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Wastewater from a mountain village treated with a constructed wetland

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ABSTRACT

The "Asiago-Sette Comuni" plateau (Italy) is the main contributing zone of an alpine karst aquifer supplying a multi-aquifer system in the Central Veneto plain exploited for domestic, industrial and agricultural uses. Some of the communities in the upland are connected to public sewers discharging to treatment works. Conversely, several small isolated communities, farms and tourist resorts discharge to short sewers ending in septic tanks, whose overflows feed local streams, which are most of the time dry because waters infiltrate the karst bedrock and reach the plain aquifer within 24–50 h. The two aquifers are highly vulnerable to contamination, due to fast water transport with limited attenuation processes. The aim of the present research is to evaluate the efficiency of a small subsurface constructed wetland system in improving wastewater from a mountain village. In the first 16 months of operation, removal capacity of the experimental system averaged more than 98% of pathogenic organisms, more than 90% of TSS, COD and, BOD_5, about 50% of N-NH_4^+, N-NO_3^-, N-total, Cl^-, SO_4^{2-} and PO_4^{3-}, even in the cold season. The vegetal cover is good and there are no operational problems.

Keywords: Aquifer; Wastewater; Constructed wetland

1. Introduction

The "Asiago-Sette Comuni" plateau, with elevations of 1000–1500 m a.s.l. in its middle basin and reaching 1500–2300 m a.s.l. in its northern border, is a tourist resort, partly devoted to pasture and mostly covered with fir and beech woods [1]. The plateau is characterised by the absence of a network of perennial streams, in spite of substantial precipitation (about 1500 mmy^{-1} [2]), because meteoric waters infiltrate through porous terrains and flow in karst conduits to reach caves and springs at the base of the epikarstic zone (100–200 m a.s.l.) within 24–50 h [3,4]. The groundwater flow from the alpine karstic aquifer supplies a connected multi-system plane aquifer in the Central Veneto, exploited for domestic, industrial and agricultural uses. The two systems are highly vulnerable to contamination, due to fast water transport with limited attenuation processes.

A proportion of the population on the "Sette Comuni" plateau lives in communities provided with sewers discharging to treatment works. Conversely, several small communities, farms and tourist resorts are connected to short sewers ending in septic tanks. The overflow from these tanks goes into local streams, most always dry because of water infiltration [3,4]. Consequently, ineffective treatment of domestic and livestock sewage can contaminate underground waters and related supplies. Where septic tanks are inadequate, additional systems are needed [5]. The aim of the present research was to construct an experimental wetland system to reclaim

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wastewater from an isolated mountain village [6]. The study, submitted to the Scientific Board of "Project Biotech I", was supported by the Regione Veneto, University of Padova, CNR (the Italian Research Council), ETRA S.p.A. and Novatech s.r.l. companies.

2. Materials and methods

Toccoli, a typical mountain village of 40 inhabitants, was previously connected to a short drain (400 m) ending in a receiving chamber with bar screens and an "Imhoff" septic tank (9.5 m^3). An experimental macrophyte system with horizontal subsurface flow was constructed as final treatment. Since the terrain is sloping, the 108 m^2 artificial wetland was terraced into upper and lower units of the same rectangular shape (12.0 m long, 4.5 m wide, 0.48 m deep). Both units, with a 1% longitudinal gradient, were completely lined with HDPE (high-density poly-ethylene) plastic sheeting and contained crushed limestone (of 1–4 cm) of local origin. The system was designed for a hydraulic residence time of 4.5 days, with average flow of 5.0 m^3d^{-1}. The vegetal cover, planted in April 2005, included *Typha angustifolia* in the first unit and *Phragmites australis* in the second. The system operates automatically, without any external energy supply (pumpless operation) because a hydraulic gradient is available. It cost about € 10,000 to build in 2005, mainly for materials and labour. The maintenance is about € 500/y, mostly for mowing and weed control. About every second week, survey samples were taken from the inflowing wastewater, the "Imhoff" septic tank outlet, and reedbed effluent waters. Analytical procedures followed the APAT CNR IRSA manual [7].

