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Wastewater characteristics and pre-treatment efficiency in small localities in north-west Spain

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ABSTRACT

Wastewater from small localities (<2.000 inhabitants) in Leon Province (north-west of Spain) and the quality of their sewers and wastewater treatment plants were surveyed and characterized during spring and summer. A total of 821 localities were visited and wastewater was characterized in 76 of them. Two different regions below (plain region) or above (mountain region) 1.000 m.a.s.l were considered, having mountain regions lower mean winter population (76 inhabitants) and higher ratio winter/summer population (3 times) than plain regions (191 inhabitants and 2 times, respectively). Mean flow per person was 705 l/p.e./d, being higher in the mountain (946 l/p.e./d) than in the plain region (521 l/p.e./d). Infiltration was responsible for these high flows and their correspondent low organic concentrations (mean values of 16 g BOD_5/p.e./d and 12 g TSS/p.e./d). Wastewater treatment systems were mainly septic tanks (47% of localities) and Imhoff-type tanks (38%). Most of systems (83.4%) had no any maintenance or was very deficient. Septic tanks were higher efficient than Imhoff tanks in BOD_5 removal (33% and 15% for septic and Imhoff tanks, respectively). Reduction of infiltrations and wastewater characterization is essential for the design of wastewater treatment systems in rural areas of northern Spain.

Keywords: Small localities; Wastewater characteristics; Pre-treatment; Septic tanks; Efficiency; Rural areas

1. Introduction

Application of Wastewater Treatment Directive in localities below 2,000 inhabitants is nowadays a main subject for the Environmental Administration in Spain, being selection of most adequate treatment system one of the important aspects in its application. Adequate selection depends on several variables like wastewater characteristics. Estimation of wastewater flow and influent concentrations in small localities is still commonly based on bibliographic data, this criterion producing important fails in system design and adequacy to the socio-economical situation of these localities. The consequence is that absence of maintenance is very common in small wastewater treatment plants. To avoid this problem, regional government and other administrations are nowadays interested in the study and detailed characterization of wastewater previously to plant design in small localities. Current situation of wastewater treatment systems in León Province (north-west Spain) and analysis of domestic wastewaters in localities below 2.000 inhabitants will be presented in this study. Performance efficiency of those treatment systems properly maintained will be also evaluated.

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2. Methodology

All localities in León Province (North-west of Spain) with 2000 or less inhabitants (1.382 localities) were initially selected for study. A total of 821 localities were finally considered for wastewater treatment characterization being the rest excluded as they were already considered for surveying by other Regional or National Administrations. All selected localities were visited and a detailed analysis on the existent deficiencies in operation and management of their wastewater treatment plant was annotated. Once all data on the real population, livestock and industrial activities on these 821 localities was known, a total of 76 localities were selected for wastewater characterization and analysis of their wastewater treatment plant performance, when available. Due to the geographic characteristics of León Province, mountains in the northern half and a plateau in the southern half, localities were divided in this two regions: mountainous (>1.000 m.a.s.l.) and plain (<1.000 m.a.s.l.) a limit which also separate two distinctive climatic regions (dry and wet). Four population intervals were selected in each region having in account the histogram of population frequencies for the studied area (current population in winter): <25, 26–50, 51–100, >100. Three livestock density intervals were selected for each population range based on the ratio: livestock (in pop. equiv.)/current population: <1, 1–4, >4. Population equivalents (p.e.) for loadings of the different livestock species were selected using data from previous studies [1–3], as follows: 1.6 p.e. (pigs), 3.8 p.e. (cows), 0.8 p.e. (horses), 0.05 p.e. (hens). Three to five localities were sampled for each of the selected intervals, given a total of 76 sampled localities. Wastewater for each of the localities was sampled in April at two hours interval during 12 h and proportionally integrated using the measured flow for each sampling hour. COD, BOD_5, TSS, TKN, TP, ammonia, and nitrates were analyzed following [4]. Flow was measured either by volumetry or using a speed-flow meter (Oceanics Inc.). Sixteen selected localities were sampled again in summer to compare wet and dry periods. Effluents from the existent treatment plants were also sampled using the same procedure.

