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ORIGINAL ARTICLE

Oxi-P GUI: A Graphical User Interface (GUI) for wastewater treatment process in oxidation pond

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ABSTRACT – The wastewater treatment process is aimed to reduce pollution to the appropriate level. An oxidation pond system can treat contaminants in wastewater. Oxidation ponds are use sunlight, bacteria, and algae to treat wastewater. This study developed an improved mathematical model and a graphical user interface (GUI), called oxi-P GUI to predict the wastewater treatment process in an oxidation pond. The correlation between dissolved oxygen (DO), chemical oxygen demand (COD), coliform bacteria, as well as concentrations of phototrophic bacteria (PSB) were examined. In MATLAB software, a revised model consisting of ordinary differential equations (ODEs) set of integrating the Monod equation was numerically solved utilising the fourth order Runge-Kutta method. The current model's root mean square error (RMSE) values were compared to the suggested model's RMSE values for model validation. The model offered a more accurate estimate than the existing model of changes in the amount of concentration in oxidation pond, which was necessary to produce acceptable water quality. A wastewater management personnel may use GUI to track water quality and determine the most effective wastewater treatment mechanism. Additionally, this user-friendly GUI will give a better understanding about the treatment process, especially to people with less programming skills.

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INTRODUCTION

Water of satisfactory quality is crucial, as every living creature on earth is dependent on it. Contaminated water can cause diseases in humans, which in the worst-case scenario can be fatal. Several methods of wastewater treatment were utilized to ensure high water quality. Oxidation ponds are popular because they have maintenance costs and low construction, which contribute to a substantial financial benefit over other accessible treatment options for small communities [1]. The oxidation ponds are wide, and shallow. They are used to treat wastewater by using sunlight, bacteria, and algae [2]. Algae assist to oxygen production through the process of photosynthesis [3]. Oxidation ponds are complex biological systems, which are mainly dependent on variables, and they are different between locations. These variables comprise temperature, wind speed, and any given combination of the variables [4]. The main goal of an oxidation pond is to degrade organic matter and contaminants in one of two instances: anaerobic (no oxygen) or aerobic (oxygen present) conditions [5]. Microorganisms are utilized to degrade inorganic and organic compounds and transform them to more compact forms, for instance, cell biomass, water, and carbon dioxide [5]. Pond systems are developed and appropriately maintained to promote the growth of anaerobic and aerobic bacteria, as well as green microalgae. Therefore, they can decompose the waterborne organic waste effectively and efficiently; hence, alleviate several issues linked with disposal and wastewater treatment [6].

Almost every real-world problem can be mathematically modelled. Computer modelling has potential to demonstrate whether therapies are effective for specific conditions. It is something which we can greatly rely on. Another possibility is to build multiple-stage treatment ponds or incorporate another treatment to ensure the most appropriate wastewater treatment management [7].

Safer operation and monitoring of the concentration in an oxidation pond can be accomplished by developing a model for predict the pond behavior based on quality parameters. In this study, a simulation tool called 'oxi-P GUI' was developed, which can be used to improve the performance prediction process. Specific vital parameters can be used to evaluate the oxidation pond efficiency. The parameters include dissolved oxygen (DO), chemical oxygen demand (COD), coliform bacteria, and phototrophic bacteria (PSB).

Some researchers have introduced the development of graphical user interface (GUI) to predict water quality for wastewater treatment process at wastewater treatment plants (WWTPs). In a past work by Mjalli et al. [8], a computer model that combined a trained artificial neural network (ANN) plant model to forecast the biological oxygen demand (BOD) concentration, and total suspended solids based on COD as the input parameter was developed. The basic knowledge of an actual wastewater treatment plant was acquired and then used as a process model by using an ANN black box modelling method. The study demonstrated that ANNs could capture plant activity characteristics accurately.

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The study was conducted in Doha West WWTP, and data were taken from the secondary treatment effluent (STE) stream outputs as well as contrasted with the crude sewage (CS) stream inputs.

In a study by Winkler et al. [9], a smoothed particle hydrodynamics activated sludge engine (SPHASE) software was presented. It is a freely available and self-developed tool to aid the operation and design of WWTPs. To comply with the high computational demand, a specially designed two-dimensional (2D) SPH (smoothed particle hydrodynamics) solver leverages graphic devices. Currently, attention is not given to GUI approaches towards a specific wastewater treatment process, such as the oxidation pond.

Existing mathematical models for oxidation ponds were successfully completed by Ockendon et al. [10]. However, the existing models require a modification to improve the quality and efficiency in predicting the dynamics of the species in oxidation pond. The reason of the existing model needs to be improved because the obtained outcomes fail to convey a good approximation of the necessary parameters. Therefore, this study used Monod equation to improve the mathematical model.

