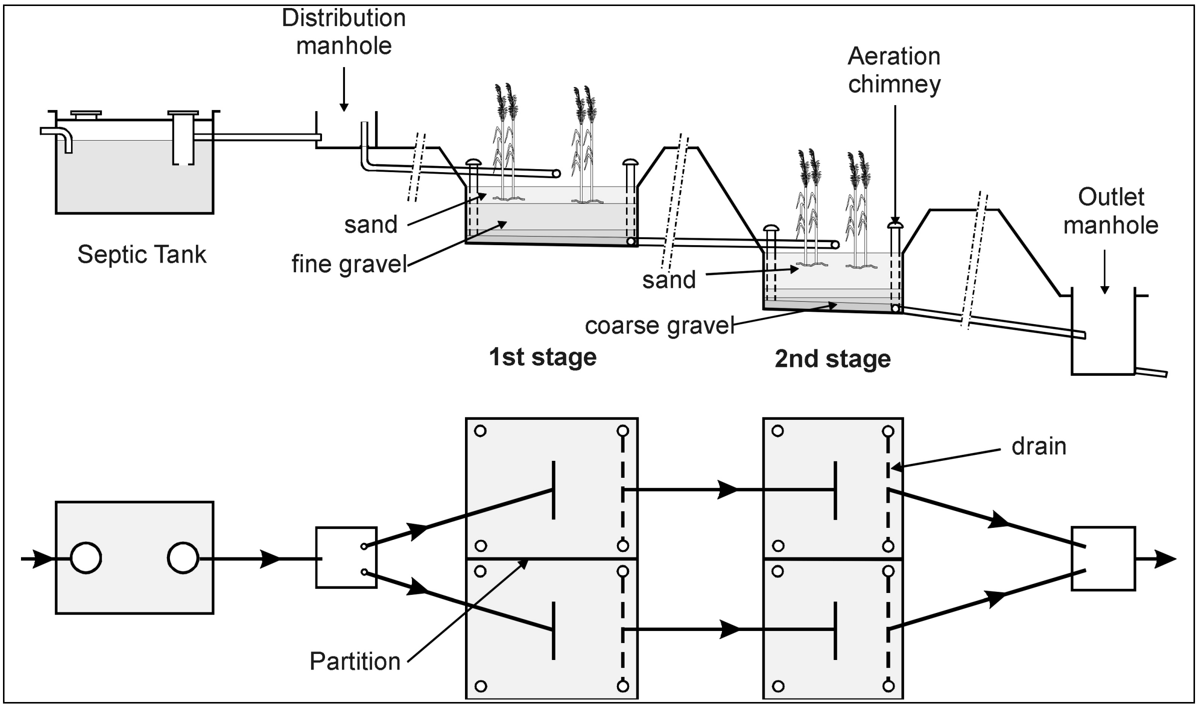

Fig.1 : Functional sketch of VFRBF for the treatment of washing parlour effluents

Dimensioning. Volumes and loads per cow could only be estimated on a low number of measurements in less than 10 farms in which practices vary greatly (residual milk quantity into the milking piping or in the storage – refrigeration tank ; more or less careful scrapping of the faeces on the milking parlour floor before washing). The volume of daily produced effluents, for ww only or for the mixture with gw, is decreasing respectively from 10 to 15 litres per cow for a 30 cows herd to 5 to 9 litres for 100 cows. It is explained by the washing automats which minimize the washing water volumes needed vs. the size of the milking machines and by the high pressure cleaning machines used for the platforms and the walls of large size cattle herds (over 80 cows). Conversely, the organic load is following a linear increase and can be estimated at 15 and 29 g of GOD/cow d^{-1}, for ww and for the mixture ww + gw, respectively.
The dimensioning parameter, which takes in account the faeces present in the gw, is the Global Oxygen Demand. It is the addition of the COD, the necessary oxygen quantity required for the degradation of organic matter carbonated part, and the oxygen quantity required for the nitrification of the reduced nitrogen load with a calculation of 4.5 g O_2 g^{-1} KN [3].
A reduction, lower than 20%, of the GOD in the ST is used to be on the safe side even if higher values could be sometimes observed thanks to a good SS retention in the ST as floating substances trapped by the siphon system or as sedimentary matter on the bottom of the tank.
Dimensioning of the total filter surface is based on a maximum surface load of 70 g GOD m^{-2} d^{-1}. This surface is split into 65% for the 1st stage filters and 35% for the 2nd one.
Finally, in order to simplify the procedures given to the technical services in charge of the system installation in the cattle-breeding, following global dimensioning criteria have been decided (Table 1):

