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To cite this article: P Hlстик 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **444** 012020

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Main parameters of a wastewater treatment plant up to 2000 PE in the Czech Republic

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Abstract. The article deals with optimising the design parameters of wastewater production and specific pollution production in wastewater treatment plants up to 2,000 PE. The values of design parameters for the WWTP calculation are laid down in the legislation (ČSN 75 6401 and ČSN 75 6402) recommending their use with a potential reduction in the pollution of up to 50% according to the size of the municipality. Determination of the pollution reduction is no longer defined in standards and design values for different drainage systems are not defined, either. The design values for WWTP calculations should be based on realistic measurements covering at least the past three years. The objective of this article is to determine more precise design values applicable to WWTP calculations and different drainage systems on the basis of statistical evaluation of individual water quality indicator analyses.

1. Introduction

The design of each wastewater treatment plant (WWTP) has its specific features. When designing a wastewater treatment plant, each design engineer should carry out water management research on the current and prospective status (number of connected inhabitants, industrial producers in the municipality, hydraulic conditions in the sewer system, structural and technical condition of the sewer system). Other important supporting data needed for the design of the WWTP are the engineering-geological surveys, hydrological, hydrogeological and climate data related to the intended wastewater treatment plant design. The design of the new wastewater treatment plant should be in line with the urban master plans of the municipalities and development plans of the water supply and sewerage system in the relevant municipality (PRVK). An important criterion in the design of waste water treatment plants is the assessment of surface water quality and its protection against pollution caused by wastewater treatment plant discharges. Assessment and compliance with pollution standards downstream the WWTP are part of every project under preparation. These approaches are usually similar in the European countries.

The category up to 2,000 population equivalent (PE) is often neglected in the design of wastewater treatment plants and offers a wide scope in the design of sewerage systems and wastewater treatment plants.

2. WWTP design parameters

The main design parameters of wastewater treatments plant are the hydraulic load (wastewater treatment plant influent) and the mass load (water quality indicators). Standardized parameters are understood as only recommended indicative values of specific pollution production per inhabitant in terms of the water quality indicators (the so-called “population equivalent”). The main WWTP design values of wastewater treatment plants include the following wastewater quality indicators: biochemical oxygen demand BOD, chemical oxygen demand COD, suspended solids SS, total phosphorus N_t , ammonia nitrogen $N-NH_4^+$ and total phosphorus P_t .



The hydraulic and mass design parameter values are further specified by the standard ČSN 75 6401 [1]. Waste water treatment plants for the equivalent number of inhabitants (PE) over 500, ČSN 75 6402 [2]. Wastewater treatment plants for the equivalent number of inhabitants (PE) up to 500 and Government Decree No. 401/2015 Sb. on indicators and values of permissible pollution of surface water and wastewater, details of permits for wastewater discharges into surface water and sewerage system and on and sensitive areas [3]. The hydraulic load of a wastewater treatment plant is defined by a specific wastewater production indicator, which has been decreasing in the long term. This main design indicator determines the size of the main WWTP facilities, and its determination should be a priority.

2.1. Hydraulic load of WWTP

The main design parameter is specific wastewater production expressed per person per day, which has been steadily decreasing in recent years and significantly affects capacities of the main process tanks. When designing wastewater treatment plants, the value of 150 l per capita/day was used by the design engineer for a long time as per ČSN 75 6402 (1998), some design engineers have used this value to date in wastewater treatment plant designs. This value is overestimated and the value used in the wastewater treatment plant designs is usually based on the average production of 120-150 l per capita/day (according to the WWTP category), which therefore provides a large reserve in the design of the main tank volumes at a WWTP. The ČSN 75 6401 standard does not specify the value of specific wastewater production, ČSN 75 6402 (2017) contains Chapter 5 Wastewater treatment plant design data, paragraph 5.4, which gives a recommended value is 90-120 l per capita/day with regard to the future wastewater trends and assessment of measures affecting water consumption.

2.2. WWTP mass load

The use of design values of indicative specific pollution production for waste water quality indicators compared to the values applied by EU Member States is shown in Table 1. The standards only enable their partial reduction for size categories expressed as a percentage reduction of pollution conveyed to the WWTP without more detailed explanation.

In the Czech Republic, it is defined in ČSN 75 6401, Chapter 5, Basic data for the design of wastewater treatment plants, section 5.10, showing that the indicative values of specific pollution are achieved in settlements with a higher standard of civic amenities. Therefore, in justified cases (especially for WWTPs up to 5,000 PE), these values should be reduced, however, by a maximum of 30%. ČSN 75 6402, Chapter 5 Basic data for the design of wastewater treatment plants, Section 5.8, specifies that indicative values of specific pollution are achieved in settlements with a higher standard of civic amenities. Therefore, in justified cases, these values may be reduced; however, by a maximum of 50%.

