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POLLUTANT AND MICROBE REMOVAL FROM DAIRY PARLOUR WASTEWATER USING REED BED TREATMENT

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ABSTRACT

Two horizontal subsurface flow reed beds (each 75 m^2), treating dairy parlour effluent (about 4.5 m^3) as well as domestic sewage (about 2 m^3), were set-up in 1999 to verify the efficiency of this treatment system in reducing the polluting load of these kind of effluents.
Throughout the firsts two trial years (from Spring 2000), the two reed beds operated one after the other and wastewater inflows and outflows of the septic tank and reed beds were sampled more than 30 times.
A high TSS average value of about 700 mg/l and COD and BOD_5 average values of about 1200 mg O_2 l^{-1} and 450 mg O_2 l^{-1} respectively are characteristic of plant influent waters. Analyses showed that the reduction of suspended solids and organic load remained at levels greater than 90% while those of the nutrients nitrogen and phosphorous were about 50% and 60%, respectively. Nitrates, chlorides, sulphates, anionic and non-ionic surfactants and heavy metals Cd, Cr, Cu, Ni, Pb, Zn were detected in low concentrations in these effluents. The number of coliform bacteria, Escherichia coli and faecal streptococci was reduced by 98-99%.
Results demonstrated that reed beds can be appropriate treatment for dairy parlour wastewater.

Key Words: Constructed wetland, Subsurface flow reed bed, Dairy parlour wastewater, COD, BOD_5, Nitrogen, Phosphorous, Surfactants, Heavy metals, Microbe.

INTRODUCTION

On livestock farms, as experiences have demonstrated, the application of subsurface flow systems can only be conceived for effluent with a lesser load of organic matter and nutrients, more similar to municipal wastewater (Cronk, 1996; Gray *et al.*, 1996).
In the dairy sector, loose housing barn with the milking operation in a dedicated parlour have become more and more common. This operation gives rise to considerable volumes of wastewater with a low content of fertilising elements, for which storage and spreading along with other livestock effluents are problematic and uneconomic.
For this type of wastewater, it may be more opportune to use a purification treatment which, in respect for the parameters of the law, can enable wastewater re-use or disposal in the sewage systems or in surface waters. Due to its low environmental impact, reduced or nil energy consumption, and simplicity of operation, the technique of horizontal subsurface flow constructed wetland may constitute an interesting solution (Piccinini, 1997).
The design of a milking center functional to the separation between slurries to be conveyed to storage and treatable wastewater should enable the removal of effluents coming from the areas trod on by the cows ("dirty" zone), such as the holding area and the milking stalls, separately from those deriving from the areas not trod on ("clean"

zone), such as the milking pit and the milk room, and from the milking system (Ferrari & Piccinini, 1992). In fact, the use of "soft" purification technologies, such as constructed wetland, can only be hypothesised for wastewater produced in the "clean" zone of the milking center.

A demonstration horizontal subsurface flow constructed wetland was set up by CRPA (Animal Products Research Centre) at the Santa Lucia farm, contributing to Parmigiano-Reggiano cheese production, in Casina (province of Reggio Emilia, Italy) in 1999 (alt. 682 m). The technical characteristics of the system, its method of operation, and the monitoring results of the first two years of operation are presented below.

MATERIALS AND METHODS

The Santa Lucia horizontal subsurface flow constructed wetland treats the effluents coming from the washing of the milking pit, stalls, milking system, and bulk milk tank of a milking center with a herring-bone parlour with 5+5 stalls. The system was sized considering the presence of 80 lactating cows and the opportunity to include in the treatment the domestic sewage coming from the dwellings on the farm.

Plant description. The plant *(Figure 1)* is essentially composed of:

- a well for inspection of the wastewater flowing into the plant;
- an Imhoff type septic tank and a plastic filter for the removal of suspended solids;
- two SFS-h constructed wetlands (reed beds) each having dimensions of 12 x 6 x 1 m, planted with reed *(Phragmites australis)*;
- wells at the outflow of the reed beds;

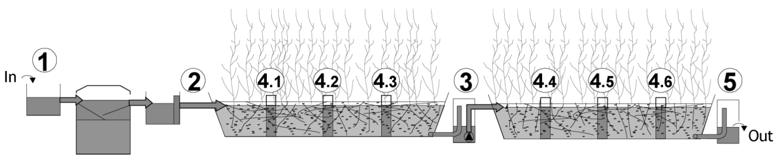
Immediately upstream from the area of the reed beds, a drainage channel filled with gravel was built to collect the rainwater run-off that could flow into the two wetlands from the surrounding areas.