Table 1: Dimensioning criteria for washing parlour effluents treatment plants.

Septic tank	< 100 cows	100 – 150 cows
white water	3 m^3	4 m^3
white water + green water	6 m^3	9 m^3
Reed bed filters	1st stage	2nd stage
white water	0.17 m^2 / cow	0.08 m^2 / cow
white water + green water	0.27 m^2 / cow	0.13 m^2 / cow

To systematically prevent the treatment process from non accidental introduction of non marketable milk. Milk is considered with good reasons as a basic foodstuff with a high nutritive value. But the potential polluting load of 1 L of milk is often not known by the breeders. Table 2 sums up the main characteristics.

Table 2: Indicative parameters of the polluting load tested on raw cow milk (in g L^{-1}).

COD	221.1
BOD_5	109.6
Fat	41.8
KN	5.0
GOD	243.7
TP	1.18

The dimensioning of all the studied processes (in the scope of the mentioned national program) obviously cannot take into consideration every deliberate and regular discharges of non marketable milk (colostrums, mamillary milk and / or milk coming from cows treated with antibiotics, for example). These discharges could represent loads leading to oversized treatment plants, difficult to manage and with high investment costs.
In consequence, instructions have been given to the breeders to take preventive measures in order to send these milk flows into liquid manure storage tanks or on manure storage areas with which they will be land spread.

To avoid direct discharges into small water streams. The required simplicity of the process does not allow to ensure a constant performance level, especially in case of accidental milk leak. To limit damages on an often high quality hydrographic network ahead the drainage basins, where are frequently located scattered farms, effluents discharge must be done on natural or equipped areas. These latter have a buffer action in case of temporary malfunctioning or tertiary treatment in order to improve the average performances of the treatment plant.
Pending on the particularities of the area located directly after the treatment plant, the following systems can be implemented:

- A at least 100 m long planted shallow trench.
- A natural hydromorph area in which retention time must be maximized and potential short-circuits prevented.
- An underground irrigation when the subsoil permeability and hydrogeologic characteristics allow it.
- An enclosed grassed parcel which would only be reaped to avoid animals trample.

PERFORMANCES

On the 3 studied farms having VFRBF, the average output concentrations of milk tank (TK) have the highest carbonated content (see Fig. 2).
It is coming from the residual milk content which was more important in one of them having 2 storage-refrigeration tanks. The largest (6000 L) was emptied from the top, two or three times a week, thanks to a plunging pipe connected to the milk collection truck. This operating principle doesn't permit an emptying as complete as with a valve in the bottom of the tank. The second tank (220 L), used for the direct commercialisation of milk and soft cheese production, is washed every day, but both of them together (named TK) have a definite influence.
The washing water SS from the milking machines [MM] and refrigeration tanks mainly are coming from proteins (mainly casein) which are agglomerating because of the high pH coming from alkaline washing. The most important part is obviously in the gw. The gw naturally are

richer in SS of which the organic nitrogen is leading to a GOD increase of concentrations 1.5 to 2 times more concentrated than in strictly domestic wastewater.