3. Results and discussion

3.1. pH (Fig. 1)

The pH ranged from 6.7 to 8.2, with means of 7.5 at the inflow point, 7.6 at the Imhoff septic tank outlet, and 7.5 at the effluent point. Standard deviations were 0.34, 0.26, and 0.26, respectively. The wetland system did not affect pH levels. Influent and effluent pH values remained within one pH unit after the settlement of the rhizosphere environment, since the development of plant roots in July 2005.

3.2. Conductivity (Fig. 2)

Conductivity data, linked to the amount of dissolved ions, varied from 1800 to 300 µScm^{-1}, with means of 1007 at the inflow point, 867 at the Imhoff outlet, and 610 at the effluent point (standard deviations were 283, 193, and 197 respectively). The decrease in dissolved ions indicated mean retention capacities of 13.9% at the septic tank and of 39% at the constructed wetland.

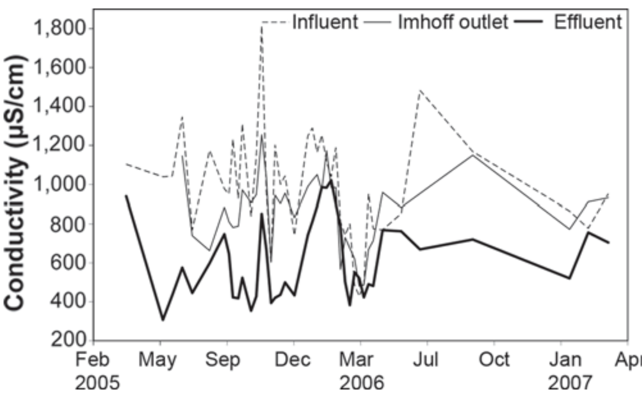

Fig. 2. Time pattern of conductivity.

3.3. Redox potential (Fig. 3)

The redox potential level is linked to the amount of oxygen delivered to the wastewater and describes induced biological activities. The data ranged from –271 to +330 mV, with means of –154 mV at the influent, +59 at the Imhoff outlet, and +181 at the effluent (standard deviations were 78, 168 and 96 mV respectively). The aerated parts of the system had higher potential values

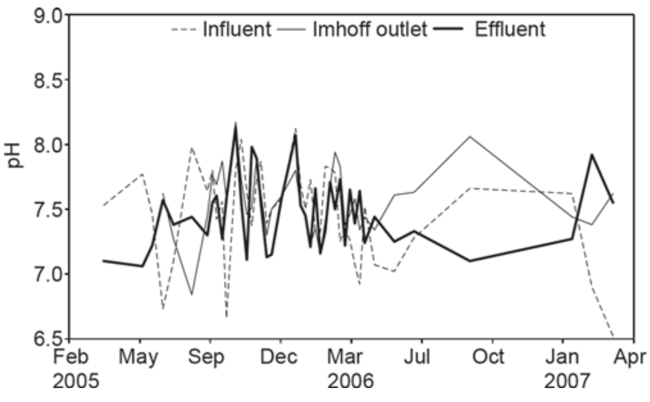

Fig. 1. Time pattern of pH.

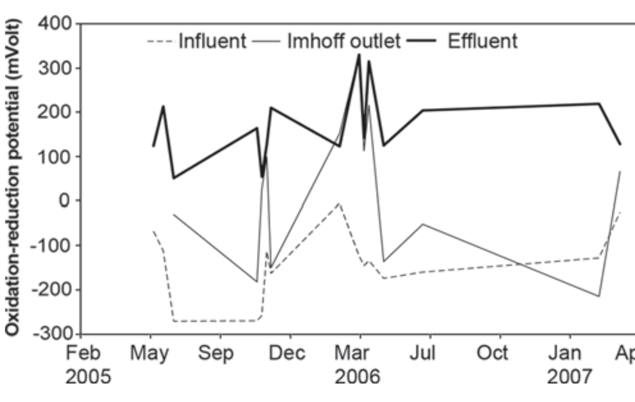

Fig. 3. Time pattern of redox potential.

than the anaerobic ones. The occasional aeration of the septic tank may have been due to physical mixing at the inlet. Conversely, convective through-flow mechanisms, common in wetland plants [8], enhanced constant aeration in the two reedbeds.

