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OPTIMIZATION OF THE BIOLOGICAL TREATMENT PROCESS OF RURAL WASTEWATER BY APPLICATION OF SURFACE METHOD

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CMAS bioreactor, biological treatment, optimization, surface method, BOD.

SYNOPSIS

In the frames of this work, an optimization response of the outlet BOD has been studied in a biological treatment process of a real treatment plant in the western region of Republic Macedonia, which is based on the Completely Mixed Activated Sludge model. The process of optimization has been conducted through application of 3D surface model and obtained results are presented in graphical and analytical form. Result's processing, as well as the process of optimization, were performed by "Statgraphics Centurion" software package.

INTRODUCTION

Communal and industrial wastewaters, due to numerous reasons including health, economy etc., are subjected to a treatment process before they are released to surface waters. Which methods are applied in a wastewater treatment process depends on the extent of the pollution, the type of the pollution (organic, inorganic, toxic) and the further use of the treated effluent. Basically, the treatment process includes mechanical, physical, chemical and biochemical methods incorporated in the basic scheme that includes primary, secondary (biological) and tertiary treatment stadiums (Bjerre et al., 1995).

In order to eliminate the dissolved and colloidal dispersed organic matter, a secondary treatment of a wastewater must be applied, which is a biochemical process. In the presence of sufficient amounts of dissolved oxygen, and subjected to microorganisms' biochemical processes, the organic matter is mineralized to carbon dioxide and water, while less soluble organic compounds are being flocculated (Matsche & Nikolavcic, 2007).

MATERIALS AND METHODS

The wastewater treatment plant, located in the western region of Republic of Macedonia, includes a secondary (biological) treatment of the communal wastewater, conducted in a typical “suspended growth” system - Activated Sludge system, based on the CMAS (Completely Mixed Activated Sludge) model, as shown in figure 1:

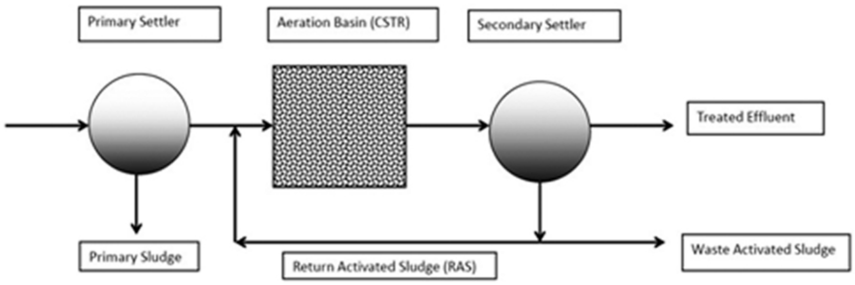

Figure 1: Flow scheme of Activated Sludge system wastewater treatment plant.

Activated sludge plant involves:

1. wastewater aeration in the presence of a microbial suspension,
2. solid-liquid separation following aeration,
3. discharge of clarified effluent,
4. wasting of excess biomass, and
5. return of remaining biomass to the aeration tank.

In activated sludge process wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter (Haider, 2000). Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. In activated sludge systems, the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

The optimization of the process parameters in the rural wastewater treatment was performed by application of a 3D surface method through “Statgraphics Centurion” software. The usage of this software provides monitoring of interactions between the process parameters and the process dynamics (Dupont & Sinkjær, 1994). Obtained 3D graphical presentations provide a solid visual clue of the entire process of optimization (Kuvendziev, 2009).

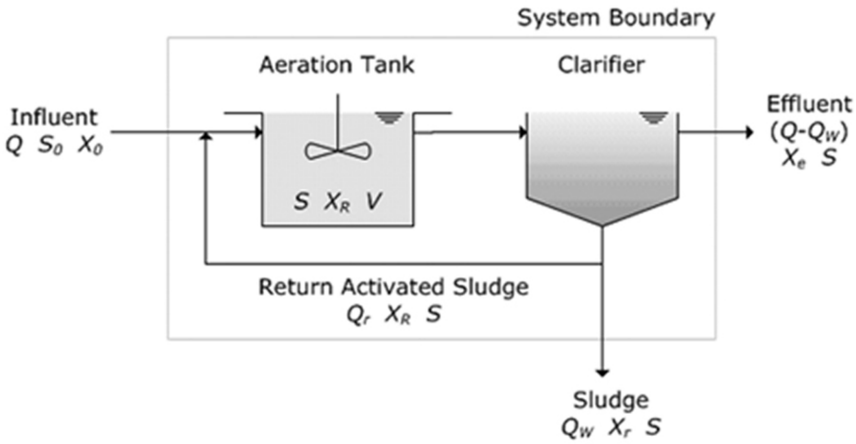

Figure 2: System boundary of the biological treatment stadium.

