ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ
СОФИЯ

Том Volume 51 | 2018 | Брой Issue 6

ANNUAL OF THE UNIVERSITY OF ARCHITECTURE, CIVIL ENGINEERING AND GEODESY
SOFIA

Получена: 11.10.2017 г.
Приета: 22.10.2017 г.

INFLUENCE OF THE DATA QUALITY ON THE WASTEWATER TREATMENT PLANT SIZING

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Keywords: *wastewater treatment plant, design models, BOD_5, total suspended solids, total nitrogen, total phosphorus, uncertainty, data reliability*

ABSTRACT

Numerous determinations of water quality are made daily in different laboratories with the sole purpose to provide information in terms of results for different water types. The content of this information depends on the intended use of the results, which are usually presented with their accompanying uncertainty. This means that not only the average, but every value in the uncertainty interval may be the true value. Real data for the content of BOD_5, suspended solids, total nitrogen and total phosphorus is used for the WWTP's sizing. The average, the upper and the lower value of the uncertainty interval are used for comparison.

In the present paper, the effect of the laboratory results on the sizing procedures based on the widely used German methodology ATV A-131 for the determination of all the technological and construction parameters is presented. Comparison is made when the average, the upper and the lower value of the uncertainty interval is used, and conclusions are made which technological parameters of the biological step are influenced to greatest extend with the different wastewater composition.

1. Introduction

Measurement results are usually presented as a quantitative characteristic of the measurement object accompanied with their accompanying uncertainty. The measurement

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uncertainty represents a doubt over measurement result accuracy and it is presented as an interval in which the true value can be found with highest probability [1, 2]. This means that any value within the interval can be the true value, not only the average value obtained by finite number of measurements. Estimation of the measurement uncertainty is best done during the method validation. It is basic characteristic of the measurement result and proves its reliability.

Credibility of results for water quality parameters can only be achieved if highest demands are laid towards the laboratories where these results are obtained. This is only achieved when the laboratory can demonstrate technical competence according to ISO/IEC 17025:2005 (E) [3] and its Bulgarian equivalent BSS ISO/IEC 17025:2005 (E) [4]. One of the main requirements of the standard is that the methods adopted or developed, the changed standardized methods and the standardized methods outside the scope of accreditation must be validated. Method validation is the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled. A validation exercise aims at proving that any analytical method is fit for its intended purpose. So a check is made whether the requirements can be fulfilled each time the method is used.

State norm № 6 for emission norms for harmful and dangerous substances in wastewater lays the requirement that laboratory testing for monitoring of such waters should be done only in accredited laboratories [5].

2. Materials and Methods

Measurements of the water quality

The method for the determination of the biological oxygen demand (BOD_5) after 5 days is based on sample incubation at 20 ± 2 °C in dark for 5 days and measurement of the concentration of dissolved oxygen in the beginning and at the end of the incubation period [6]. The oxygen concentration is determined using iodometric method [7].

The method for the determination of total suspended solids (TSS) in water is based on the air-pressured filtration of the sample through glass-fiber filters and subsequent drying of the filter at 105 ± 2 °C. The mass of the particles retained onto the filter is measured by an analytical balance with accuracy of 0,01 g [8].

The method for the determination of total bound nitrogen (TN_b) in water using spectrophotometric method with cuvette tests is based on the oxidation of the organic and inorganic forms of nitrogen with peroxydisulphate to nitrates, which then react with 2,6-dimethilphenol in sulphuric acid and phosphoric acid media, yielding nitrophenol. The solution is heated at 100 °C for one hour prior to determination of total nitrogen using spectrophotometer DR 3900 at 370 nm.

Similarly, the method for the determination of total phosphorus (P_{tot}) in water using spectrophotometric method with cuvette tests is based on the formatin of coloured complex after the addition of the sample to the pre-loaded cuvettes and heating for one hour at 100 °C prior to determination of total phosphorus using spectrophotometer DR 3900 at 890 nm [9].