3.4. Total suspended solids (Fig. 4)

The data of suspended solid content varied considerably from 6010 to 2 mgl^{-1}, with means of 614 at the influent, 159 mgl^{-1} at the Imhoff outlet, and 53 at the effluent (standard deviations were 991 mgl^{-1}, 39 and 37). The average efficiency of the treatment after the septic tank was 85% and 94% after the reedbeds.

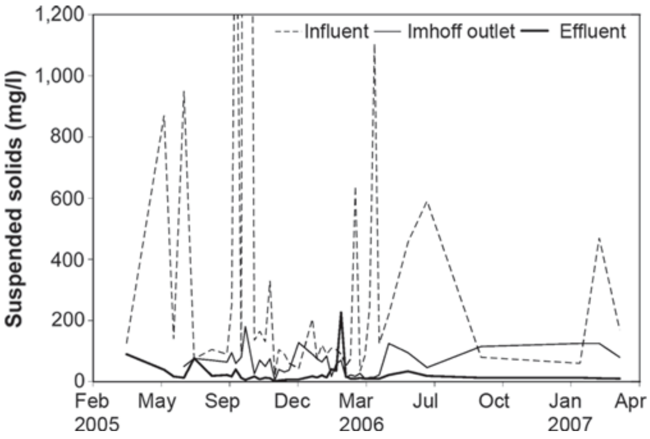

Fig. 4. Time pattern of suspended solids content.

3.5. Chemical oxygen demand (COD) (Fig. 5)

The COD represents the extent of organic loading in wastewater that can be chemically oxidized. Data ranged from 4922 to 29 mgl^{-1}, with means of 546 at the inlet, 153 at the Imhoff outlet, and 49 mgl^{-1} at the effluent (standard deviations were 791, 83 and 84 mgl^{-1}). The mean treatment efficiency after the septic tank was 73% and the mean final retention capacity beyond the constructed wetlands was 91%.

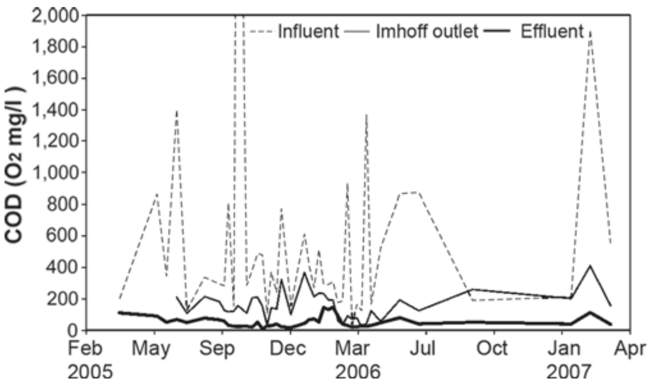

Fig. 5. Time pattern of COD content.

3.6. Biological oxygen demand (BOD_5) (Fig. 6)

Biologically degradable organic loading data ranged from 799 to 20 mgl^{-1}, with means of 256 at the inflow point, 90 at the septic tank outlet, and 25 mgl^{-1} at the effluent point (standard deviations were 206, 48 and 14 mgl^{-1}). The average treatment efficiency after the septic tank was 64% and the mean final retention capacity was 89%.

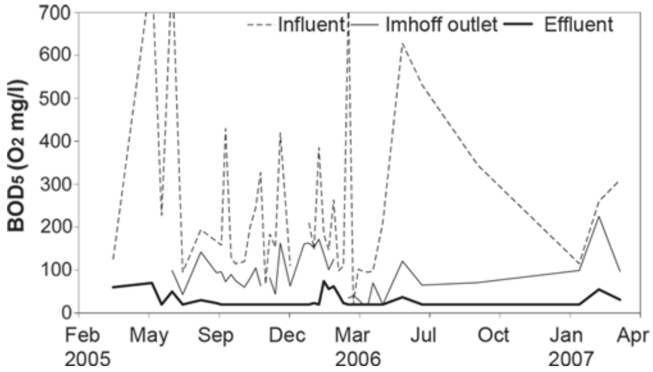

Fig. 6. Time pattern of BOD_5 content.