RESULTS AND DISCUSSION

The process of optimization conducted through "Statgraphics Centurion" software was conducted based on the influence of the main process parameters and their interactions on the outlet value of BOD, which defines the quality of the effluent and the efficiency of the biological treatment. The process of optimization is presented in the following figures:

Optimization process 1: optimization response of BOD as a function of temperature (T), flow rate (Q) and concentration of dissolved oxygen.

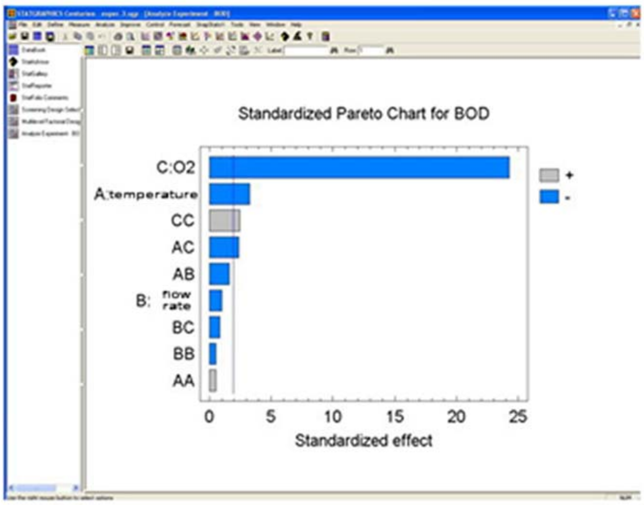

Figure 3: Statistic influence of the main process parameters and their interactions.

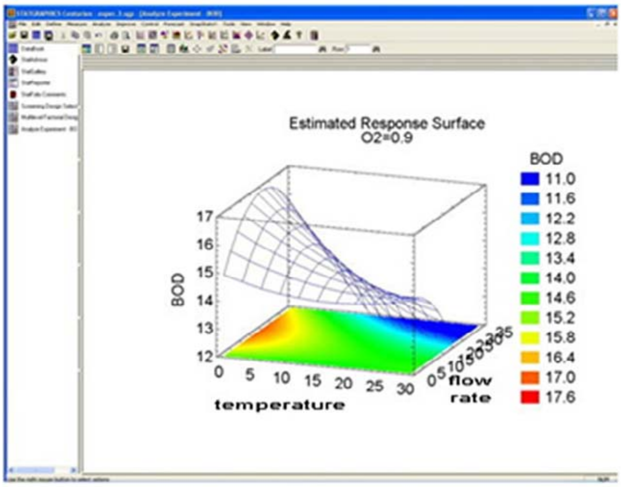

Figure 4: 3D optimization diagram of main effects at constant value of dissolved oxygen concentration (at 0.9 mg/l) and variable temperature (°C) and effluent flow rate (m^3/d).

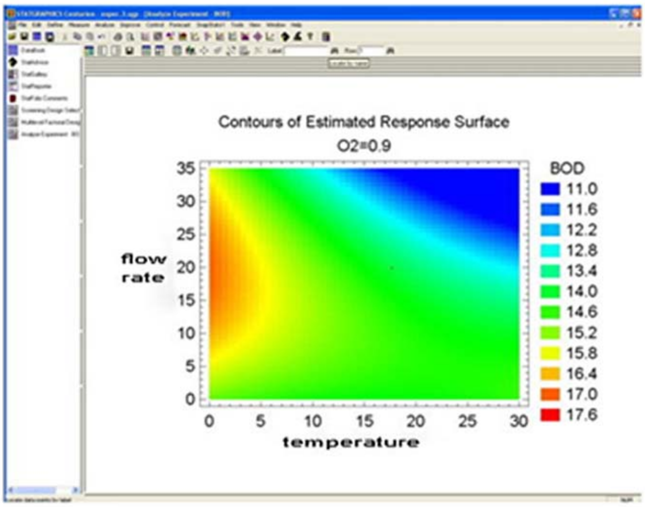

Figure 5: Optimization diagram of main effects at constant value of dissolved oxygen concentration (at 0.9 mg/l) and variable temperature (°C) and effluent flow rate (m^3/d).

