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Wastewater Characteristics in Europe – A Survey

ABSTRACT

A survey of wastewater characteristics in Europe has been conducted to evaluate the range of pollution ratios (BOD5/COD, SS/COD, N/COD and P/COD) that can be used to assess the robustness of wastewater management systems in terms of sustainability. Data were collected from questionnaires sent to wastewater treatment plants managers (Austria, France), from national data bases (Denmark, Flanders, The Netherlands), from national contacts and from literature. Average values are proposed for N/COD (≈ 0.1 mg/mg), P/COD (≈ 0.016 mg/mg), SS/COD (≈ 0.5 mg/mg) and BOD5/COD (≈ 0.4 mg/mg). But these values are subject to time-variations (short and long-term range) which merit further investigations.

1. INTRODUCTION

Pollution and excessive use seriously compromise the availability of fresh water around the world and may be the cause of serious conflicts in the future. It is necessary to protect and produce a high-quality water in sufficient quantity at an affordable cost, while preserving the ecosystems. Different techniques can be applied for wastewater treatment: source control, biological techniques (activated sludge, biofilms, anaerobic systems), as well as physical or physical-chemical techniques (sedimentation, separation, filtration, precipitation, ion-exchange techniques, treatment with ozone, use of activated carbon, etc.). By combining these techniques a large number of treatment scenarios can be formed, each with its own merits with respect to sustainability, energy use, etc. The characteristics of the wastewater are among the parameters influencing the appropriateness of a scenario. Furthermore the models used to describe the different units of operation should be calibrated depending upon those characteristics.

The Working Group on Treatment Scenarios of the COST Action 624 (“Optimal Management of Wastewater Systems”) (http://www.ensic.inpl-nancy.fr/COSTWWTP) has undertaken a survey on these characteristics in European countries. The survey, based on questionnaires and on the analysis of national databases, deals primarily with municipal wastewater, which is often a mixture of domestic and industrial wastewater and water from diffuse sources. Comparisons with literature data and with "pure" industrial waters is also proposed, and some indications of variations with time (short and long-term range) are also given.

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2. METHODS

The following parameters were considered: total Chemical Oxygen Demand (COD in mg/L), Biochemical Oxygen Demand 5 days (BOD5 in (mg/L) (with or without addition of ATU (Allyl-thiourea)), suspended solids (SS in mg/L), Kjeldahl nitrogen (N in mg/L), total phosphorus (P in mg/L). From these the ratios N/COD (mg/mg), BOD5/COD (mg/mg), P/COD (mg/mg) and SS/COD (mg/mg) were calculated for each plant.

Although these parameters are very usual, they are not systematically collected and compiled, as the different European countries do not base their regulations in terms of wastewater on the same rules.

In Austria, wastewater treatment facilities are requested to measure the wastewater flow as well as the concentrations for COD, BOD5 (with the addition of ATU) and NH4-N of the raw wastewater. In general, at larger plants (> 20,000 PE) total N and total P in the influent are analysed, too. Usually, at these plants, COD of the influent is measured daily (at least during the working week), BOD5 2 to 3 times a week and total-N and total-P 3 (up to 5) times a week. The data presented here have been collected in the course of a project on energy optimisation at municipal treatment plants. These data have been checked by means of mass balances [1] and by the values for the specific VSS load in the stabilised sludge [2].

In Belgium, Flemish Environmental Organisation (VMM, Vlaamse Milieumaatschappij) continuously performs measurements campaigns to assess the quality of the Flemish waters. As such the industrial discharges are verified on a regular basis. The results used in this paper are received from VMM and based on regular measurement campaigns performed during 1997 for 492 industrial discharges and 148 wastewater treatment plants.

In France, 400 questionnaires have been sent to City Councils and about 150 were returned with data. They are yearly averages obtained in years 1998 and 1999 by plant self-monitoring procedures or specific measurement campaigns conducted by the SATESE (Service d'Assistance Technique aux Exploitants de Systèmes d'Epuration) over the year. Further information was also collected on the website of RNDE (Réseau National des Données sur l'Eau: http://www.rnde.tm.fr).

In the Netherlands, wastewater treatment plants are operated by in total 25 water boards. Wastewater treatment plants are obliged to measure a number of plant data according to the Dutch national standards. Yearly averaged data of individual wastewater treatment plants are published in reports. Statistics Netherlands collects these data and publishes average concentrations for the whole country. The level of detail in this paper is generally not published, and for the present purpose data were provided by Statistics Netherlands.