3.7. Ammonia-nitrogen and total nitrogen (Fig. 7)

The two parameters coincide, the concentration of N-NO_2^- and N-NO_3^- being negligible. Ammonia-nitrogen ranges from 154 to 2 mgl^{-1}, with means of 62 at the inlet, 51 at the septic tank outlet, and 23 mgl^{-1} at the effluent point (standard deviations were 37, 26 and 25 mgl^{-1}). The removal of ammonia-nitrogen was about 15% after the septic tank treatment and 63% beyond the constructed wetlands.

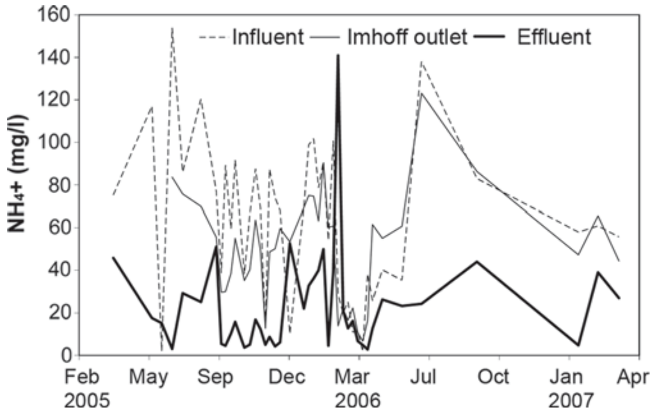

Fig. 7. Time pattern of ammonia-nitrogen content.

3.8. Phosfate, chloride, sulfate, metal ions, anionic surfactants (Fig. 8)

Influent levels for the first four parameters were lower than Italian permitted public health values. Their time

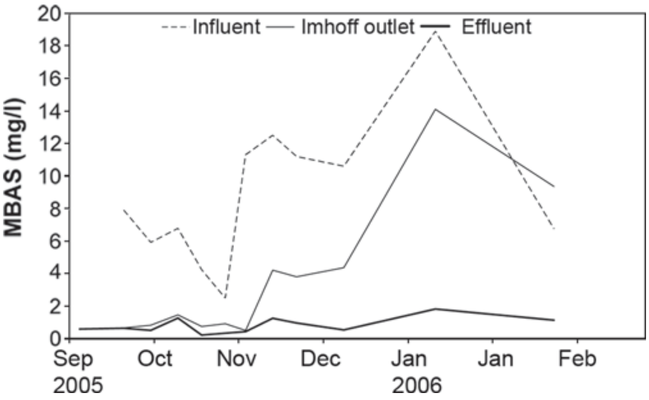

Fig. 8. Time pattern of MBAS (methylen blue active substances) representative of anionic tension-active materials.

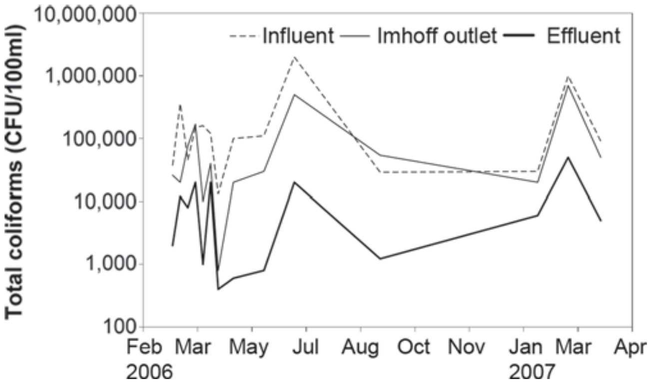

Fig. 9. Time pattern of total coliforms.

patterns are not reported because there were also substantial declines in effluent levels, with reductions of 79%, 49%, 59% and 91% respectively.

The time pattern of the fifth parameter, concentration of anionic surfactants, is shown in Fig. 8. The removal of MTBAS (methylen blue active substances), representative of anionic tension-active materials, averaged 55% at the septic tank treatment and 83% at the effluent point, beyond the constructed wetlands.