Estimation of the measurement uncertainty

Estimations of the measurement uncertainties for the determinations of BOD_5, TSS and TN_b are made using ISO 11352 [10], while the measurement uncertainty estimation for the determination of P_{tot} – using ISO 21748 [11]. Data is presented in Table 1. Method validation experiments and measurement uncertainty calculations are described elsewhere [12 – 15]. The results obtained for the measurement uncertainties using both the standards are negligible for most of the parameters [16].

Table 1. Uncertainty estimations for the determination of BOD_5, TSS, TN_b and P_{tot} in water

Parameter	Range	Method	Uncertainty of the determination
BOD_5	0,5 – 6,0 mgO_2/L	ISO 5815-2:2003 [6]	13%
Total suspended solids	2,0 – 50 mg/L	BS EN 872:2005 [8]	4%
Total Nitrogen	1,0 – 16 mg/L	LCK 138	11%
Total Phosphorus	2,0 – 20 mg/L	LCK 350 [9]	15%

Plant sizing methodology

Real data for the concentration of BOD_5, TSS, TN_b and P_{tot} is used for the sizing of a wastewater treatment plant (WWTP). Measurement results with their inherent uncertainties are used for comparative analysis – the average and the values for the lower and the upper limit of the uncertainty intervals (table 2).

Table 2. Real data for BOD_5, TSS, TN_b and P_{tot} used for the WWTP sizing

Parameter	Average ± uncertainty (mg/L)	Lower limit of the uncertainty interval (mg/L)	Upper limit of the uncertainty interval (mg/L)
BOD_5	303,32 ± 39,43	263,89	342,75
Total suspended solids	353,88 ± 14,16	339,72	368,04
Total Nitrogen	55,61 ± 6,12	49,49	61,73
Total Phosphorus	9,10 ± 1,37	7,73	10,47

3. Results and Discussion

The most widely used standard for technical design and biological wastewater treatment facilities calculations is the German Standard ATV-A131 [17]. The results obtained above for mean value, upper and lower limits of the uncertainty interval for main pollution indicators, are used as initial values for biological step design. The main objectives are to compare the results obtained using ATV-A 131 for structural dimensions and basic technological parameters calculated at different initial values for pollution concentrations shown in Table 2. All results are presented in table 3 [17].

When carrying out the design procedures, the same value for wastewater flowrate $Q_{average}$ is used in all calculations in order to perform a comparative analysis of all basic technological and constructive parameters obtained from the design procedure at the same hydraulic capacity, but with a different composition of the wastewater influent obtained during the measurement campaign. Thus, it is possible to give a real idea of how laboratory wastewater measurements and subsequent results used as inputs, influence the design of biological treatment facilities.

The different BOD_5 and Total Nitrogen influent concentrations shown in Table 2, as lower and upper limits of the confidence interval, respectively reflect the influent load that will afterwards be used as start-up parameters for wastewater treatment plant design shown in Table. 3. The load on these two indicators vary by more than 10%, which then substantially reflects some of the basic technological parameters.

Table 3. Basic technical parameters obtained from calculation procedures, at different initial values for influent concentrations

