APPLICATION OF THE CORRELATION METHOD FOR ESTIMATION OF THE BIOMETHANATION OF SLUDGE IN MUNICIPAL WASTEWATER TREATMENT PLANTS

Rayno Popov, Assistant professor, University of Mining and Geology, Sofia, BULGARIA
Anatoliy Angelov, Assoc. Prof., PhD, University of Mining and Geology, Sofia, BULGARIA

ABSTRACT: Studies conducted in the biogas installation of the Sofia wastewater treatment plant for waste water have proven the feasibility of the correlation analysis to establish correlations with regard to different target functions and technological parameters of the process biomethanation. Data has been obtained about the input and output indicators of sludge at different values of the technological parameters. Using the correlation method, the direction of the relationship (positive or negative) has been defined, the dependence (forward or reverse) has been determined and the values of correlation coefficients have been established. Two target functions have been selected, namely production of biogas and degree of mineralization, and the dependence of the remaining indicators has been established with regard to these two target parameters. The results confirm the already known from international experience factors which influence the anaerobic digestion process. This gives reason to believe that the correlation analysis can be successfully used for studies of processes in plants producing biogas from liquid organic sludge.

1. INTRODUCTION

This study was based on results of monitoring conducted in 2015 in the installation of biogas in the municipal water treatment plant in Sofia. In this production by methanisation of sludge produced in waste water treatment, to be achieved two main objectives: first – obtaining the maximum amount of biogas; second – to obtain maximum stabilized compost for use as a soil improver. These objectives are contradictory (often mutually exclusive), which requires the search for balance between the two trends at various operating conditions [1]. Notably, so far satisfactory solution is not found. In engineering practice, the analysis complex systems (such as biogas installations) include a set number of variables that characterize the system at any given time. According to current scientific concepts, the degradation of the organic substances and the yield of biogas depend on factors such as temperature, time of hydraulic retention substrate concentration al., which must be controlled constantly. Continuous operation requires rapid analysis of results and timely adjustment process. In the currently used methods to control multiple parameters of the substrate, pH, alkalinity, volatile fatty acids, suspended solids, organic part of the suspended solid etc [2]. Analyzing multiple data takes considerable time and measures to regulate the process often undertaken late.

Therefore the definition of a small number of indicators describing sufficiently state of the system would cut response time in process deviating from normal conditions.

The aim of this study was: 1.Using correlation analysis to determine the degree of correlation between the studied parameters of sludge and target functions (biogas yield and degree of mineralization of the substrate); 2.Based on the quantified levels of dependency to identify the parameters that characterize most complete state of anaerobic fermentation; 3.To identify measures to intensify the process in methanisation of organic sludge from waste water into the WWTP.

2. MATERIALS AND METHODS

The term stochastic correlation means (dysfunctional, probabilistic) relationship between two random variables **x** and **y**. If the correlation is positive, with a rising value of a random variable, the value of the other also tends to rise if the correlation is negative – the second value decreases. Only the absolute value of the correlation, however, can't judge the interdependence between the two figures, as the degree of correlation depends on the dispersion of values. The correlation scale can be normalized by dividing the covariance of the product of the mean-square deviation (square root of variances). This results is the so-called correlation coefficient of Pearson:

$$\mathbf{R(x,y)=Cov(x,y)/[\sigma(x).\sigma(y)]}$$, respectively:

$$\mathbf{Cov(x,y)=R(x,y).\sigma(x).\sigma(y)}$$

(σ it is secondary square deviation). The values of **R** are always in the range **[-1,+1**]. Random variables having zero covariance (**R=0**) are uncorrelated. Independent random variables are always uncorrelated, but the opposite is not always true. In strictly linear relationship between the variables, **R=±1**. At the indicated figure it can be seen that the values of **R** are close to **± 1**, so the correlation is stronger [4,6,7].