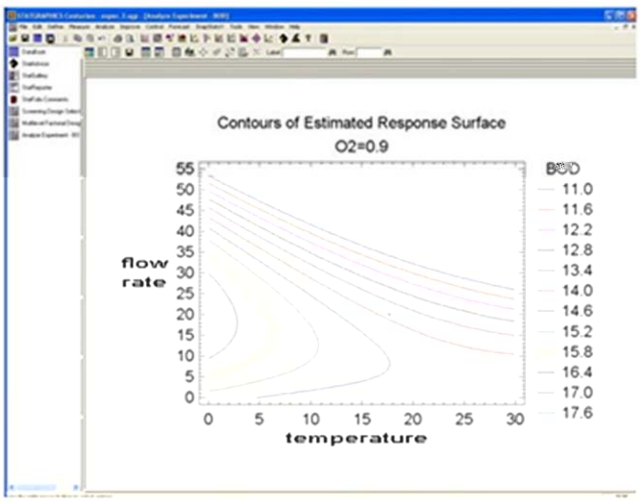

Figure 6: Optimization contours of the influence of process variables on BOD (extended frame in relation to flow rate)

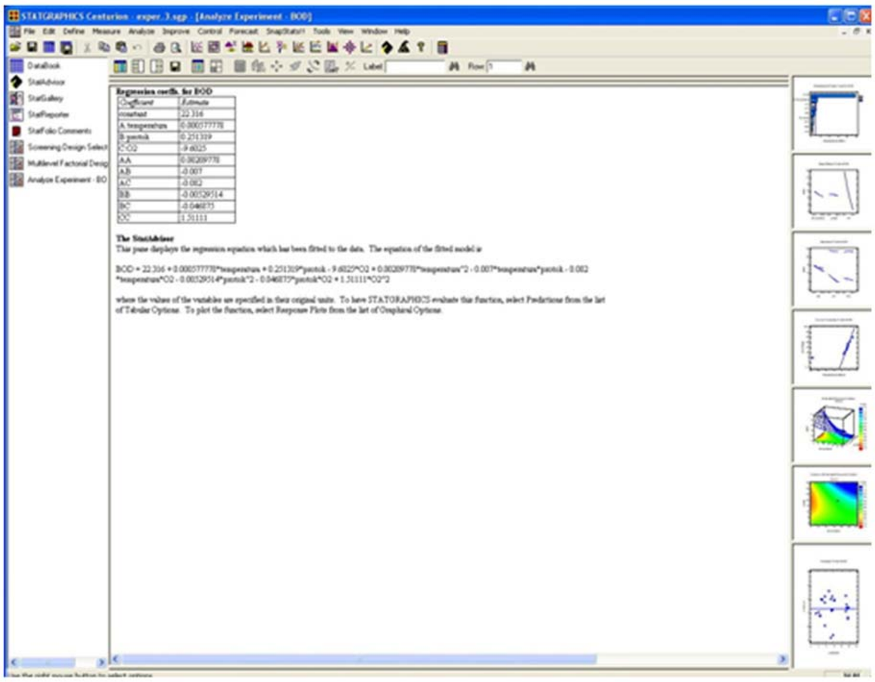

Figure 7: Final model equation of the functional dependence of the BOD from the process parameters - flow rate, temperature and dissolved oxygen concentration and their interaction.