Parameter	Lower limit	Upper Limit	Unit
Average wastewater flowrate	73353,00	73353,00	m^3/d
BOD_5 load	20469,15	24030,44	kg/d
Total Nitrogen load	3630,24	4528,08	kg/d
Total Nitrogen in influent	49,49	61,73	g/m^3
Nitrates in effluent	10,00	10,00	g/m^3
Ammonium Nitrogen in effluent	3,00	3,00	g/m^3
Organic Nitrogen in effluent	2,00	2,00	g/m^3
Ammonium Nitrogen for nitrification	30,54	40,35	g/m^3
Nitrate concentration for denitrification	20,54	30,35	g/m^3
NO_3/BOD_5 ratio	0,07	0,09	
Total phosphorus in influent	7,73	10,47	g/m^3
Total phosphorus in effluent	2,00	2,00	g/m^3
Sludge age	10,27	10,27	D
Nitrification volume	67259,42	77635,25	m^3
Denitrification volume	16814,86	19408,81	m^3
Total volume	84074,28	97044,06	m^3
Hydraulic retention time in nitrification area	22,01	25,40	h
Hydraulic retention time in denitrification area	5,50	6,35	h
Activated sludge concentration	3000,00	3000,00	g/m^3
Recirculated activated sludge flowrate	1922,68	1922,68	m^3/h
Internal recirculation flowrate	4701,58	7700,65	m^3/h
Volumetric organic load	0,24	0,25	$kgBOD/m^3.d$
Activated sludge growth	24569,51	28359,74	kg/d
Excesses sludge	2785,66	3215,39	m^3/d
required oxygen for nitrification	1414,66	1719,92	kg/h
recovered oxygen from denitrification	182,03	269,01	kg/h
Air flowrate	42931,72	51783,38	m^3/h
BOD_5 concentration in effluent	25,00	25,00	g/m^3
Nitrates concentration in effluent	10,00	10,00	g/m^3
Required volume for biological facilities	84074,28	97044,06	m^3

As it can be seen from Table 3, all nitrogen values in the various forms (nitrite, nitrate, and ammonium) remain unchanged in calculations. The nitrate/BOD_5 ratio is not altered, which in turn will not lead to a change in the ratio between the aerobic, in the nitrification part of the bio step needed for construction and in the oxygen-free denitrification part. There is also no change in the total age of the sludge, which in this case remains for 10 days, regardless of the different influent parameters for wastewater composition.

Parameters that are subject to a significant variation depending on different wastewater composition, respectively the accuracy of the laboratory measurements, are the activated sludge growth obtained from BOD_5 and Total suspended solids reduction, which accordingly substantially affect the required volume of all tanks – nitrification and denitrification part. The change in volume is shown in Fig. 1. At average value for all pollutants (Table 2), the volume of the biological step is $V = 90\ 600\ m^3$. The variations in the laboratory measurements varying between the lower and the upper values of the uncertainty interval also substantially reflect the required volume which varies between $V = 84\ 074\ m^3$ and $V = 97\ 044\ m^3$ – 8% of its average value.

The same concentration of active sludge in all facilities (3000 g/m^3) is taken to calculate the volumes indicated. The constant concentration of the microorganisms in the biological step is maintained by the external recirculating active sludge, the flowrate of which does not depend on the change in wastewater treatment plant influent concentrations [18].

