Calculation of the concentration of organic matter in anaerobic ponds using graphs

Facundo Cortes-Martínez, Francisco Luis Camporredondo-Reyes, Arturo Tadeo Espinoza-Fraire, Rosa Angélica Zamora Ríos

***Abstract*- A graphic criterion is presented to calculate the concentration of organic matter in anaerobic ponds, considering the design criteria established by the Comisión Nacional del Agua in Mexico. A graph was generated where temperatures from 15 to 20°C., were considered, and then an example of application was carried out. It was observed that the values calculated with graphs are similar to those indicated with the traditional design method.**

***Index terms*- anaerobic pond, graphic design, organic matter**

I. INTRODUCTION

Stabilization ponds are used for wastewater treatment, they mainly remove organic matter also known as Biochemical Oxygen Demand (BOD) and Fecal Coliforms. They require large areas of land [7]. Currently, there are three—stabilization ponds: anaerobic, facultative and maturation. In this work, only anaerobic ponds are analyzed; they operate in the absence of dissolved oxygen and stagnation times are reduced. An important characteristic is that they must operate above 15°C, and the maximum suggested depth is 5 meters [9]. This document aims to determine a graph for the calculation of organic matter in anaerobic ponds, considering the official design criteria in Mexico.

II. BACKGROUND INFORMATION

Anaerobic ponds are natural wastewater treatment systems commonly used in small communities due to their low construction and operating costs. One of the factors that most influences their efficiency is the microbial growth caused by the climate of the region [1].

These ponds are more efficient in the removal of organic matter than facultative ponds. The design of treatment systems with ponds is like a tailor-made suit, i.e., depending on the flow and concentration of pollutants [2].

Facundo Cortes-Martinez, Faculty of Engineering, Science and Architecture of Durango State Juarez University, (FICA-UJED). Gómez Palacio, Durango México. (e-mail: fcortes@ujed.mx).

Francisco Luis Camporredondo-Reyes, Faculty of Engineering, Science and Architecture of Durango State Juarez University, (FICA-UJED). Gómez Palacio, Durango México.

Arturo Tadeo Espinoza Fraire, Faculty of Engineering, Science and Architecture of Durango State Juarez University, (FICA-UJED). Gómez Palacio, Durango México.

Rosa Angélica Zamora Ríos Profesora investigadora de la Facultad de Ciencias Exactas de la Universidad Juárez del Estado de Durango México.

They are designed by fixing an organic load per unit volume or through empirical expressions. In 1963, Vincent proposed the following empirical expression under conditions of complete mixing and water temperature of 20°C:

$$Se = \frac{Sa}{(\frac{Se}{Sa})^n * K * PR + 1}$$

n= 4,8
K=6,0
Sa y Se= BOD in influent and effluent respectively

The investigation on the performance of a wastewater treatment plant located in Iracema, Brazil by means of a bathymetric study of facultative and anaerobic ponds monitored the influent and effluent in three different climatic seasons for a period of 3 months each. As a result, they obtained sludge accumulations of 1.3% and 6.5% of the volume of the ponds. The average BOD removal was 73.6% and the number of fecal coliforms in the effluent was 9.55*106/100 ml [6].

III. MATERIALS AND METHODS

For the design of the anaerobic ponds, we used the calculation criterion applied by the Comisión Nacional del Agua [3]. Although this criterion considers 17 mathematical expressions, only the equations involved in the elaboration of the graph for the determination of organic matter will be stated.

A. Design criteria for anaerobic ponds

BOD_5 removed

$$\% BODremoved = 2T + 20 \quad (1)$$

$$BOD_e = (100 - \% BOD_{removed})BOD_i \quad (2)$$

B. Graph for BOD calculation at anaerobic pond outflow

To obtain the BOD graphically, the two independent variables must be taken: BODi and temperature. For this, the expression (1) is substituted in the formula (2) of the methodology, and the equation (3) is obtained.

$$BODe = BODi\left[1 - \frac{2T+20}{100}\right] \quad (3)$$

Table 1 shows the results of expression (3) for each of the conditions of temperature and BODi in the influent.

Table 1. Temperatures and organic matter in the influent from 15 to 20 °C.

Temp. DBOi	15 DBOe	16 DBOe	17 DBOe	18 DBOe	19 DBOe	20 DBOe
100	50	48	46	44	42	40
105	52.5	50.4	48.3	46.2	44.1	42
110	55	52.8	50.6	48.4	46.2	44
115	57.5	55.2	52.9	50.6	48.3	46
120	60	57.6	55.2	52.8	50.4	48
125	62.5	60	57.5	55	52.5	50
130	65	62.4	59.8	57.2	54.6	52
135	67.5	64.8	62.1	59.4	56.7	54
140	70	67.2	64.4	61.6	58.8	56
145	72.5	69.6	66.7	63.8	60.9	58
150	75	72	69	66	63	60
155	77.5	74.4	71.3	68.2	65.1	62