The goal of this research was to look at how wastewater pollutants react as they transit via an oxidation pond treatment system. In addition, the following were the objectives of this research. First, to formulate a modified mathematical model for wastewater treatment process in an oxidation pond. Second, to develop a GUI. Third, to determine the relation between the concentrations of PSB, coliform bacteria, COD, and DO. The novelty of this research are the improvement of the predictive model to predict the behaviour of some parameter for the wastewater treatment process in the oxidation pond and this research created the GUI application namely oxi-P GUI.

MATHEMATICAL MODELLING

The purpose developing oxi-P GUI was to have a predictive model for wastewater treatment process in oxidation ponds. It was to investigate the performance of oxidation ponds by applying a beneficial microorganism product, namely mPHO. The wastewater treatment quality was driven by DO, COD, PSB, and coliform bacteria.

According to Ockendon et al. [10], the oxidation pond has two main points at different positions. The first point is CP1 (influent), which is water that flows into the oxidation pond. This water is often referred to as raw and untreated wastewater, and it contains a variety of contaminants. The second point is CP2 (effluent), which is treated wastewater that comes out of the oxidation pond. This research aimed to assess the parameters of the oxidation pond concentration at the CP2 point to ensure that the water flowing into the river is pure and of high quality. The mPHO product was added at CP1 point. Experimental data from the CP2 point was contrasted to the improved model.

A mathematical concept was used to develop oxi-P GUI. The model was written utilizing ODEs that included the Monod equation. The Monod equation was utilised to accommodate for the oxidation pond's restricted resource requirements on COD. The model was then numerically solved utilizing the MATLAB software's inbuilt 4th order Runge-Kutta method. Furthermore, Ockendon et al. [10] constructed a model for all concentrations, which was adjusted for our study. The results of a modified model were then contrasted to the experimental data in [10] at the CP2 point.

The mathematical model representing the wastewater treatment process was formulated by using a set of ODEs Ockendon et al. [10], as shown below:

$$\frac{dP(t)}{dt} = c_1 P(t) - \big(c_2 P(t) + c_3 M(t)\big)P(t) + \frac{c_4 X(t) P(t)}{X(t) + c_{11}} + \frac{v_{in} P_0(t)}{v_p} \tag{1}$$

$$\frac{dM(t)}{dt} = c_5 M(t) - c_6 M^2(t) + \frac{c_8 X(t) M(t)}{X(t) + c_{12}} + \frac{c_{18} v_{in} m U(t)}{v_p} \tag{2}$$

$$\frac{dD(t)}{dt} = -c_9 D(t) - c_7 M(t) + \frac{c_{10} X(t) D(t)}{D(t) + c_{14}} + \frac{v_{in} D_0(t)}{v_p} \tag{3}$$

$$\frac{dX(t)}{dt} = c_{13}(X_{atm} - X(t)) - c_{15} X(t) M(t) - c_{16} X(t) P(t) - c_{17} X(t) D(t) + \frac{v_{in} X_0(t)}{v_p} \tag{4}$$

in which $P(t)$ denotes the coliforms concentration in the pond (mg/liter), $M(t)$ represents the PSB concentration in the pond in which t ranges from initial time up to 70 days (mg/liter), $D(t)$ refers to the COD concentration in the pond (mg/liter) as well as $X(t)$ denotes the DO concentration in the pond (mg/liter). The other parameters' description is recorded in Table 1. The parameters $m, P_0, D_0, X_0, X_{atm}, v_{in}, v_p$ as well as $U(t)$ were acquired from the data in [10]. The amount of mPHO over the pond, $U(t)$ was accompanied by the JBMI schedule, as expressed in Figure 1. Apart for two days during the weekend, the mPHO was administered every day.

Table 1. Parameters utilised in the mathematical model.