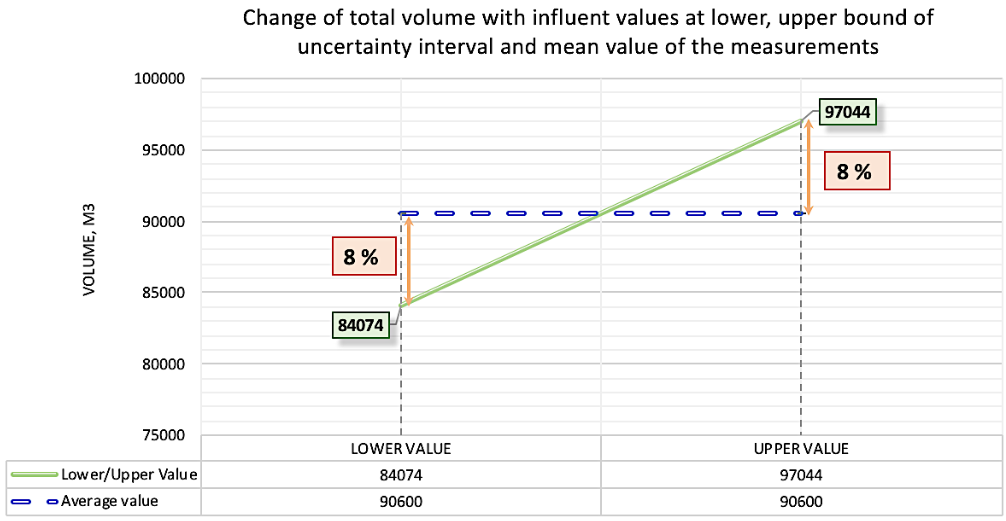

Figure 1. Volume change depending on wastewater composition in influent

The accuracy of the laboratory measurements, which are then used as initial parameters for the technological design of the treatment plants, has an impact not only on the volumes of the facilities but also on the expected operating costs afterwards. The required amount of air for oxidation of organic matter in wastewater can vary up to 20% between the lower and upper values of uncertainty interval, which will then have a significant impact on the WWTP's power consumption. Even at a later stage, when oxygen supply could be optimized depending on wastewater composition in influent, the installation of more powerful blowers or those with insufficient capacity would result in a significant inefficiency in the operation of the equipment.

