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QUALITATIVE AND QUANTITATIVE CHARACTERIZATION OF WASTE WATER FOR SMALL COMMUNITIES

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ABSTRACT

An understanding of the waste water nature, from both the qualitative and quantitative points of view, is a fundamental factor in the selection of treatment techniques and their subsequent operation. This is even more so in the case of small communities whose discharges are more subject to variation. An analysis of French data in this field provides values for small communities in rural areas (the majority). So far as other communities are concerned there are three examples which particularly illustrate the effects of the different factors (way of life...) on specific loads.

KEYWORDS

Waste water - small communities - flows - concentrations - specific loads.

INTRODUCTION

The protection of water supplies involves treatment plants both in heavily organized areas and in those with a low population density where the nature of the receiving environment is often fragile. The financial investment required is all the greater when the community is small.

In order to carefully select the treatment process according to economical and technical criteria, it is first of all necessary to have a full knowledge of the waste water to be treated. In the case of small communities, qualitative and quantitative variations in waste water are in relation to the availability of water supplies, the way of life (time spent at home), the level of hygiene and comfort (extent of sanitary and household equipment).

The term "small communities" covers a very wide diversity of situations. Here, we are concerned principally with data relating to small rural communities which constitute a predominant group. The main characteristics of such waters will be analysed (flows, concentrations, loads), as well as their development over a period of time, based on the study of a typical community.

For comparison, data relating to three specific small communities will be described : a hospital, a children's centre, a mountain refuge.

CHARACTERISTIC PARAMETERS OF WASTE WATER

Pollutants in water are identified by techniques involving an analysis of the different components. The most frequently used parameters are :

- Suspended Solids (SS) and its organic fraction, Volatile Suspended Solids (VSS) which characterize the particular type of pollution,

- the Chemical Oxygen Demand (COD) and the Biochemical Oxygen Demand in five days (BOD); these parameters quantify the organic content of the waste water,

- forms of nitrogen (N) and phosphorus (P), fertilizing elements whose discharges are, under certain conditions, likely to accelerate the eutrophic process,

- the pH and the conductivity, which give a good indication of the water ionicity.

In special cases, temperature must be taken into account (mountainous areas) ; microbiological analysis (faecal contamination germ tests) are necessary if there is a health risk (bathing areas, shellfish breeding...).

The volume of water discharged must also be determined : the dimensioning of installations depends in principle on the daily quantities to be treated, peak flows having a major role in the case of certain tanks (pretreatment, clarifiers). Much information can be obtained by analysing hourly flow curves, for example the night water volume gives an indication on clear water infiltration into the sewerage systems.

Concentrations and flows can be used to calculate the pollution load, a well known notion in waste water treatment. The pollution load is equal to the product of the flow volume by the concentration of a representative sample of the water quality discharged during the same time.

Current practice is to divide the load values by the number of inhabitants connected to the network ; these specific values are known as "persons equivalent" (p.e.).

Origin of waste water

The characteristics of domestic waste water are linked to their origin. There are :

- sewage water from toilets. This represents approximately 30 l per day and per user. It contains essentially organic matter.

- domestic water from kitchens, bathrooms,... The daily volume can vary considerably depending on the extent of the equipment and the hygienic habits (showers, baths,...). Generally speaking, consumption of household water is high in an urban area (100 to 300 l per day per user), but is smaller in a rural environment (50 to 100 l per day per user). These waters contain principally organic matter as well as household products (detergents, phosphates...).

WASTE WATER IN SMALL RURAL COMMUNITIES

For most of the time, such water is predominantly domestic, even if, sometimes, a particular local activity or small industries generate waste water collected by the sewerage system (butchers, restaurants...).

Data relating to waste water from rural communities has been collected during surveys of treatment plants, involving the determination of the pollutants flows into the installations. The results are taken from measurements made in dry weather on good separated sewerage systems. The mean daily samples taken from the sewerage system are made up in proportion to the measured hourly flows. The concentrations of these samples have been calculated in accordance with standard French analytical procedures.

The mean results obtained from some thirty rural waste water treatment plants (population < 5 000 inhabitants) are given in table 1.

Table 1 - Main characteristics of the waste water in rural communities

COD	= 700 mg/l	± 100	
BOD	= 300 mg/l	± 65	
SS	= 250 mg/l	± 30	
N	= 80 mg/l	± 20	(60 mg $N\text{-}NH_4^+$)
P	= 35 mg/l		(30 mg $P\text{-}PO_4$)

The COD and BOD concentrations confirm the organic nature of the waste water. The COD/BOD ratio, which is slightly greater than 2, indicates the biodegradable nature of such water. The N and P concentrations permit any biological process (BOD/N/P ratio = 100/26.6/11.6).