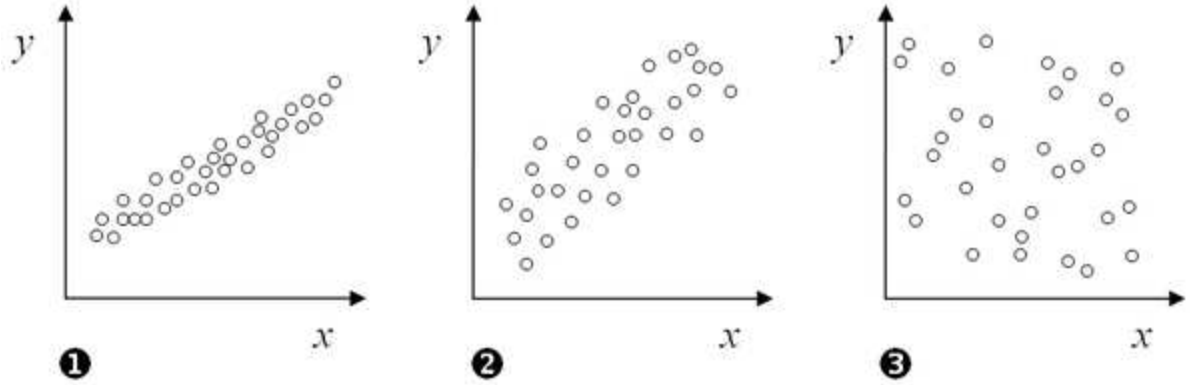

Figure.1. 1-strong correlation; 2-low correlation; 3-there is no correlation between the variables.

Table 1. Value of correlation coefficient of Pearson [3].

Value of R	Strength (degree) dependence
0	depending missing
До 0,3	low
0,3÷0,5	medium-strong
0,5÷0,7	significant
0,7÷0,9	strong
Над 0,9	very big
±1	functional

3. RESULTS AND DISCUSSION

This study was conducted in 2015 in the plant to produce biogas from organic sludge of Wastewater treatment plants-Kubratovo. The plant has been in operation since 1985, producing an average of 32,370 m^3 of biogas per day (data since 2015). The gas was extracted in four mesophilic methane tank with a total volume of 28,000 m^3, intended for the treatment of primary, redundant active and mixed sludge. After purification and compression, biogas was utilized in CHP, at the same time generate about 3,2 MW and 3,3 MW electric heat. Rotten sludge was dewatered and it used to improve soil in Sofia field.

To analyze the collected data was selected correlation method. The correlation scale is ordinal – categorizes variables so that they were marked qualitative differences between the various categories and ranking categories meaningful signs. The results obtained were sorted tabular, which is the first condition for applying the method. Is satisfied the second condition of correlation analysis – data for all pairs of variables in which each value of one variable value corresponds to the second. The information obtained can be classified as follows: data input (raw) sludge data for output (rotten) sediment data extracted biogas and data about the parameters of bioreactors [5].

Accordingly, the main objectives in sludge treatment were selected two target functions - biogas ($\mathbf{Q_{BG}}$, m^3) and degree of mineralization of the substrate (**S**, %). Throughout 2015, daily are determined technological parameters: pH, volatile fatty acids, humidity raw sludge organic content in the raw sludge volume of the loaded material, quantity of loaded solids and organic load of bioreactors. Received monthly averages are presented in Table 2.

Below was displayed correlation between target functions and calculated values of the measured parameters. Table № 3 presents the results of correlation analysis relating to the establishment of correlation coefficients – $\mathbf{R_1}$ and $\mathbf{R_2}$. The values of coefficient $\mathbf{R_1}$ reflects on the correlation between $\mathbf{Q_{BG}}$ and each of the process parameters. The values of the ratio $\mathbf{R_2}$, reflecting the correlation between **S** and each parameter. Through the coefficient of determination (a determination) $\mathbf{R^2}$ was presented dependence between variables as a percentage of variation between them. Coefficient $\mathbf{R^2}$ shows what part of changes in factors will lead to changes in the resultant value. The interdependence between the variables can be measured through the coefficient of uncertainty $\mathbf{K^2}$, which adds to the coefficient of determination unit ($\mathbf{R^2+K^2=1}$).

In the interpretation of the correlation analysis was described in the connection direction (positive or negative) defined dependence (forward or reverse) and found to how the values of the determination coefficient is close to 100 %.

3. CONCLUSION

1.The objective function „produced biogas", the following dependencies of the studied parameters:

- Great – from dry organic matter in the raw sludge;
- Substantial – the amount of the charged raw sediment;
- Substantial – the concentration of volatile fatty acid in the crude precipitate;
- Moderate – from temperature fluctuations;
- Moderate – the humidity of raw sludge;
- Weak or absent – for other indicators.