For Denmark the data were provided by the Danish Environment Protection Agency and for Slovenia by the Environmental Agency of the Republic of Slovenia. For Catalonia, Cyprus, Switzerland, Turkey, Hungary, Germany, UK, the data were provided by members of the COST 624 Working Group on Treatment Scenarios.

Table 1. Statistical results of influent characteristics: **average value** - *median value* - [standard deviation] - number of plants; n.d. = not determined.

Country / plant size range	COD (mg/L)	BOD_5 (mg/L)	SS (mg/L)	N (mg/L)	P (mg/L)
Austria 2500 – 400000 PE	**526** *498* [218] 97	**285**[b] *256* [120] 94	n.d.	**44** *40* [18] 90	**7.1** *7* [3] 90
Belgium-Flanders	**477** *382* [314] 152	**187**[b] *152* [128] 152	**236** *174* [222] 152	n.d.	n.d.
Denmark 30 – 750000 PE	**455** *404* [440] 836	**163**[a] *135* [119] 348 **155**[b] *121* [150] 137	n.d.	**36** *30* [31] 677	**7.8** *6.2* [7.6] 686
France 1200 – 6.5M PE	**634** *592* [315] 149	**268**[a] *245* [137] 149	**302** *267* [170] 148	**52** *51* [23] 144	**9.3** *9* [3.8] 130
Netherlands	**450** *426* [151] 384	**171** [b] *159* [66] 384	**237** *194* [252] 205	**42** *40* [16] 384	**6.7** *6.1* [6.1] 3
Slovenia	**581** *418* [613] 100	**267** [b] *217* [245] 94	**426** *341* [292] 12	**37** *39* [19] 18	**5.5** *4.8* [3.8] 77

[a] without ATU; [b] with ATU

3. RESULTS

Table 1 summarises the results obtained in terms of concentrations. They can be compared to literature data concerning Scandinavia and Morocco and to sparser data from other European countries (Table 2). Mediterranean countries such as Morocco, Cyprus, Turkey and the region of Catalonia exhibit larger concentration values but, surprisingly, Finnish values for COD and SS are also very high. For nitrogen and phosphorous, Norway has much lower values than the other countries and Sweden has an intermediate value for nitrogen. If the average values of COD, BOD5 and SS for municipal wastewater vary largely, the N/COD, P/COD and SS/COD ratios are more independent of the location as seen in Table 3. The values for N/COD and P/COD recalculated from the data on contaminant flows given by Gray and Becker [5] for a urban residential area in Australia are quite similar to what is observed in Europe. On the contrary the SS/COD ratio is lower in the Southern hemisphere.

Table 2. Other data available: average value - *median value* - [standard deviation] - number of plants; n.d. = not determined.

	COD (mg/L)	BOD_5 (mg/L)	SS (mg/L)	N (mg/L)	P (mg/L)
Cyprus	**522** 6	**547** [b] 6	**436** 6	**98** 6	**16** 6
Finland [3]	**559** [161] 7	**266** [b] [78] 7	**378** [144] 7	**43.8** [10.4] 7	**7.47** [1.34] 7
Germany	**548** 6	**319** [b] 6	**208** 6	**59** 6	**8** 6
Hungary	n.d.	**377** [b] *400* [155] 27	n.d.	n.d.	n.d.
Morocco [4]	**928** *900* [357] 60	**353** [b] *350* [140] 60	**397** *400* [174] 60	n.d.	n.d.
Norway [3]	**233** [69] 12	**113** [b] [28] 12	**143** [39] 12	**22.0** [6.2] 12	**3.00** [1.12] 12
Spain - Catalonia	**762** 3	**434** [b] 3	**290** 3	**71** 3	**11** 3
Sweden [3]	**477** [123] 17	**171** [b] [72] 17	**243** [87] 17	**33.1** [8.1] 17	**6.14** [1.65] 17
Switzerland	**239** 6	**133** [b] 1	**98** 5	**28** 6	**4** 6
Turkey	**656** 6	**356** [b] 8	**423** 9	**65** 6	**12** 8
UK	**613** 12	**212** [b] 10	**150** 6	**40** 3	n.d.

[a] without ATU; [b] with ATU

Table 3. Statistical results of influent characteristic ratios: **average value** - *median value* - [standard deviation] - number of plants; n.d. = not determined.