Symbol	Description	Value
$\boldsymbol{m}$	The PSB concentration in one liter of microbe-based product (mPHO).	19.1 mg/liter
$\boldsymbol{X_{atm}}$	The saturated oxygen concentration.	10 mg/liter
$\boldsymbol{v_{in}}$	The average amount of sewage coming in.	290304 liter/day
$\boldsymbol{v_p}$	The pond's volume.	2864130 liter
$\boldsymbol{P_0(t)}$	The coliform concentration at CP1 point (influent and the mPHO application).	Refer to [10]
$\boldsymbol{D_0(t)}$	The concentration of COD at CP1 point.	Refer to [10]
$\boldsymbol{X_0(t)}$	The concentration of DO at CP1 point.	Refer to [10]
$\boldsymbol{U(t)}$	The amount of mPHO employed to the pond in accordance with the JBMI schedule per liter in 70 days.	Refer to Figure 1
$\boldsymbol{c_1 - c_{18}}$	The cost functions.	Refer to [10]

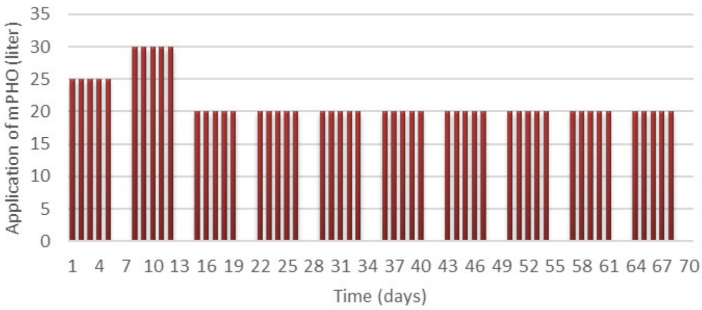

Figure 1. Microbe-based product (mPHO) amount administered to the pond in accordance with the JBMI schedule, $U(t)$.

The oxygen content of the pond was minimal, and the pond required sufficient oxygen to support the reaction between the mPHO and coliform bacteria. Therefore, in this investigation a modified model which had incorporated the Monod equation. The modified model concerning COD was depicted in the equations below. The model of [10] was adjusted by integrating the Monod equation to (3) and (4). Moreover, the modified (5) to (8) can be written as follows:

$$\frac{dP(t)}{dt} = n_1 P(t) - \big(n_2 P(t) + n_3 M(t)\big)P(t) + \frac{n_4 X(t) P(t)}{X(t) + n_5} + \frac{v_{in} P_0(t)}{v_p} \tag{5}$$

$$\frac{dM(t)}{dt} = n_6 M(t) - n_7 M^2(t) + \frac{n_8 X(t) M(t)}{X(t) + n_9} + \frac{n_{10} v_{in} m U(t)}{v_p} \tag{6}$$

$$\frac{dD(t)}{dt} = -n_{11} \frac{w_1 D(t)}{w_2 + D(t)} - n_{12} M(t) + n_{13} X(t) \frac{w_1 D(t)}{w_2 + D(t)} + \frac{v_{in} D_0(t)}{v_p} \tag{7}$$

$$\frac{dX(t)}{dt} = n_{14}(X_{atm} - X(t)) - n_{15} X(t) M(t) - n_{16} X(t) P(t) - n_{17} X(t) \frac{w_1 D(t)}{w_2 + D(t)} + \frac{v_{in} X_0(t)}{v_p} \tag{8}$$

in which w_1 express the maximum growth rate coefficient happening at $0.5\mu_{max}$ (day^{-1}), as well as w_2 denotes the half-saturation coefficient $(mg/liter)$ [11].

The modified model was solved numerically by employing the 4th order Runge Kutta method entrenched in the software known as MATLAB, as well as it comprises (5) until (8). The parameter fitting technique is called as the Nelder-Mead simplex algorithm and it was utilized to gain all parameter values (n_1 until n_{17}, $w_1$and w_2). The Nelder-Mead Simplex algorithm is a build-in tool in fminsearch (MATLAB software). Thus, the Runge-Kutta method and Nelder-Mead simplex algorithm were used in this analysis as the optimization technique for estimating unknown parameters.

The objective function was used to obtain the minimum error. The predictive model was contrasted with experimental data in [10], as well as RMSE method was calculated to fulfill the model to the data. The following is the RMSE equation:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(xexp_i - xcal_i)^2} \tag{9}$$

in which $xcal_i$ denotes the computed value from the model, $xexp_i$ denotes the experimental value of the dependent variable for $i = 1,2,3, \dots N$, and N denotes the data points' total number.

All these methods were repeated until the parameter's appropriate values were determined. Then, this study used all parameters obtained from the above procedures to develop the oxi-P GUI as a predictive tool for the oxidation pond wastewater treatment process.

RESULTS AND DISCUSSION

Numerical solutions

The wastewater treatment quality was discovered by the DO, COD, coliform bacteria, and PSB concentration. The Monod equation was employed to account for the constraint of limited resources of COD in the oxidation pond. After conducting the procedure of parameter fitting technique to (5) until (8), the best-fit value of parameters to the experimental data in [10] was obtained, as shown in Table 2.

Table 2. Parameter values of proposed model.