To complement these characteristic values it should be noted that the mean temperature of water collected approaches 15°C (extremes 10°C - 18°C). In cold mountain areas the minimum measured was 4°C, but the sewerage system collected large quantities of waters from melting snow (this data has not been taken into account when drawing up table 1). Concentrations of greases (substances which can be extracted using chloroform) are less than 100 mg/l. The pH is normally alkaline, between 7.5 and 8. Exceptionally, in the case of long sewerage systems or when the slope is slow, a pH less than 7 indicates the septicity of such water (prolonged stay in the sewer). The waste water contains some 10^9 of total coliforms per litre.

When preparing projects for waste water plants, load measurements are generally not possible, the pollution flow calculation is based on specific values related to a user connected to the sewerage system (the person-equivalent already referred to).

On the basis of results shown in table 1, these calculations give the daily discharge of one person-equivalent (table 2) :

Table 2 - Guide values for one person-equivalent (p.e) in rural area

Volume	=	150 l	±	50
COD	=	75	to	80 g
BOD	=	30	-	35 g
SS	=	25	-	30 g
N	=	8	-	9 g
P	=	3.5	-	4 g

These figures are lower than the absolute values generally used for an urban area (eg. BOD = 50 to 60 g per person-equivalent).

Analysis of variation factors

The preceding data is useful as a guide, but it must be weighted to take account of local factors.

The first variation factor as to concentrations and flows is the presence of clear water in the sewerage system. The greater the quantity of infiltrated water the greater the degree of dilution, concentrations are reduced and the hydraulic load increases. Apart from the fact that more treatment will be required, the admission of large quantities of clear water into the sewerage system may have other unfortunate consequences, such as reduced efficiency of the settling tanks or, in the most critical cases, the impossibility of initiating a biological process (absence of floculation...) : this was the case of one plant where the volume of water by person-equivalent exceeded 1 m^3.

The second variation factor relates to specific activities (small workshops, semi-industrial activities) which may modify to a greater or lesser extent the concentrations of the water to be treated. It is not unusual to find in a village some establishment of this type whose discharges may, in due course, prejudice the satisfactory functioning of the treatment plant, unless special constructive measures are taken.

Finally, criteria such as the length and type of the sewerage system (separate, combined), the collection of water from numerous septic tanks, may have an influence on the nature of the water requiring treatment.

ANALYSIS OF VARIATIONS FOR A PLANT IN A RURAL ZONE

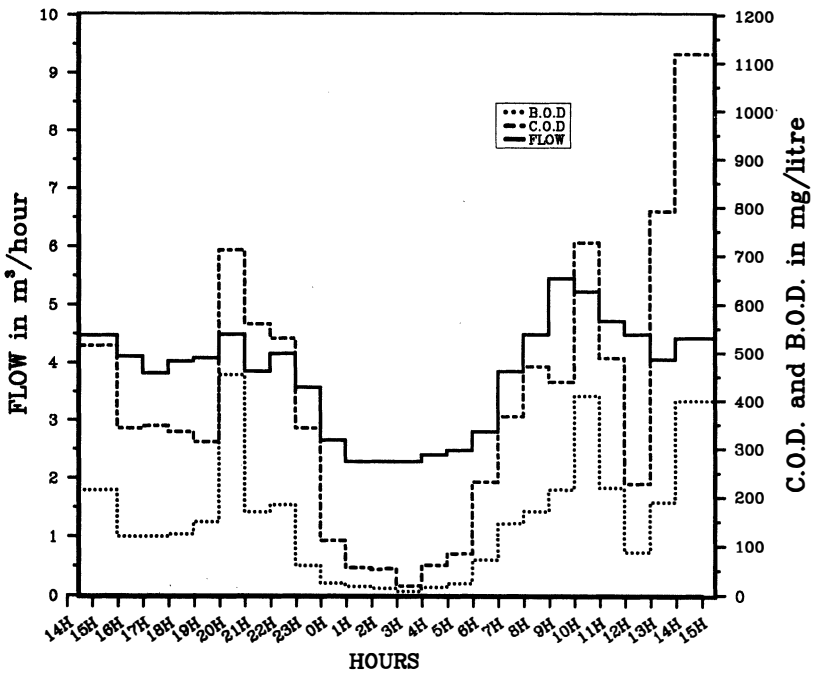
Do the concentrations and flows recorded at the inlet plant vary ?

The reply to this question, based on a survey in a rural community of 2000 person-equivalents, is not clear.

Measurements were made over a period of one week ; the main hourly values were analysed in detail over a 24 hours cycle (from Monday at 3 pm to Tuesday at 3 pm).

The daily pollution load was stable between 14 and 17 kg BOD/day over a period of one week. The installation underload (dimensioned on the basis of 100 kg BOD/day) was important. The plant has been in operation for three years, but connections to the sewer are limited : only some 500 users being connected. On the other hand, on the basis of one day, hourly variations in bath flow and concentration were considerable (Figure 1).