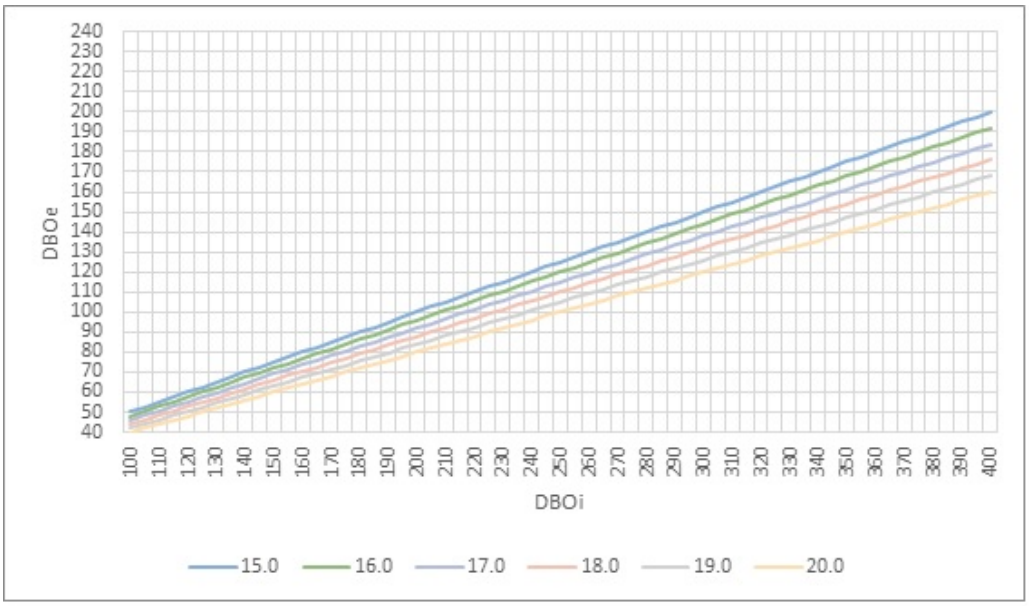

Figure 1. Curves corresponding to equation (3) for temperatures between 15 and 20 degrees Celsius in the elimination of organic matter.

Fig. 1 shows graphically Table 1 for temperature ranges from 15 to 20ºC.

IV. RESULTS AND DISCUSSION

With the following data to design an anaerobic pond: Flow Q = 220 m3/d., BOD at the pond outlet = 320 mg/l., Average temperature = 15 °C.

A. Organic load

$$\frac{Q_i DBO_i}{1000} = 70.40\ kg/day \quad (4)$$

B. Design volumetric load

$$\lambda_v = 20(T) - 100 = 200 \frac{gBOD5}{m^3} * day \quad (5)$$

C. BOD removal

$$\%BOD_{REMOVED} = 50\% \quad (6)$$

D. Pond volume

$$\frac{L_i Q_i}{\lambda_v} = 352\ m^3 \quad (7)$$

E. Anaerobic pond area

$$\frac{V_a}{Z} = 88\ m^2 \quad (8)$$

F. Hydraulic retention time

$$O_a = \frac{V_a}{Q_i} = 1.60\ days \quad (9)$$

G. BOD5 concentration

$$BOD_c = (100 - \%BOD_{removed})BOD_i = 160\ mg/L \quad (10)$$

The concentration of organic matter in the influent is located on the X axis, then intercepted on the curve with a temperature of 15 °C. The line is then plotted to the Y-axis

to obtain the BOD in the effluent. The result is 160 mg/l, this result is shown in Fig. 2.

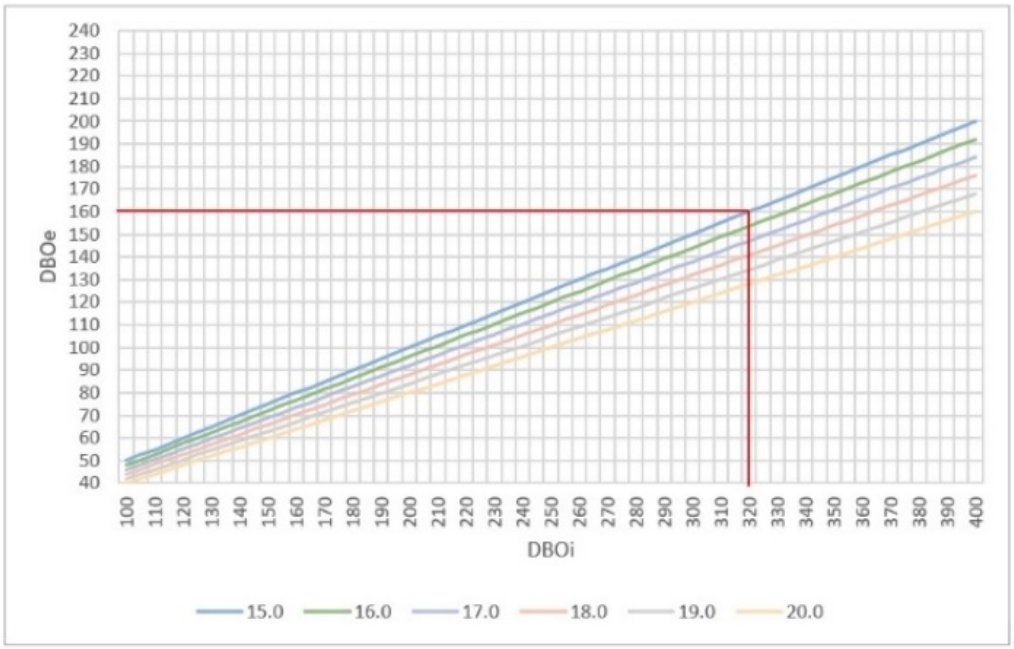

Figure 2. Example of application to determine BOD in anaerobic pond effluent at temperatures of 15 to 20 degrees Celsius.