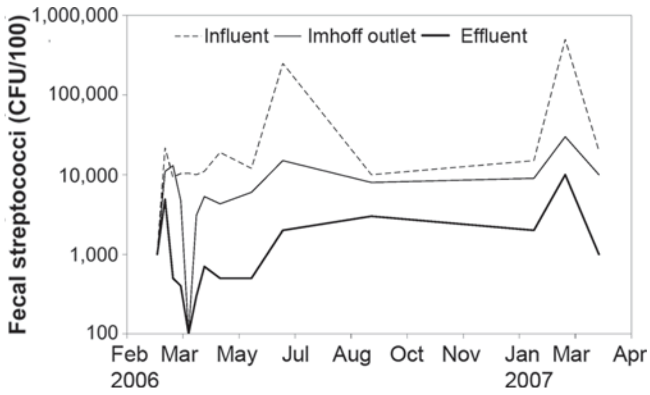

Fig. 10. Time pattern of fecal streptococci.

3.9. *Microbiological determinations (Figs. 9–11)*

Significant removals of total coliforms (from 10^6 to less than 10^3 CFU/100 ml), of E. coli (from 10^6 to 10^3 CFU/100 ml) and fecal streptococci (from 10^4 to 10^3 CFU/100 ml) are consistent with reclaim of waters. The time patterns of these microbiological parameters are similar and suggest good quality disinfection.

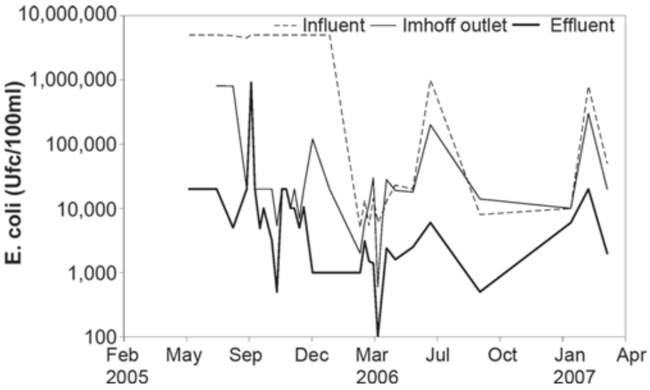

Fig. 11. Time pattern of E. coli content.

3.10. *Seasonal influences*

There were no marked seasonal removal variations, although the "Sette Comuni" plateau undergoes temperature ranges from a summer peak of +30°C to a winter minimum of –20°C, often with a snow blanket more than 1 m thick.

Table 1
Comparison of wetland results and Italian standards

Parameter	Italian standard	Influent	Imhoff outlet	Wetland effluent
pH	5.5–9.5	7.5	7.6	7.5
TSS, mg/L	<200	401	63	24
BOD_5, mg/L	<190	249	92	29
COD, mg/L	<380	571	161	53
Boron, mg/L	<4	0.507	<0.5	<0.5
Cadmium, mg/L	<0.02	0.005	<0.005	<0.005
Chromium, mg/L	<2	0.500	<0.5	<0.5
Iron, mg/L	<4	2.618	<0.5	<0.5
Manganese, mg/L	<4	0.496	<0.5	<0.5
Silver, mg/L	<0.005	<0.005	<0.005	<0.005
Nickel, mg/L	<2	0.475	<0.5	<0.5
Lead, mg/L	<0.2	0.060	<0.05	<0.05
Copper, mg/L	<0.1	0.115	<0.05	<0.05
Zinc, mg/L	<0.5	0.815	<0.2	<0.2
Sulfate (SO_4^{2-}), mg/L	<1,000	49.1	26.3	19.6
Chloride, mg/L	<1,200	53.2	42.6	27.6
Total phosphate (P), mg/L	<20	5.5	3.3	1.3
Ammonia nitrogen (NH_4^+), mg/L	<30	63.1	51.2	23.1
MBAS, mg/L	—	9.0	3.5	0.8
*Escherichia coli**, CFU/100 mL	<5,000	1,598,815	43,120	4,305

**E.coli* data are average from October 2005, after growth of reedbeds.

3.11. Effluent quality compared with permitted Italian public health standards (Table 1)

Average analytical parameters never exceeded standard levels.

4. Conclusions

The previously existing Imhoff septic tank, and the constructed wetland system, composed of two units (upper and lower), turned out to be effective and reliable for domestic wastewater treatment and removal of pathogens. Their efficiency, with low capital and maintenance costs, ensures improved quality of effluent water, both in the cold season and with snow more than 1 m thick.

Acknowledgments

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