Table 2. Values of technological parameters

Month	pH	Volatile fatty acids, gCH_3COOH/l	Humidity of raw sludge, %	Organic substance in the raw sludge, %	Volume on loaded sludge, m^3	Loaded dry substance, t	Tempe-rature, °C	Loaded organic substance, t/мес.	Organic load, $kg/(m^3.d)$	S, %	Q_{BG}, m^3/мес.
1	**6,41**	**10,67**	**95,9**	**73,1**	**56520**	**2317**	**35,9**	**1693,5**	**1,95**	**50,1**	**992280**
2	**6,46**	**8,09**	**95,8**	**66,8**	**48340**	**2030**	**34,8**	**1357,4**	**1,73**	**35,2**	**842740**
3	**6,52**	**8,96**	**95,2**	**65,3**	**55760**	**2676**	**32,9**	**1748**	**2,01**	**37,7**	**923600**
4	**6,57**	**6,96**	**95,5**	**62,1**	**53280**	**2184**	**33,3**	**1356,6**	**1,62**	**32,2**	**795720**
5	**6,57**	**10,4**	**95,9**	**64,4**	**55800**	**2511**	**38,2**	**1616,1**	**1,86**	**38,5**	**1020500**
6	**6,49**	**11,82**	**96,3**	**67,8**	**53760**	**1989**	**40,1**	**1348**	**1,6**	**29,7**	**1009990**
7	**6,09**	**13,96**	**95,9**	**71,0**	**54560**	**2237**	**41,0**	**1588,7**	**1,83**	**38,2**	**1034740**
8	**6,11**	**11,74**	**96,1**	**69,5**	**54570**	**2128**	**41,1**	**1478,8**	**1,7**	**29,5**	**986806**
9	**6,00**	**12,22**	**96,2**	**70,2**	**52800**	**2006**	**40,6**	**1408,5**	**1,68**	**30**	**936372**
10	**6,10**	**10,07**	**96,5**	**69,5**	**53440**	**1870**	**38,1**	**1299,9**	**1,5**	**25,3**	**977120**
11	**6,29**	**11,73**	**96,0**	**72,7**	**53400**	**2136**	**37,5**	**1552,9**	**1,85**	**30,8**	**1131410**
12	**6,11**	**9,59**	**96,2**	**74,0**	**56640**	**2152**	**35,5**	**1592,7**	**1,83**	**29,8**	**1164600**
Values of correlation coefficient of Pearson											
R_1	**-0,412**	**0,559**	**0,475**	**0,741**	**0,54**	**0,001**	**0,356**	**0,401**	**0,296**	**-0,086**	**-**
R_2	**0,431**	**0,001**	**-0,429**	**0,039**	**0,317**	**0,698**	**-0,269**	**0,679**	**0,726**	**-**	**-0,086**
R_1^2	**0,170**	**0,312**	**0,226**	**0,549**	**0,292**	**0,000**	**0,127**	**0,161**	**0,088**	**0,007**	**-**
R_2^2	**0,186**	**0,0001**	**0,184**	**0,002**	**0,100**	**0,487**	**0,072**	**0,461**	**0,527**	**-**	**0,007**

2. The objective function „mineralization", the following dependencies of the studied parameters:
- Great – from the organic load of the reactors;
- Substantial – the amount of loaded solids;
- Substantial – the amount of the charged organic substance;
- Moderate – of the pH of the medium;
- Moderate – the volume of the charged residue;
- Weak or absent – for other indicators.

3. For optimal ratio between the two trends ($\mathbf{Q_{BG}}$ and **S**) in the fact are following dependencies of the studied parameters:
- Significant – charged from organic matter;
- Significant – from organic load;
- Moderate – the volume of the charged residue;
- Moderate – the content of organic substances in the raw sludge;
- Moderate – of dry matter loaded into the reactor;
- Weak or lacking – than other indicators.

4. The effect of the studied parameters is not unique and depends on the goals. For example, the process could be intensified without increasing the amount of inserted raw material, through:
- Increasing the organic substance in sediments (when the priority task is extracting large amounts of biogas);
- Adding suitable enzyme preparations (where the aim is a high degree of stabilization of compost).

4.REFERENCES

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