V. CONCLUSIONS

According to the proposed objective, a graph was generated for the calculation of the concentration of organic matter, the results compared with the traditional criterion show similar numbers. It is recommended to use this criterion to verify the results of the analytical method. A characteristic of the use of these graphics is the ease and speed of calculation. In the bibliographic search, no articles were found for the calculation of organic matter with the criteria presented in this manuscript.

REFERENCES

[1] Brito-Espino, S., Ramos-Martín, A., Pérez-Báez, S. O., Mendieta-Pino, C., & Leon-Zerpa, F. (2021). A Framework Based on Finite Element Method (FEM) for Modelling and Assessing the Affection of the Local Thermal Weather Factors on the Performance of Anaerobic Lagoons for the Natural Treatment of Swine Wastewater. Water, 13(7), 882. MDPI AG. Retrieved from http://dx.doi.org/10.3390/w13070882

[2] Chavez Jordan, J. F. (2022). Determinación de la efectividad entre los métodos de Lagunas de Estabilización aerobias y anaerobias para la reducción de Materia Orgánica.

[3] Conagua. 2007. Manual de diseño de agua potable, alcantarillado y saneamiento. Paquetes tecnológicos para el tratamiento de excretas y aguas residuales en comunidades rurales. Comisión Nacional del Agua, Instituto Mexicano de Tecnología del Agua. Jiutepec, México. 188 p.

[4] Cubillos Z., A. (2011). Estado del Arte en el Diseño de Lagunas de Potabilización. INGENIERÍA Y COMPETITIVIDAD, 3(2), 80–91. https://doi.org/10.25100/iyc.v3i2.2331

[5] Kaya, D.; Dilek, F. B. & Gökcay, C. F. 2007. Reuse of lagoon effluents in agricultura by post-treatment in a step feed dual treatment process. Desalination. 215(1-3): 29-36. DOI: 10.1016/j.desal.2006.11.013

[6] Matsumoto, Tsunao, & Sánchez Ortiz, Iván Andrés. (2011). DESEMPEÑO DE UNA LAGUNA ANAEROBIA CON BAFLE DIVISOR SEGUIDA DE UNA LAGUNA FACULTATIVA, POSIBLE AFECTACIÓN DE LA SALUD PÚBLICA. Universidad y Salud, 13(1), 46-60. Retrieved July 12, 2023, from http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0124-71072011000100005&lng=en&tlng=es.

[7] Metcalf Eddy Inc. 1991. Wastewater Engineering. Treatment Disposal, reuse. New York, USA: McGraw-Hill. 729-744 pp.

[8] Naddafi, K.; Hassanvand, A. S.; Dehghanifard, E.; Faezi-Razi, D.; Mostofi, S.; Kasaee, N.; Nabizadeh, R. & Heidari, M. 2009. Performance evaluation of wastewater stabilization ponds in Arak-Iran. Journal of Environmental Health Science & Engineering. 6(1): 41-46.

[9] Rolim, M. S. 2000. Sistemas de lagunas de estabilización, cómo utilizar aguas residuales tratadas en sistemas de regadío. Santa Fe de Bogotá, Colombia: Nomos. 370 p.

Facundo Cortes-Martinez Doctor in Engineering, He is currently a professor-researcher at the Faculty of Engineering Sciences and Architecture of the Juarez University of the State of Durango, author of articles and books on sanitation, optimization and mathematical model

Francisco Luis Camporredondo-Reyes Architect, Master of Science and PhD student in Architecture and Urbanism, assigned to the Faculty of Engineering, Science and Architecture of the Juárez University of the State of Durango (UJED) in Gomez Palacio, Durango, Mexico; he was a senior staff member at the college and is now a full-time undergraduate and graduate professor. He has written articles on urban studies, mainly on territorial phenomena and on issues of built heritage, with emphasis on the Laguna Metropolitan Area, Mexico.

Arturo Tadeo Espinoza-Fraire obtained the BSc degree in electronic engineering from the Superior Technological Institute of Lerdo, Cd. Lerdo Durango Mexico, in 2007, and the MSc and the Ph.D. in electrical engineering from the Technological Institute of La Laguna, Torreon Coahuila Mexico, in 2011 and 2015 respectively. Since January 2017, is in the Faculty of Engineering, Science, and Architecture of the University Juarez of the state of Durango, Mexico as research professor, his interests are in linear and nonlinear control theory, navigation and control of UAVs and embedded systems.

Rosa Angélica Zamora Ríos Research professor at the Faculty of Exact Sciences of the Juárez University of the State of Durango.