According to the results of the process of optimization presented by the software package, a final model equation of the BOD dependence is as given (Fig.7):

$$BOD = 22.316 + 0.000577778 \cdot temperature + 0.251319 \cdot flowrate - 9.6025 \cdot dissOxygen + 0.00209778 \cdot temperature^2 - 0.007 \cdot temperature \cdot flowrate - 0.082 \cdot temperature \cdot dissOxygen - 0.00529514 \cdot flowrate^2 - 0.046875 \cdot flowrate \cdot dissOxygen + 1.51111 \cdot dissOxxygen^2$$

In this case of optimization, the response value of BOD was examined as a function of the process parameters - flow rate, temperature and concentration of dissolved oxygen (Fig.3, 4, 5 and 6). It is evident that BOD, as a main process parameter that defines the water pollution degree, is directly dependent on the concentration of dissolved oxygen. The concentration of dissolved oxygen itself is in a direct correlation to the operating temperature as the oxygen's solubility is in a thermodynamic and kinetic dependence of the temperature and pressure. The entire process, observed as a complex heterogeneous system, depends on fluid's retention time in the bioreactor. Therefore, the first step of optimization was to determine the optimal minimum through the surface method of the outlet value of BOD as a function of before mentioned main process variables.

Optimization process 2: optimization response of BOD as a function of temperature (T), flow rate (Q) and pH value:

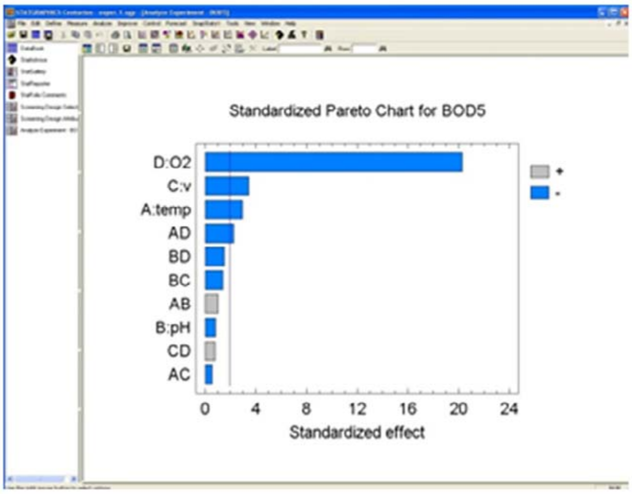

Figure 8: Statistic influence of the main process parameters and their interactions.

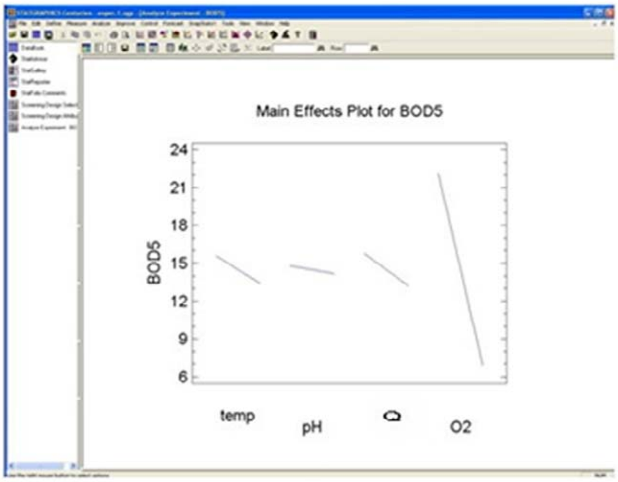

Figure 9: Diagram of the main effects of the process variables.

According to the results of the process of optimization presented by the software package, a final model equation of the BOD dependence is as given (Fig.12):

$$BOD = 21.2586 - 0.379056 \cdot T + 0.421667 \cdot pH + 0.360556 \cdot Q - 2.36417 \cdot dissOxygen + 0.0516667 \cdot T \cdot pH - 0.00377778 \cdot T \cdot Q - 0.111667 \cdot T \cdot dissOxygen - 0.07 \cdot pH \cdot dissOxygen - 0.575 \cdot pH \cdot dissOxygen + 0.04 \cdot Q \cdot dissOxy$$

In this case of optimization (Fig.8, 9, 10, 11), by analyzing the Pareto chart, it is evident that the concentration of dissolved oxygen has the highest influence on the outlet BOD. The dissolved oxygen concentration is directly affected by the process of aeration, the operating temperature and the influent' flow rate. The 3D optimization diagram clearly distinct, as a linear function, the zones of optimal minimum and optimal maximum, when examining the influence of the operating flow rate and dissolved oxygen concentration at constant pH value and constant operating temperature.