Country	N/COD (mg/mg)	P/COD (mg/mg)	SS/COD (mg/mg)	BOD_5/COD (mg/mg)
Austria	**0.087** *0.085* [0.021] 90	**0.014** *0.014* [0.003] 90	n.d.	**0.529** [a] *0.549* [0.122] 94
Belgium-Flanders	**0.113** *0.113* [0.036] 152	**0.019** *0.019* [0.006] 151	**0.489** *0.437* [0.300] 152	**0.375** [b] *0.388* [0.041] **152**
Denmark	**0.110** *0.088* [0.113] 677	**0.022** *0.019* [0.030] 686	n.d.	**0.448**[a] *0.416* [0.200] 348 **0.339**[b] *0.365* [0.135] 137
France	**0.094** *0.088* [0.066] 144	**0.016** *0.016* [0.005] 130	**0.480** *0.465* [0.125] 148	**0.429**[b] *0.425* [0.116] 149
Morocco [4]	**0.115**	**0.019**		**0.38** [b]
Netherlands	**0.097** *0.092* [0.026] 384	**0.015** *0.015* [0.005] 384	**0.512** *0.443* [0.502] 205	**0.378** [b] *0.533* [0.045] 384
Slovenia	**0.069** *0.065* [0.042] 82	**0.013** *0.012* [0.009] 76	**0.641** *0.500* [0.348] 12	**0.485** *0.486* [0.155] 94
Perth, Australia [5]	**0.12**	**0.014**	**0.44**	