3. Results and discussion

Main values of the studied locations are presented in Table 1. Mean permanent population (winter population) was below 130 habitants, with 60% of locations having less than 100 habitants and 95% less than 500 habitants in winter. Only 3 localities were above 1,000 habitants in winter. Industrial activity was almost negligible, with less than 1 p.e. in average. Differences between mountain and plain zones were significant for most of values. Mountain locations are less populated, with lower livestock but with higher ratios livestock p.e./population. Increases in summer populations (ratio summer/winter) were higher in the mountain zone were population was multiplied by a factor of 80 in some case (i.e. from 2 people in winter to more than 160 in summer).

Mean flow was higher in plain localities because of two factors, higher mean population and higher infiltration than in mountain zones (Table 2). Daily flow per habitant was higher in the mountain region, being infiltration relatively higher in this zone than in the plain localities. Daily flow produced per person (705 l/p.e/d) was much higher than expected (173 l/p.e./d) in both zones.

Mean flow measured was even higher than the maximum flow estimated when both, inhabitants and livestock (in p.e.), were considered. Infiltration from underground waters into the domestic sewers was the main problem of the sewage systems in León Province. This high infiltration rate is due to several reasons like direct connection of former wells into the sewers and very bad conservation of pipelines. Similar situation have been found in other regions in north Spain. Ojanguren y Pereda [5] found that infiltration in 6 cities from 3.000 to 15.000 inhabitants in Bizkaia province (Vasque Country) was about 60% of the measured flow.

Organic matter and suspended solids concentration were much lower than expected (Table 3). Wastewater

Table 1
Mean and maximum values of population and livestock in person equivalents (p.e.) for the studied zones. Maximum flow was estimated considering total p.e. and standard flow values per p.e.

	Plain (360 localities)		Mountain (461 localities)		All zones
	Mean	Max.	Mean	Max.	Mean
Winter population	191	1562	76	952	126
Summer population	365	4562	170	3500	375
Livestock (p.e.)	466	12,040	138	2020	282
Total p.e.	840	13,090	308	3896	542
Maximun flow estimated (m^3/d)	86	857	34	805	57
Ratio summer/winter	2	14	3	80	3
Ratio livestock p.e./winter population	3	34	3.5	144	2

Table 2
Mean flow characteristics in spring for each of the studied zones. Mean daily flow measured (Q_m) and maximum flow estimated in summer considering all p.e. (Q_{max}). $F_{h,max}$: Maximun hourly constant for Q_m

Zone	Q_m (m^3/d)	Q_{max} estim (m^3/d)	$F_{h,max}$	Flow (l/p.e/d)
Mountain	97.9	53.0	×1.20	946
Plain	254	128	×1.13	521
All	190	105	×1.14	705

can be considered highly diluted following classical textbooks [6]. Daily loads per person were also much lower than expected (i.e. 60 g BOD_5/p.e./d and 90 g TSS/p.e./d.), even when only inhabitants, not p.e., were considered. Due to their higher population, locations in the plane zone were more loaded than those in the mountains.

The abundance of livestock in almost all localities is not reflected in the nutrient concentration of the wastewaters (Table 4). About 90% of livestock is considered not to affect urban sewers. Loading is higher in the plain zone where animal production uses to be intensive whereas animals tend to be in extensive, non cowshed conditions in the mountain zone. Loading per person equivalent was much lower than expected, (i.e. 35 g/p.e/d for TKN and 3-6 g/p.e./d for TP).