Table 1. Specific production of “so” wastewater pollution in g per capita/day.

Substance	Inorganic	Organic	Total	BOD	COD	N _t	P _t
Suspended, non-settleable	10	30	40	20	40	1	2
Dissolved, settleable	5	10	15	10	20	-	-
Dissolved	75	50	125	30	60	10	2.3
Total	90	90	180	60	120	11	2.5

When calculating the volume flow coming to the WWTP, the incoming pollution and the design of the wastewater treatment plant technology, the method of wastewater transport to the WWTP must always be taken into account [4, 5]. The current standards do not take into account the quality of incoming wastewater for various sewage systems.

3. Modification of design parameters

Improper choice of standard design parameters for WWTP calculations primarily affects the main WWTP facility volumes, the capacity of mechanical equipment and the capex for the implementation itself. A wastewater treatment plant operated in this manner is usually undersized in terms of capacity, the civil structures are loaded at about 60-70% and the mechanical and technological equipment operate at half their maximum output. It is also well known that a wastewater treatment plant should preferably be designed according to values that are verified by direct measurement.

Statistical data processing was carried out using ten thousand values of wastewater concentration indicators at the inflow to WWTPs in different years, operated by water companies. In order to optimize the design parameters of wastewater treatment plants, the WWTPs in the given category were always selected as mechanical-biological wastewater treatment plants with a low-load activation system. All selected wastewater treatment plants have technologies guaranteeing the efficacy of wastewater treatment and meet the emission indicators.

3.1. Modification of wastewater production parameter

The real average value of wastewater production is 94 l per capita/day without ballast water for systems that only drain sewage wastewater. The specific water demand indicator value for the calculation of WWTPs in municipalities up to 2,000 PE can thus be alternatively addressed by reducing the standard values to the minimum limit of 100 l per capita/day. This is a recommended value to calculate sewerage and WWTPs values.

These values can be considered for small municipalities also while taking into account the future development of wastewater production (without major industrial producers) and in combination with the urban plans and the PRVK. The future condition of wastewater treatment plants is determined for a period of 10-15 years from the expected commissioning of the WWTP [6,7].

A comparison of the design real values of wastewater production with those of the EU Member States is shown in Figure 1.

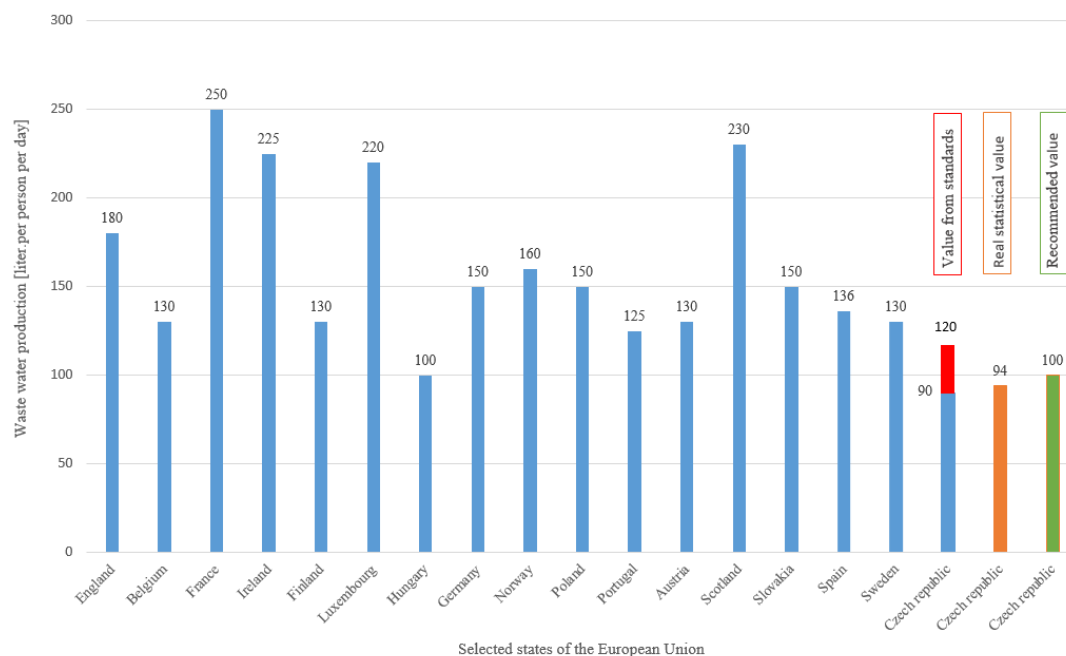


Figure 1. Comparison of the design value of wastewater production in EU Member States. Based on these results and considering sufficient reserves to operate sewer systems and WWTPs, it is advisable to modify the specific wastewater demand value.