[a] without ATU; [b] with ATU

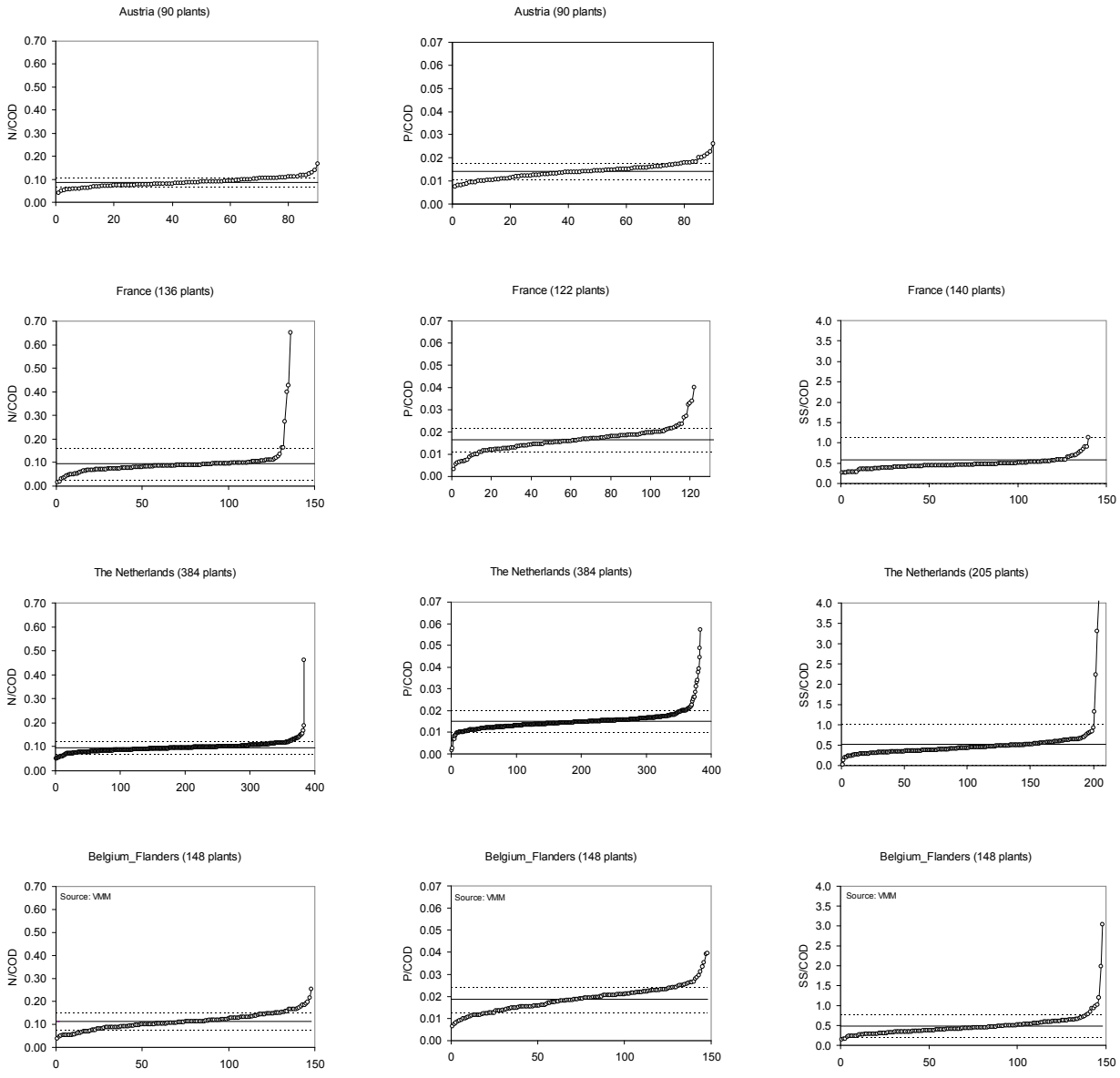

Figure 1: Comparison of the distribution of N/COD, P/COD and SS/COD for municipal wastewater (—) average value, (- - -) average value ± standard deviation. The number of wastewater treatment plants having provided data is indicated for each case.

In Figure 1, the distributions of N/COD, P/COD and SS/COD in function of the number of plants are compared for Austria, France, Flanders and the Netherlands. The average industrial N/COD ratio observed in France and Flanders is similar to the average municipal N/COD ratio but the standard deviation is much larger (Table 4). The average industrial P/COD ratio is about twice as large as the average municipal one. Large differences can be seen for the average industrial SS/COD ratio between Flanders and France, but a closer examination of the data is necessary concerning the type of industry.

Table 4. Statistical results of industrial influent characteristic ratios: **average value** - [standard deviation] - number of plants; n.d. = not determined.

Country	N/COD (mg/mg)	P/COD (mg/mg)	SS/COD (mg/mg)
Belgium-Flanders Industrial	**0.101** [0.167] 492	**0.033** [0.131] 492	**0.343** [1.338] 492
France Industrial 1997*	**0.112** [0.102] 26	**0.033** [0.067] 16	**1.06** [2.47] 67
France Industrial 1998**	**0.117** [0.108] 131	**0.047** [0.081] 87	**1.74** [4.11] 144

* 40% Food industries, 22% Wood and paper, 21% Chemical industries
** 53% Food industries, 8% Wood and paper, 40% Chemical industries

The effect of the randomness of the selection of the plants has been examined on the data from Netherlands: the values of N/COD and P/COD obtained by a random selection of 192 plants out of the 384 (~89% of all municipal wastewater plants) available data sets were 0.100 mg/mg (standard deviation = 0.040 mg/mg) and 0.015 mg/mg (standard deviation = 0.005 mg/mg) respectively, which is quite similar to the values obtained on 384 plants.

If the average yearly ratios vary from one location to the other, they can also be expected to vary along the year according to seasonal activity and rainfall, as in many cases, an unitary (total or partial) sewage system is used. Monthly data were collected for eight cities in France (Figure 2 and Table 5) over a period of one year and the annual variability was calculated as:

Variability = 100 . annual standard deviation / annual average

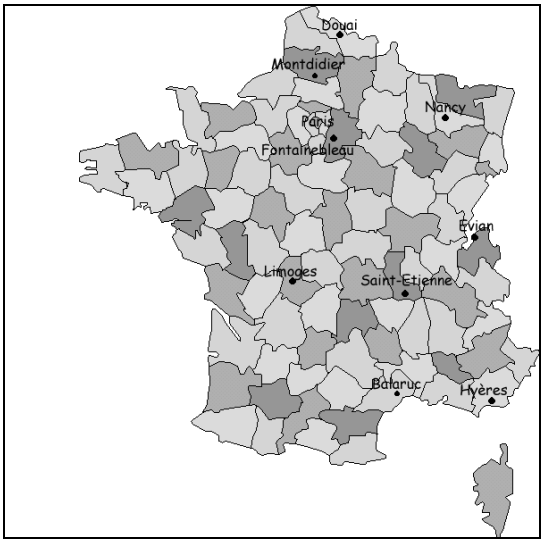

Figure 2: Location of French cities considered for time-dependency study

Table 5: Monthly variability in France during one year (%); n.d. = not determined.

City	BOD_5/COD	SS/COD	N/COD	P/COD	Flow rate	Rainfall
Limoges	6	15	7	8	17	53
Nancy	11	8	17	13	15	n.d.
Evian	12	11	23	6	23	55
Saint-Etienne	14	9	6	7	18	n.d.
Douai	10	14	16	n.d.	21	n.d.
Fontainebleau	20	19	17	20	8	n.d.
Hyeres	6	7	8	18	21	n.d.
Balaruc	10	10	n.d.	n.d.	22	n.d.