The bottom of the two reed beds was suitably impermeabilised using a synthetic covering in PVC protected on both ends with geotextile.

One wetland was filled with washed gravel of 3-6 mm diameter, and the other with washed gravel of 8-12 mm diameter. In each wetland, the parts near the wastewater inflow and outflow points were filled with coarser gravel, with a diameter of 8-35 mm, to favour the inflow of water at the bottom of each section on entering and, at the opposite end, its outflow.

Perforated tubes for inspecting the water flow that cross each of the two beds were placed vertically at 1/4, halfway, and 3/4 of the length of each wetland.

Figure 1. Diagram of the horizontal subsurface flow constructed wetlands of the Santa Lucia farm.
Note: starting from the entry point, there are in succession: the inspection well, the Imhoff tank, the well with filter, the first reed bed, the discharge well of the first wetland with recirculation system, the second reed bed, and the discharge well in outflow. The numbers correspond to the sampling points.



Operating conditions. The constructed wetland system went into operation in March 2000, when the reeds were planted at a density of 5 seedlings/m^2, using seedlings with bare root from a nursery. Since that time the two wetlands have functioned one after the other in succession, with recirculation of the waters flowing out of the wetland with coarser gravel to the one with finer gravel.
The mean incoming flow rate to the plant was recorded at 6.3 m^3 of wastewater per day, divided into 4.4 m^3 produced in the milking center (1.6 m^3 from the milking operation and 2.8 m^3 from parlour and system washing) and 1.9 m^3 coming from the dwellings on the farm. The retention time of the overall plant was calculated at approximately 10 days.
The water level in the reed beds was maintained at just a few centimetres (5-10) below the open surface of the gravel to prevent the development of unpleasant odours and the proliferation of undesirable insects.
With the purpose of limiting even more effectively the load of sedimentable solids arriving at the first of the two wetlands, and therefore to prevent the reduction of purification capacity due to the progressive organic matter accumulation on the gravel beds (Tanner *et al.*, 1998), it is being considered to create a simple buried tank that can contain the effluents produced in the course of one milking of the entire herd. By regulating the flow coming into the plant, this should favour the sedimentation of solids in the sections that precede the reed beds.

Wastewater Sampling and Analysis. The following wastewater sampling points *(Figure 1)* were established:
1) at the first well for wastewater control;
2) at the inflow to the first reed bed;
3) at the outflow of the first reed bed (inflow to the second);
4) at the three flow inspection tubes of each of the two reed beds (6 points);
5) at the outflow of the second reed bed (closure of the system).

From the moment of plant activation, in the course of two years from April 2000 to April 2002, wastewater sampling was carried out 34 times, for a total of 237 samples on which the following parameters were always determined:
- pH,
- total suspended solids (TSS - Dried at 103 °C +/- 105 °C),
- chemical oxygen demand (COD - Titrimetic Method),
- biological oxygen demand (BOD_5 - Polarographic Method),
- total nitrogen (TKN - Kjeldahl Method),
  - ammoniacal nitrogen (NH_4-N - Preliminary Distillation Step and Ammonia Determination with Titrimetic Method),
- total phosphorous (total P - Persulfate Digestion Method - Vanadomolibdophosphoric Acid Colorimetric Method),

The value of organic nitrogen was obtained by the difference between total Kjeldahl nitrogen and ammoniacal nitrogen.
From 2001, in addition, every 3 months were analysed nitrates, chlorides and sulphates (Ionic Chromatography), anionic and non-ionic surfactants (Sublation+ Spectrophotometry), the heavy metals Cd, Cr, Cu, Ni, Pb, Zn (ICP) and the micro-biological parameters coliform bacteria, Escherichia coli (Inoculated Plate - Petrifilm) and faecal streptococci (Membrane Filtration).

RESULTS AND DISCUSSION

Table 1 shows the average values and the range of fluctuation for each of the parameters measured at the inflow and outflow of the plant (sampling points 1 and 5), the average percentage reductions found and, for purposes of comparison, the limits of the current laws of the Emilia-Romagna Region for discharging these wastewater into the surface water (Table III Regional Law no. 7 of 29 January 1983).
Though the organic and nutrient load of the wastewater flowing into the plant are higher than those of the typical municipal wastewater, the percentages of removal obtained with the whole system are high and the good purification performance make it possible to respect the legislative limits imposed by the Emilia-Romagna Region.
For the first wetland, the purifying efficiency was greater than that of the second, whose role was to give a final touch to wastewater purification at the outflow of the first wetland. The total reduction of suspended solids and organic load was maintained at levels above 90%; those of the nutrients nitrogen and phosphorous were about 50% and 60%, respectively.
Chlorides, sulphates, anionic and non-ionic surfactants and heavy metals Cd, Cr, Cu, Ni, Pb, Zn were detected in low concentrations in these effluents. The total number of coliform bacteria and Escherichia coli was reduced by more than 99% and the number of faecal streptococci by more than 98%.
The comparison between the first year of operation and the second made it possible to verify the increase in purification capacities of the reed beds, probably due to the progressive vegetal and microbial colonisation. During the autumn-winter periods, despite low temperatures and the dried-up vegetation, depuration performances were maintained at high levels.
The evolution of the concentrations of the various forms of nitrogen through the plant attests to conditions of anoxia that do not allow significant nitrate accumulation inside the wetlands; this despite the fact that there were good levels of mineralisation of the organic nitrogen and elimination of total nitrogen.