3.2. Modification of the mass load parameter

Modification of the design values is based on statistical processed data proposed with a reserve. The determination takes into account potential deviations in terms of chemical analyses of water quality and statistical error in the parameter calculation. The mutual ratios of the individual wastewater indicators are not strictly observed during optimization, nor when determining the average values of water quality indicators for individual drainage methods.

The values of design pollution production depend on the social, economic and environmental conditions of the relevant country. The design production of pollution in terms of wastewater quality indicators BOD, COD, SS, N_t and P_t differs for each country and the values oscillate around the standard values used in the EU Member Countries. The legislation applicable in the individual EU Member States specifies the design production of pollution set in g per capita/day [8, 9]. These values are recommended values and are usually different when designing a WWTP. The difference in the design values is influenced by several factors that significantly affect the WWTP calculations. The factors always depend on the population, civic amenities in the municipality, the type of catchment area, water management survey, hydraulic conditions of the sewer network and the engineering-geological survey of the locality. The WWTP operator usually recommends design values of wastewater production in the relevant region (area, state) [10].

Values of average design pollution production for selected EU Member States and worldwide are given in Table 2. The values of pollution production are given in a range in which they were detected, it was not always possible to find comprehensive information on the design pollution values. For EU Member Countries, the usual design values of pollution production are specified by Council Directive 91/271/EEC.

Table 2. Design values of pollution production in grams per person/day for selected countries.

State	BOD	COD	SS	N_t	P_t
EU Member Countries	50-60	110-120	55-75	11-12	2-3
US EPA	35-65	115-150	35-75	6-17	1-2
Brazil	55-70	110-140	55-70	8-14	0.6-1
Egypt	27-40	55-80	40-70	8-14	0.4-0.6
Turkey	27-40	55-80	40-70	8-14	0.4-2
Denmark	55-68	160-190	82-96	14-19	1.5-2.0
Germany	55-68	160-190	82-96	11-16	1.2-1.6
Italy	49-60	120	55-82	8-14	0.6-1.0
Sweden	68-82	140-160	82-96	11-16	0.8-1.2
Uganda	55-68	110-140	41-55	8-14	0.4-0.6
Tehran	31-34	60-70	35-40	6.2-7.3	1.8-2
South Africa	50	100	-	10	2.5
Kenya	23-36	60	-	9	-
Zambia	23	50	-	-	-
Japan	40	80	-	10	1
Vietnam	45-60	82-102	-	8-13	0.8-4.5
	Value from standards ČSN 75 6401, ČSN 75 6402				
Czech Republic	60	120	55	11.5	2.5
	Recommended value				
	50	100	45	12	1.4

The value of wastewater production is defined by the BOD indicator, which is the main design value in the WWTP calculations. The indicator value varies for the European Countries in a range of 50-60 g per capita/day for non-EU countries the values are approximately the same.

4. Conclusions

Due to the constantly decreasing water consumption, it is important to correctly determine the volume flow and mass load, i.e. determination of specific water production for equivalent determination of the capacities of civil structures and mechanical-technological equipment. When reconstructing existing wastewater treatment plants and constructing new ones, it is important to determine the input data (up-to-date information, monitoring, analyzes) and to propose a suitable wastewater treatment technology.

In practice, it is important to enforce a new approach to designing wastewater treatment plants up to 2,000 PE. The introduction of new design parameters will be related to the company management willingness to adapt to new directions in the field of "Sewerage and wastewater treatment". Experienced design engineers are aware of the difference in wastewater quality for various sewer systems and they usually try to adapt the design parameters for the WWTP calculation. The pollution production parameters for these sewage systems cannot be interpreted as surprising, the wastewater quality in these systems shows worse parameters in relation to all indicators.

Acknowledgements

The paper was drawn up in the framework of the standard project No. FAST-J-18-5545 "Testing of adsorption media for odour removal from sewers".

This paper / contribution / abstract has been worked out under the project No. LO1408 "AdMaS UP - Advanced Materials, Structures and Technologies", supported by Ministry of Education, Youth and Sports under the „National Sustainability Programme I".

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