Fig 1: SIMULTANEOUS VARIATIONS OF COD, BOD AND FLOW DURING 24 HOURS



An analysis of the graphs shows in the first place the correspondence of the pollution peaks and the town's activities. These peaks are particularly marked in the morning, at the beginning of the afternoon and in the evening. On the other hand, at night the concentration of waste water is very low (COD < 50 mg/l between 3 am and 4 am). The highest flows correspond fairly closely to the peaks of concentration, the maximum being recorded between 9 am and 11 am. Flow values at night represent approximately 2 m^3/h and consist of clear water infiltrated into sewerage system,ie. approximately 50 % of the total flow.

These measurements were made in dry weather and the system can be considered as draining. Pollution loads varied considerably (0.05 kg COD between 3 am and 4 am ; 5.96 kg COD between 2 pm and 3 pm). Such fluctuations are normal for small communities. The traditionally used, correctly dimensioned, biological processes (in general activated sludge with extended aeration) can handle them without difficulty. Fluctuations in flow undoubtedly disturb the operation of small plants to a greater extent; in effect losses of sludge often occur in the afternoon (after the morning and midday peaks) in activated sludge plants, when the settleability is poor. The main results collected during the detailed survey over a 24 hours cycle are given in table 3.

Table 3 - Main results of the survey

Hour	Flow	BOD	COD
Mean	3.8 m^3/h	170 mg/l	436 mg/l
Minimum	2.2 m^3/h	10 mg/l	20 mg/l
Maximum	5.5 m^3/h	450 mg/l	1,100 mg/l
Ratio COD/BOD = 2.56			

	Specific loads per person-equivalent
Flow	182 l
COD	78 g
BOD	30 g

The comparison of these results with the main characteristics of tables 1 and 2 shows:

- concentrations are lower because of dilution,
- specific loads are fully in conformity with those of rural communities.

In the case of this plant, flows are at present at 30 % of the rated value, the organic load does not reach 15 % ; this situation is representative of a wide sample of French waste water treatment plants.

CHARACTERISTICS OF WASTE WATERS IN A FEW SPECIFIC SMALL COMMUNITIES

Although villages account for a large part of rural communities there are also many isolated establishments open to the public, small housing estates...

In this case there is no need to draw up an exhaustive list of these different establishments, a few examples will suffice to demonstrate the analogies or differences in their waste water as compared with the general case of the previously studied rural communities.

An isolated hospital

This hospital receives approximately 250 to 300 patients requiring only limited treatment, the majority being convalescent. Together with the personnel, total numbers do not reach 500 persons.

Waste water is collected and discharged into an activated sludge plant 300 metres from the hospital.

This plant is monitored by the SATESE of Loire Atlantique (service of technical aid to waste-water treatment plant managers) which make regular measurements at the plant, the main results described are based on various measurements made by this service.

The volume of waste water is relatively stable (40 to 50 m^3/day) with occasional peaks of 70 m^3/day which correspond to the main washing days in the establishment.

Concentrations of water occasionally reach 1,600 mg COD/l, sufficient quantities of nitrogen and phosphorus have been observed in the influents. The mean daily load expressed in BOD is 16 kg/day for 410 persons.

A comparison with the reference rural community confirms the domestic character of the influents (COD/BOD = 2.5). The only differences concern the concentration of the water, which is higher (absence of any infiltration of clear water into the sewerage system) and the specific load, which is relatively high (39 g BOD per person-equivalent). Another difference relates to the temperature of the waste water which can reach 30°C (washing with hot water).

A children's centre

This centre receives some sixty children and pre-adolescents; the activity of this establishment follows the school periods.

The waste water is treated by two macrophyte beds treatment plants.

The most recent installation (which only receives part of the centre's waste water) was the subject of detailed analyses, particularly as to the characterization of the water to be treated. The sewerage system supplying this plant is short; in addition there is no pretreatment (coarse screening, degreasing) at the inlet and the raw influent is received by the first stage of reed beds.

Given the heterogeneity of the influent, a special sampling procedure had to be used. The representative samples were collected by separating the largest elements, sieved by a 1 cm grid, crushed, homogenized and reincorporated with the part of the liquid containing the finer particles in suspension and the dissolved part of the pollution load, collected by the usual sampling devices with a peristaltic pump.

The mean results for eight - 24 - hours measurements programmes spread over a period of 5 years are shown in table 4.

Table 4 - Measurements of pollution loads in a children's centre (mean values).