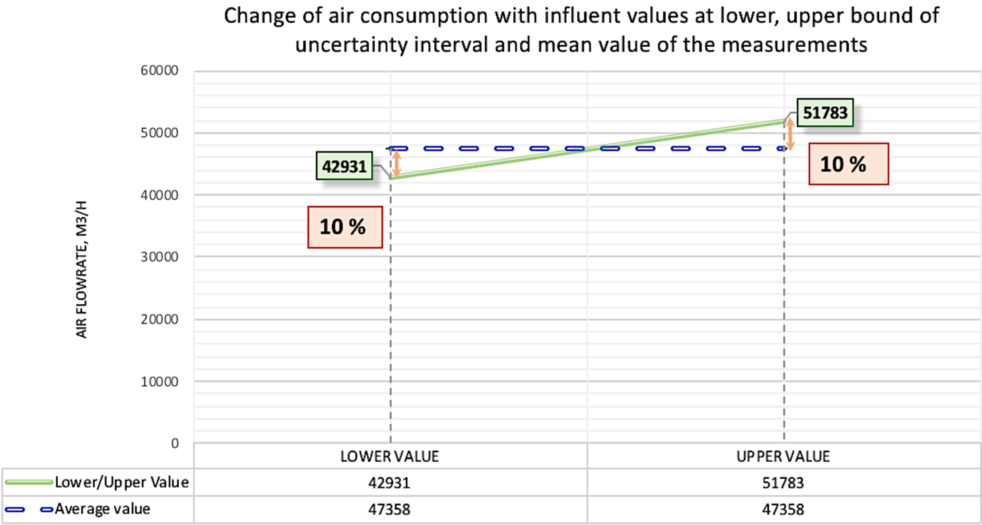

Figure 2. Oxygen consumption for nitrification

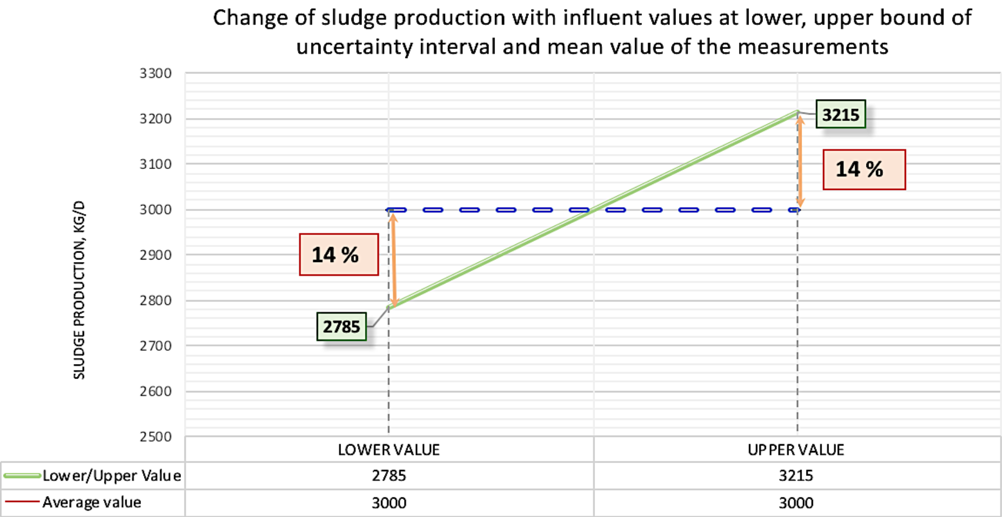

Figure 3. Change in the amount of excess active sludge calculated at different measurement values

As can be seen from Table. 3, besides the required amount of oxygen, the flow rate of excess active sludge also shows a significant dependence on the variation of wastewater composition used for equipment design. The deviation from its average value amounts to about 14% will then have a significant impact on the sizing of all facilities along the sludge line. In the first case, where initial values in the lower part of the uncertainty interval are used for calculations, the excess sludge flow rate is Q = 2785 m^3/d, while in the other case, at the upper part of the uncertainty interval, the excess sludge flow rate is Q = 3215 m^3/d (Fig. 3). This significant discrepancy in the dimensioning affects the capacity of all facilities afterwards and even their optimization due to the large inaccuracies in the main dimensional parameters; their exploitation will be extremely inefficient.

4. Conclusion

The precise design of wastewater treatment plant technological scheme is of great importance in determining initial capital and operating costs for treatment. A major problem in the preparation of investment projects is the overdesign of individual technological steps, which in turn leads to inefficient operation and high operating costs. The reason for this is the lack of sufficiently reliable data on wastewater quality, as a result of which, in many cases, the calculations are done using national standards and literature data. The reliability of the results is of great importance in conducting laboratory analyses. The accuracy of laboratory measurements for wastewater quality, which are then used as start-up parameters, have an impact on WWTP design, and these variations being most significant in determining the tank volumes (8%), air consumption (10%) and the amount of excess active sludge (14%).

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ВЛИЯНИЕ НА КАЧЕСТВОТО НА ДАННИТЕ ВЪРХУ ОРАЗМЕРЯВАНЕТО НА ПРЕЧИСТВАТЕЛНИ СТАНЦИИ ЗА ОТПАДЪЧНИ ВОДИ

М. Колева[1], Т. Венелинов[2]

Ключови думи: *оразмеряване, ПСОВ, БПК$_5$, супендирани вещества, общ азот, общ фосфор, неопределеност на измерването, надежност на данните*

РЕЗЮМЕ

Всекидневно в различни лаборатории се правят огромен брой измервания на най-различни параметри за качествата на водите с цел да осигурят информация под формата на резултати за различни видове води. Обемът на тази информация зависи от по-нататъшното използване на резултатите, като обикновено те се представят с придружаващата я неопределеност. Това означава, че не само средната, а всяка стойност в интервала на неопределеността може да е истинската стойност. За оразмеряването на ПСОВ са използвани реални данни за съдържанието на БПК$_5$, супендирани вещества, общ азот и общ фосфор във водата. При сравнителния анализ са използвани резултатите от измерването и приписаната им неопределеност, като са взети средната стойност на измерването, стойността на показателя в долната и в горната граница на доверителния интервал на тази средна стойност.

В настоящата статия е представен ефектът на лабораторните измервания на отпадъчните води, данните за чийто състав след това се използват като основа за всички оразмерителни процедури по широко използваната у нас немска методика ATV A-131 с цел определянето на технологичните и конструктивни параметри на пречиствателните станции. Направеният сравнителен анализ между средната, долната и горната стойност на доверителния интервал, чието изменение зависи от неопределеността на измерванията, показва кои основни технологични параметри на биологичното стъпало се влияят най-съществено и какви отклонения дават при съответния състав на отпадъчните води.

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