CONCLUSIONS

In the livestock production sector, constructed wetland systems can find concrete application in the treatment of effluents produced in the course of milking operations in the parlour, offering a solution to the problem, still often unresolved, of correct disposal of these wastewater with acceptable costs (such systems can be created for the most part with on-farm labour). In perspective, the widespread application of this purification technique could also respond to the problem of domestic sewage from rural dwellings not connected to the public sewage mains and situated on and/or near farms, particularly in hill or mountain zones.
The monitoring of the operating conditions and the purification performance of the Santa Lucia plant has provided important indications particularly regarding the most suitable criteria of design, construction, and management of horizontal subsurface flow constructed wetland systems serving dairy cattle farms equipped with milking parlours.

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Table 1. Results of analyses on the inflowing and outflowing wastewater from the plant and comparison with the legal limits established by the Emilia-Romagna Region. The min. and max. values found are in parentheses.

Parameters	*Average (min.-max.)* In (point 1)*	*Average (min.-max.)* Out (point 5)	*Reduction* (%)	*Limits Table III Law 7/83*
pH	7.72 (6.86-8.95)	7.50 (7.03-8.05)		5.5-9.5
TSS (mg/l)	689 (405-1538)	63 (10-260)	90.8	80
COD (mg O_2/l)	1219 (858-2312)	98 (32-205)	91.9	160
BOD_5 (mg O_2/l)	451 (241-887)	28 (2-98)	93.7	80
Total Kjeldahl N (mg/l)	64.7 (44.7-173.9)	33.3 (17.2-54.4)	48.5	
Ammoniacal N (mg/l)	22.4 (10.3-36.4)	24.5 (11.2-35.3)	-9.3	25
Organic N (mg/l)	42.3 (24.1-138.2)	8.8 (0.5-25.1)	79.1	
Total P (mg/l)	12.8 (6.5-27.4)	5.0 (0.8-8.3)	60.6	15
Nitrates (mg/l)	< 0.5 (<0.5-<0.5)	< 0.5 (<0.5-<0.5)	33.8	20
Chlorides (mg/l)	54.3 (43.2-71.8)	27.9 (26.8-28.9)	48.7	1200
Sulphates (mg/l)	171.3 (111.5-273.6)	20.8 (4.8-44.7)	87.8	1000
Cadmium (mg/l)	0.0022 (<0.001-0.004)	0.0017 (<0.001-0.002)	23.7	0.02
Cromium (mg/l)	0.010 (0.070-0.013)	0.005 (<0.003-0.007)	51.6	2
Copper (mg/l)	0.081 (0.032-0.136)	0.017 (0.010-0.022)	79.4	0.1
Nichel (mg/l)	0.027 (0.018-0.044)	0.011 (<0.004-0.015)	58.6	2
Lead (mg/l)	0.035 (0.016-0.072)	0.011 (<0.009-0.012)	69.6	0.2
Zinc (mg/l)	0.354 (0.298-0.399)	0.051 (0.031-0.071)	85.7	0.5
Anionic Surfactants (mg/l MBAS)	0.061 (0.051-0.067)	0.080 (0.060-0.110)	-32.2	
Non-ionic Surfactants (mg/l CTAS)	1.263 (0.681-1.820)	0.387 (<0.100-0.700)	69.4	2
Coliform bacteria (col./100 ml)	$2.2 \cdot 10^6$	$8.4 \cdot 10^3$	99.6	
Escherichia coli (col./100 ml)	$1.1 \cdot 10^6$	$3.0 \cdot 10^3$	99.7	
Faecal streptococci (col./100 ml)	$88.2 \cdot 10^3$	$1.1 \cdot 10^3$	98.8	

*Values calculated as weighted average according to the incidence of the type of wastewater sampled (domestic, from milking, from washings) on the total inflow value.