Figure 3 shows the relative variations of the influent flow rate with respect to their average influent flow rate for the same cities:

Relative variation = 100 . (value of month i – annual average) / annual average

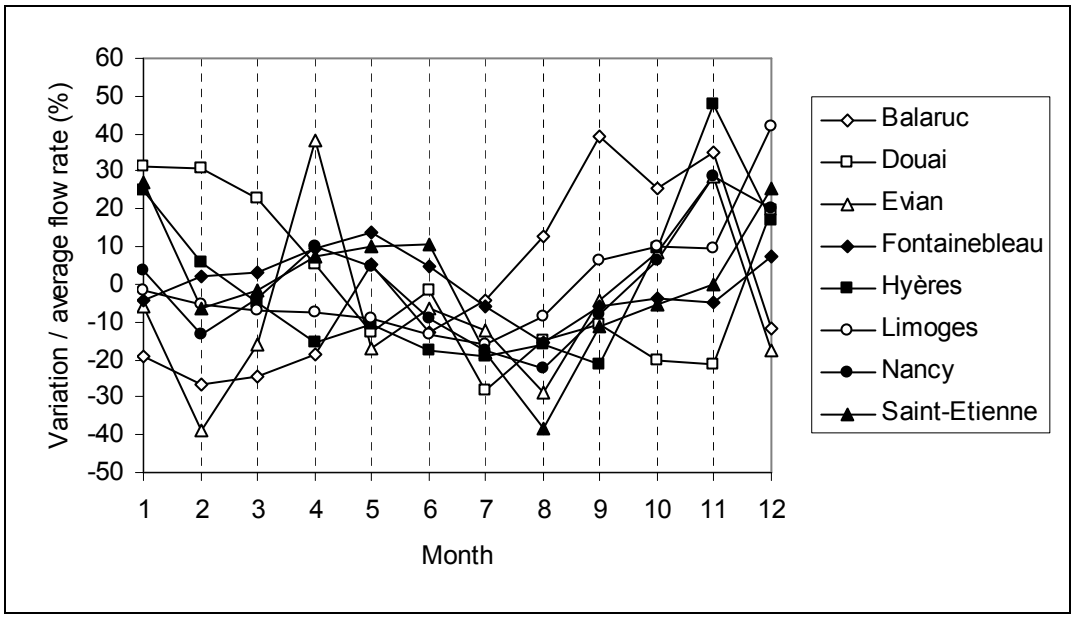

Figure 3 : Relative wastewater flowrate variation over one year for eight French cities

As expected the influent flow rate is generally lower in summer due to reduced rainfalls. In large cities situated in the North of France, this effect is combined with a vacation effect. A population migration toward tourist areas situated in the South can be observed. However, except for one southern location (Balaruc) this increase of population do not counter-balance the decrease due to reduced rainfalls. The ratios themselves do not show any specific evolution pattern along the year and have a variability ≤ 20%.

Sustainability should be assessed over a number of years and long-range changes in the composition of wastewater should be considered. These changes are related to changes in the population behaviour, to the increase or decrease of small industries connected to the sewage network, to the implementation of wastewater treatment plants in those industries, to the separation of rain water and domestic water with the building of temporary storm water storage tanks and the climate variations. Yearly ratios have been computed for four cities in France and one city in Belgium over two to seven years. The highest variability is observed for N/COD and P/COD, but no systematic trend (increase or decrease) could be observed. For Nancy (F) SS/COD and BOD5/COD are respectively 20% and 10% lower since 1997, with respect to the four previous years. For Evian (F), it is an increase of SS/COD (13%), of P/COD (22%) and N/COD (20%) since the beginning of 1998 which can be observed. No specific trend could be seen in the case of Deurne (NL). In this case a larger variability is observed for the ratios, but the flow rate variability is also much larger than for the considered French cities. Those variations are very location-dependent and an analysis of the changes having taken place (and foreseen) should be done for sustainability assessment.

4. CONCLUSIONS

An extended survey of the characteristics of influent wastewater has been conducted in six European countries (Austria, Belgium, Denmark, France, the Netherlands, Slovenia). Average values can be proposed for N/COD (≈ 0.1 mg/mg), P/COD (≈ 0.016 mg/mg) and SS/COD (≈ 0.5 mg/mg). It is more difficult to propose an average value for BOD5/COD because BOD5 can be measured with or without addition of ATU. The average value seems to be close of 0.4 mg/mg, with is lower than the value generally used for design (0.5 mg/mg). The results concern countries situated in mid-Europe. The data collection is on-going to extend the geographical range of the database and see if those average values can be confirmed in the rest of Europe.

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