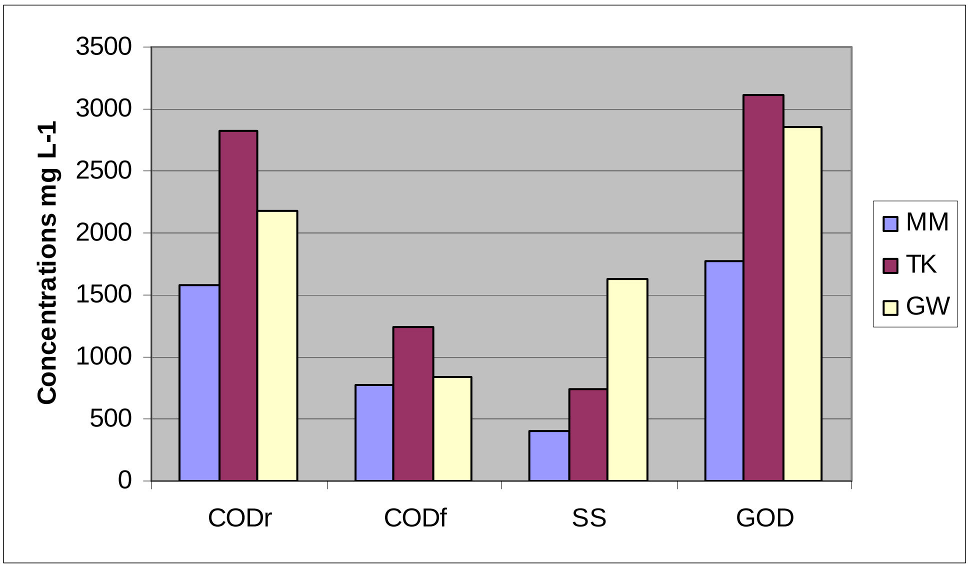

Fig. 2 : Average concentrations of the raw influents of 3 farms.

The dissolved carbonated fraction (DCOf, measured on a filtered or centrifugated sample) of the ST output water (Figure 3) is about the same level than on Figure 2. The SS, which are trapped in this equipment, with an average yield of 55% , are then releasing few dissolved compounds ; it can be explained because emptying is done every 6 months for green water and every year for white water. For both cases, it is not sufficient time to permit the installation of efficient anaerobic digestion processes.

In spite of important hydraulic residence time (6 to 9 days), the SS residual concentrations are still high (340 mg L^{-1} in average). With strictly domestic water, ST output concentrations are usually lower than 200 mg L^{-1}. It points out the interest of the reeds planting which allows the filters lining material, especially the superficial sand layer, to keep a sufficient permeability of about
10^{-5} m sec^{-1}. We have to remember that sand filters (unplanted) have not been authorized inside the national program because of the clogging observed on several installations yet oversized (0.45 to 1.0 m^2 per cow) and in use for minimum 5 years.