3.1. Wastewater treatment plants and efficiencies in León Province

A high percentage of localities (88.7%) presented some kind of treatment or pre-treatment system. Most of systems were septic tanks (46.9% of localities), settling tanks or Imhoff-type tanks (38.1%). Only 2.2% of localities had some kind of secondary system (e.g. activated sludge). Most of existent wastewater treatment systems (83.4%) had no any maintenance or it is very deficient. Six septic tanks and ten Imhoff-type tanks with an appropriate maintenance were sampled in summer to study their removal efficiency (Fig 1). High dilution and flow from the infiltrated water made these systems not efficient enough with regards reference values following regional authorities [1,2]. Septic tanks were more efficient than Imhoff systems with regards organic matter removal. Nevertheless, removal efficiencies of septic tanks were very low and sometimes even negative in spring with respect summer. This could be due to the high degrada-

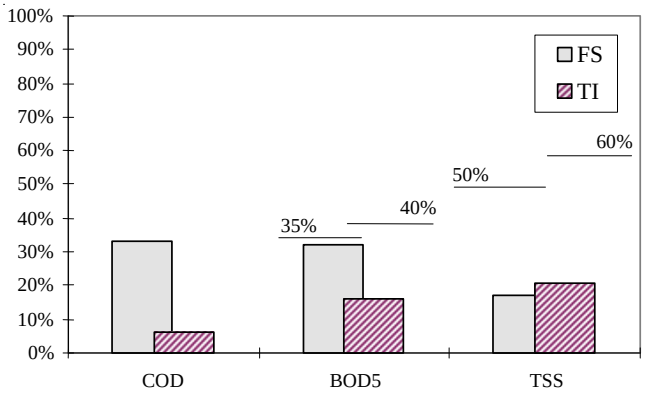

Fig. 1. Removal efficiency of pre-treatment systems properly maintained in León Province. Septic tanks (FS) (n = 6) and Imhoff-tanks (TI) (n = 10). Lines are reference objectives following [1].

Table 3
Mean concentration values and daily loading per person equivalent (g/p.e./d) in the studied wastewaters in spring. Values between brackets are based in current inhabitants not to p.e.

Zones	COD		BOD_5		TSS	
	(mg/L)	(g/p.e./d)	(mg/L)	(g/p.e./d)	(mg/L)	(g/p.e./d)
Mountain	151	31	56	13 (44)	45	9 (31)
Plain	184	44	89	20 (55)	65	15 (57)
All	167	38	72	16 (48)	55	12 (38)

Table 4
Mean values for nutrient concentrations and daily organic loading per p.e. in spring. Values between brackets are related to current inhabitants not to p.e.

Zones	TKN		Ammonium		Nitrates		TP	
	(mgN/L)	(gN/p.e./d)	(mgN/L)	(gN/p.e./d)	(mg/L)	(g/p.e./d)	(mgP/L)	(gP/p.e./d)
Mountain	18	3.2 (10)	10	1.6 (5.4)	1	0.5 (1.9)	2	0.5 (1.4)
Plain	34	8.6 (24)	19	4.7 (13)	5	2.0 (5.5)	4	1.1 (2.9)
All	25	5.9 (17)	15	3.1 (9.1)	3	1.3 (3.6)	3	0.8 (2.1)

tion of organic matter accumulated during winter as temperature rises in spring [7].

4. Conclusions

Wastewater in small localities (below 2.000 inhabitants) in Leon Province is characterized by their very low concentration and extremely high dilution. Infiltration of freshwater from the wells or from the underground water due to the bad conditions of the pipelines is the main cause. Localities in mountainous and plain areas are significantly different from each other. Lower winter population, stronger increase in summer and higher ratio livestock/inhabitants than in the plain zones are characteristics from mountain localities. Absence of maintenance is the main problem of the existent wastewater treatment systems in Leon province. Analysis of performance efficiency in pre-treatment systems shows better performance for septic tanks than Imhoff systems. Estimation of flow using standard values from the bibliography is not recommended in small localities in northern regions of Spain. Upgrading of the existent systems or construction of new wastewater treatment plants should consider the previous correction of the very high infiltration flows.

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