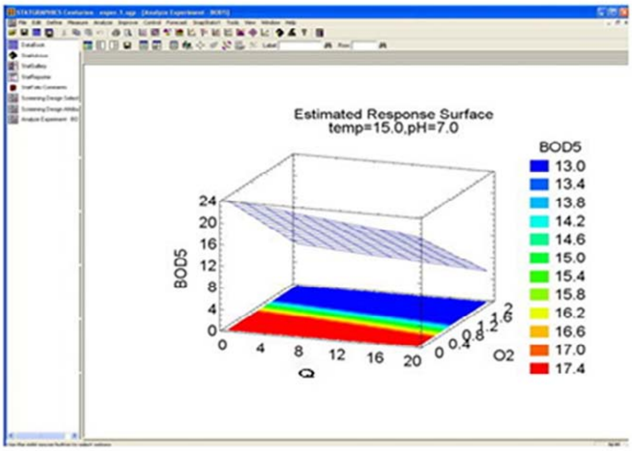

Figure 10: 3D optimization diagram of main effects at constant temperature (15 °C) and pH value (7.0).

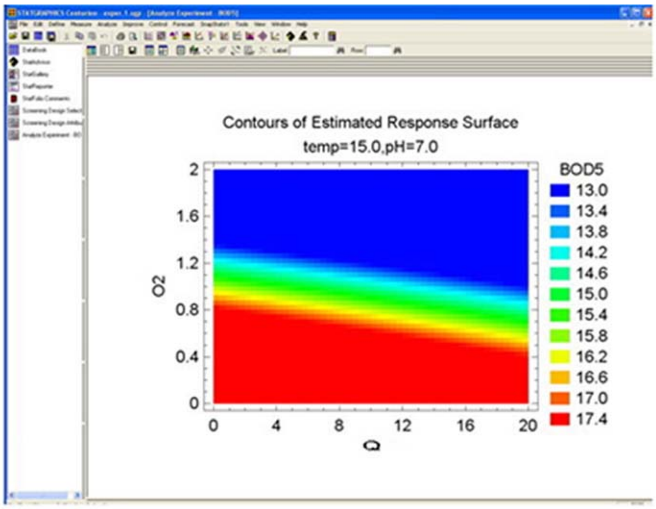

Figure 11: Optimization diagram of main effects at constant temperature (15 °C) and pH value (7.0).

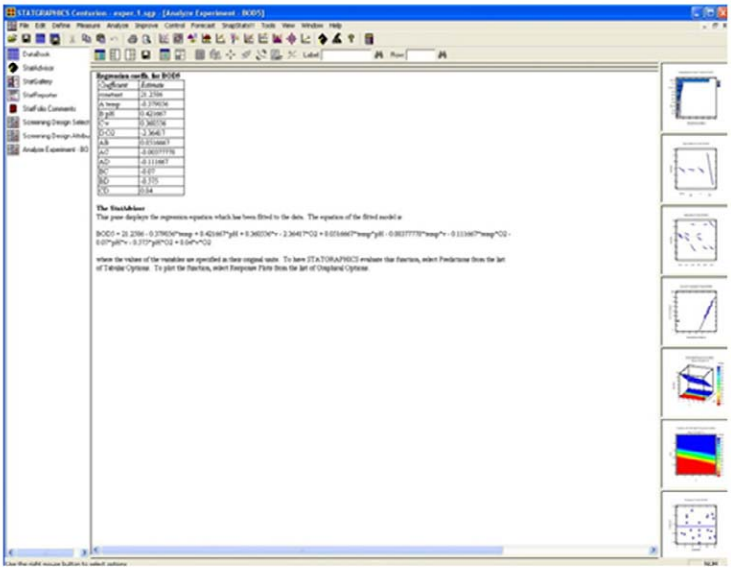

Figure 12: Final model equation of the functional dependence of the BOD from the process parameters - flow rate, temperature and pH value and their interaction.

CONCLUSION

According to presented results of the process of optimization and the analysis of the BOD response values, the following can be concluded:

- The comparative analysis of the characteristic inlet - outlet values of the monitored variables clearly indicates the high efficiency of the overall treatment of the rural wastewater;

- 3D optimization method has been successfully applied in order to determine the optimal operating areas (minimal outlet value of BOD);

- By analyzing the presented optimization diagrams of BOD response and the final model equation, it can be concluded that the process variables' interactions have negligible influence on the main parameter BOD compared to the influence of the process variable- dissolved oxygen concentration.

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