	Flow	COD	BOD	SS	NK	PT	Anionic detergent
	in l/day	in g/day					
Mean	6,626	5,177	2,151	1,867	440	113	65
Standard deviation	1,539	1,287	814	667	86	42	30
Coefficient of variation in %	23.2	24.9	37.8	35.7	19.5	37.2	46.2

These figures relate to days of full activity and were obtained during weekdays out of holiday periods.

The variations recorded were however relatively important and were due to :

- the internal reorganization of the activities (grouping together of all the centre's kitchens),
- appreciable daily fluctuations (washing days, cleaning of floors), normal for a unit of this size with an organized structure.

On the other hand, solid matter retained on the 1 cm grid screen was always within a bracket representing respectively :

- 0.2 to 0.4 % of the volume of water screened,
- 5 to 7 % of the overall COD load.

The resultant pollution load could be considered as equivalent to 62 persons, corresponding to :

- permanent activity of 24 adolescents and 8 adults,
- preparation of meals and the washing of linen for 60 children, equivalent to that for 30 persons full time.

On the basis of mean calculations, the specific ratios per inhabitant-equivalent can be calculated :

- 106 litres
- 83.7 g COD
- 34.7 g BOD
- 30.1 g SS
- 7.1 g nitrogen
- 1.8 g phosphorus.

It will be noticed that these do not differ very much from those shown in table 2 but are subject to considerable variations in time.

A high mountain refuge

Located at 2,600 m in the French Alps, 2 hours walk from a town, the refuge has 200 beds and limited sanitary facilities (7 toilets, 11 washbasins, 4 water points).

The restaurant can seat approximately one hundred persons per service.

Detailed investigations were made over a period of 5 days in summer (maximum occupancy and water available).

The occupancy results for the refuge are summarized in table 5.

Table 5 - Occupancy of the mountain refuge

Day	Number of visitors (8 a.m-6 p.m)	Nights = beds occupied	Weather
1	1,700	191	Sunny
2	450	98	Cloudy
3	650	160	Variable
4	230	78	Rainy
5	1,100	190	Sunny
Mean	826	143.4	

The occupancy of the refuge is closely linked to weather conditions. The occupancy rate gave an average of 71 % of the refuge's total capacity.

The maximum number of meals served was 150 (first day of the survey). The flow of waste water had the characteristics indicated in table 6.

Table 6 - Characteristics of waste water from the mountain refuge

day	Flow in l/day	Loads in kg/day				
		COD	BOD	SS	N	P
1	8,395	9.57	3.69	2.68	2.28	0.2
2	7,556	7.07	2.35	2.21	1.23	0.1
3	6,948	9.14	2.78	2.55	1.61	0.1
4	6,041	6.80	2.11	2.04	1.24	0.1
5	8,743	7.87	3.58	1.60	1.89	0.1
Mean	7,538	8.09	2.90	2.21	1.65	0.1

Accumulated flows for a day do not give an idea of hourly variations (minimum flow nearly zero at night and a maximum flow of 1 m^3/hour). The peak coefficient is about 3. These values are explained by the short length of the sewer.

Samples taken after coarse screening were very concentrated (mean COD = 1,073 mg/l). Their domestic characteristics are obvious in spite of a COD/BOD ratio of nearly 3, explained by the high proportion of cellulose in the water (torn-up paper).

Flow and concentration peaks were principally in the evening (7pm) and in the morning (7am).

As an indication, the volume of waste recovered after coarse screening was 16 l/day, ie. approximately 500 g COD/day, that is to say less than 10 % of the total pollution load.

An analysis of all the data (including residues of coarse screening), weighted by safety coefficients for the flows, gives a maximum specific flow reference of 25 g BOD per "night equivalent" and a corresponding flow of 45 l/day in dry weather. This value can reach 80 l/day with rain water.

These results, which are not very high, are explained by the small quantity of household and sanitary equipment, the limited availability of water and the very special conditions of life in this type of establishment.

CONCLUSION

Three main points emerge from this qualitative and quantitative analysis of the waste water of small communities :

- the volumes and concentrations of discharges depend on the way of life of the users, the level of equipment of the dwellings, the hygiene habits.

- the scale of variation in the flow of pollutants varies inversely with the size of the community.

- the length and condition of the sewerage system (infiltration of clear water) have a direct effect on the volume of water collected and the water concentration.

Small rural communities are a very important group for which the characteristics of waste water are known : the mean ratios correspond to 150 l/day and 32 g BOD/day per person-equivalent. Depending on the condition of the sewerage system, the volume of water will be greater if it is well drained, but the volume will rarely fall below 80 l/day even for a short and really separated system. The mean figure of 32 g BOD/day is less than the commonly accepted values for urban areas, in future the increase in this ratio should be moderate.

In the absence of specific measurements it is difficult to give precise data for other communities. The cases studied demonstrate the importance of some factors affecting the pollution load discharged (rhythm of activity, internal organization,...).

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