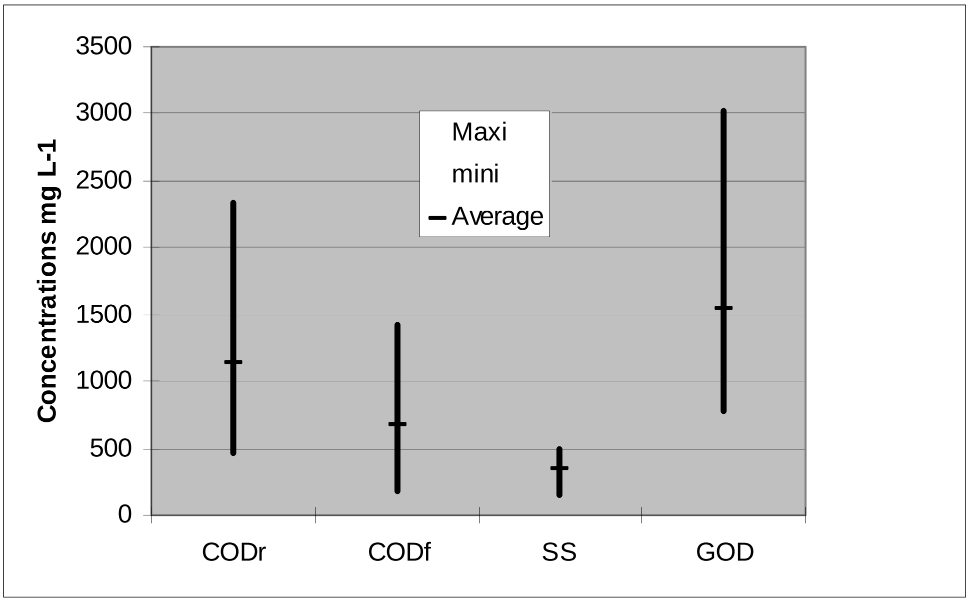

Fig. 3 : Water concentrations at ST outlet

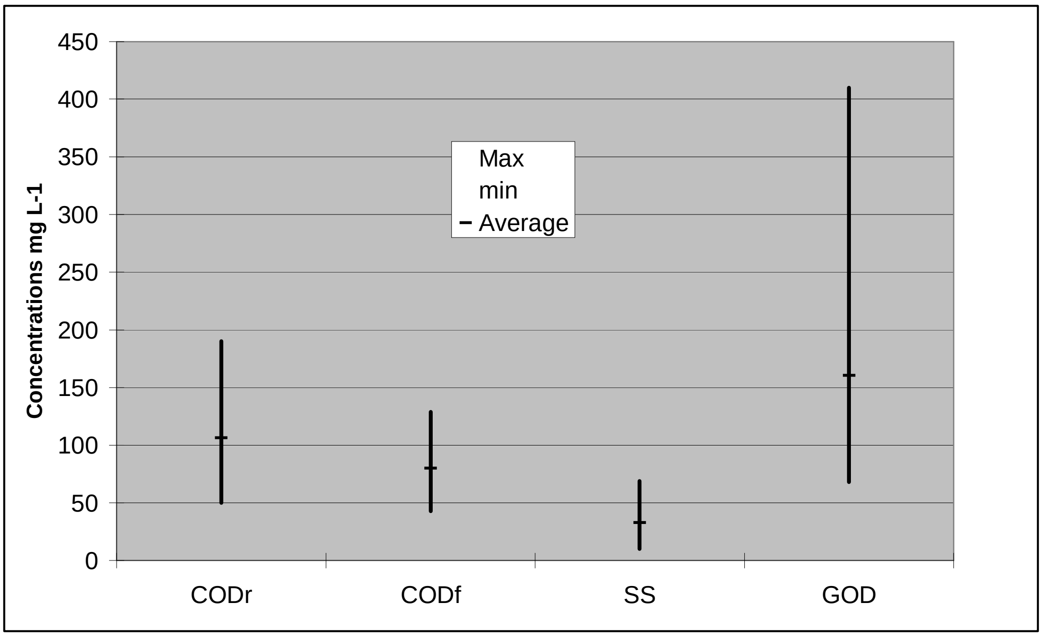

Figure 4 shows the main parameters as calculated from 18 observations (6 measurements at the outlet of each of the 3 farms).

Fig. 4 : Effluents concentrations at VFRBF outlet.

COD have always been lower than 200 mg L^{-1}. The soluble organic matter, which is given by the COD measured on filtered effluents [DCOf] is about 80% of the total, what means a still insufficient treatment capacity after the 2 treatment steps. It is confirmed by the fact that really higher concentrations in GOD coming from ammoniacal nitrogen residual concentrations at a level reaching 15 mg L^{-1} on one site yet they are always lower than 10 mg L^{-1} on both others.

A surface increase, especially on the 2nd stage filters, would not help because of the difficulty of effluent repartition if, at this level, a batch feeding system is not installed. An increase of sand thickness above 40 cm again would not help because of the difficulty in maintaining aerobic conditions in the sand (low granulometry). Diffusion of atmospheric air inside unsaturated material interstices has an effect only on about 30 cm depth from surface. From the bottom, even

if the coarse gravel draining layer is aerated, a capillary fringe is creating, at the base of a sand mass, even though it is drained and not saturated, a barrier which can only be crossed with a 35 mm water column pressure for a virgin sand of d10 0.34 mm and CU 2.9. This phenomenon has been shown and explained during the studies about groundwater recharge [4] and confirmed by pressure measurements, not yet published, based on experimental sand columns.
But it is more efficient to increase the 2/6 mm fine gravel height from 10 to 40 cm below the 40 cm of sand already designed for the 2nd stage filters. These latter are mainly done in order to improve the residual organic matter treatment and to develop nitrification. In spite of an increase of the slope necessary for construction, this modification is the best compromise because the fine gravel granulometry does not allow water to be retained by capillarity. So this material can be accessed by diffusion passive aeration through the filters draining layer connected to atmosphere thanks to 4 aeration chimneys.

CONCLUSION - DISCUSSION

A process combining septic tank and reed bed filters can be a technical solution for washing parlour effluents if, close to the farm, a surface of 2 to 3 m² per milk cow and with a natural slope of at least 2.5 m between inlet and outlet, is available. On the economical point of view, based on a 15 years depreciation for the storage tank and a 7 to 10 years depreciation for the treatment, this solution is less expensive than storage – land spreading, especially when there are no other liquids to dispose of in the farm.
Operating constraints are about 30 hours per year with following distribution:

Table 3 : Maintenance of the process ST +VFRBF for washing parlour effluents.

	Frequency
General filter inspection	once a week
Valves handling	once a week
Septic tank emptying	1 to 2 / year
Feeding system maintenance	1 / 2 months
Repartition verification	1 / 2 months
Outlet manholes cleaning	once a year
Reeds cutting	once a year
Surrounding maintenance	4 times / year

This process is even more interesting when the farm is not connected to the public sewerage network. Such a situation is frequent in France for isolated farms or for farms located in hamlets. Therefore the implementation of a washing parlour effluents treatment process should be combined with a global diagnosis of domestic wastewater treatment.
It is better to gather all water effluents and to treat them together when the buildings layout and the site topography allow it, for financial reasons and simplicity of operation.
Table 4 sums up the dimensioning criteria for the septic tank and the filters, respectively, when they receive domestic wastewater and washing parlour effluents.

Table 4 : Dimensioning criteria for joint treatment of washing parlour effluents and domestic wastewater.

Septic tank	Add 0.5 m^3 per inhabitant if only one installation	
Reed bed filters	Add 1.0 m^2 per inhabitant to the 1st stage filters	Add 0.50 m^2 per inhabitant to the 2nd stage filters

If it isn't possible to gather all effluents in an unique septic tank, in France, according the "arrêté of May 6, 1996", this latter will be dimensioned with a minimal volume of 3 m^3 for 5 main rooms and 1 additional m^3 per additional room.
Milking parlour effluents are diluted thanks to the low domestic wastewater concentrations (COD between 800 and 1000 mg L^{-1} and GOD from 1100 to 1400 mg L^{-1}). So, even if we consider:
i) the highest values for daily volumes of ww of 10 L/cow
ii) the highest values for daily volumes of the mixture ww and gw of 15 L/cow ;
iii) a reject of 100 effluent litres / inhabitant if no parasite water added in the sewerage network ;
iv) filters specific surface as mentioned in Table 1 ;
then the domestic wastewater are adding about 1.0 g of GOD mm^{-1}, yet this ratio is minimum 1.5 to 1.9 g of GOD mm^{-1} for milking parlour effluents.
The contribution of domestic wastewater for 70 $mm.d^{-1}$ (100 L on 1.5 m^2 and net peaks corresponding to miscellaneous uses in a private house) helps also for a better repartition on filters infiltration beds of 1st and 2nd stages. Therefore, for equivalent yields, the common treatment of domestic wastewater and washing parlour effluents should lead to lower concentration of treated effluents.

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