Parameter	Value
n_1	$0.000409029499245 \times 10^2$
n_2	$0.002866940467725 \times 10^2$
n_3	$0.000036548032468 \times 10^2$
n_4	$0.000078937029870 \times 10^2$
n_5	$0.000000000113246 \times 10^2$
n_6	$0.210296024358310 \times 10^2$
n_7	$0.000039543422006 \times 10^2$
n_8	$0.000000000070273 \times 10^2$
n_9	$0.002996285744190 \times 10^2$
n_{10}	$0.000003094300853 \times 10^2$
n_{11}	$0.000114777112258 \times 10^2$
n_{12}	$0.000110412492382 \times 10^2$
n_{13}	$0.000047352855172 \times 10^2$
n_{14}	$0.000078606677829 \times 10^2$
n_{15}	$0.000245967181715 \times 10^2$
n_{16}	$0.000025949634164 \times 10^2$
n_{17}	$0.000000000153149 \times 10^2$
w_1	$1.430694365464235 \times 10^2$
w_2	$1.096690597352796 \times 10^2$

In a previous work by Ockendon et al. [10], studies were conducted for a three-month treatment period. The application of mPHO products was varied. Two phases were used in the implementation of mPHO. Phase 1 is intensive procedure which in the first week, 25 litres were added, while in the second week, 30 litres. Then, phase 2 is a continuous procedure that consumed 20 litres of mPHO. Therefore, this study had conducted the procedure in MATLAB software to obtain the best fitting of 19 parameters by using the amount of mPHO stated above.

The modified model was numerically solved employing the parameters listed in Table 2 to produce the outcomes shown in Figure 2 to 5. The experimental data was contrasted to the modified model. From Day 1 to Day 70, the DO, COD, coliform bacteria, and PSB performance was monitored.

The simulation result with regards to the microbe's experimental data and the coliform concentration collected from the pond at point CP2 [10] is shown in Figure 2. Additionally, the figure illustrates the simulation result by the blue curve of coliform bacteria concentration gradual increase from day 1 until day 37 and rapid increase until almost the end of the treatment period and then the curve showed the decrease. Coliforms are bacteria found in the digestive tracts of animals, including humans, human wastes, plant, and soil materials. The graph of the experimental data demonstrated that the coliform concentration was low, following the sharp increase on Day 42. Coliform bacteria are the primary indicators of water purity for residential, agricultural, and other uses [12]. Coliform bacteria are one of the most prevalent types of bacteria found in feces-contaminated water, a significant public health hazard [13].

Figure 3 compares the PSB simulation findings to the experimental data. Note that PSB in mPHO are microorganism products that help to enhance the quality of water. The simulation result showed that the PSB concentration kept increasing until the end of the treatment. The rate of PSB concentration climbed dramatically from Day 42 to Day 49, as demonstrated in Figure 3, and subsequently abruptly declined until the completion of the treatment process, as evidenced by experimental data. This is since bacteria can only consume a specific amount of soluble substrate. As with every other living organism, the microorganisms which treated this wastewater evolved, and their growth showed the extent to which the wastewater was treated [1]. The word "substrate" refers to the organic matter or nutrients in wastewater that are converted or limited during biological treatment [11]. Talaiekhozani & Rezania [14] summarize that PSB could remove pollutants and briefly addressed three critical factors which affected the rate of PSB growth: light, temperature, and nutrients. The growth temperatures used ranged from 25°C to 55°C, which embraces all microbial community conditions for growth capable of surviving heat and decomposing o-xylene at varying concentrations [15].

Figure 4 depicts the COD concentration simulation findings and experimental data over time. The simulation result for COD concentration provided the variation from the commencement of the days to the conclusion of the time, as represented in the figure. At the CP2 point, though, the COD concentration was always lesser than the experimental results. Until the completion of the treatment, the experimental data continued to rise. Despite the expansion illustrated in Figure 4, the COD concentration rate increases at the CP1 point (influent and mPHO application) as recorded in [10] as well as the CP2 point (effluent) as illustrated in Figure 4 was much lower. The oxygen amount needed to oxidize soluble and particulate organic matter in water was determined by the COD value [16]. A higher COD indicated that the water contained more contaminants [17]. The simulated result indicated that it would reduce the COD concentration to an ideal level for water quality. The decline in COD removal throughout time is due to the death and decomposition of algae that build a thick layer on the surface of the water, increasing the COD concentration in the systems [18]. Nonetheless, COD is a crucial quality control parameter in the treatment of effluent wastewater [16].

In addition, Figure 5 depicts the evolution of DO throughout time (days). The DO concentration exhibited changes from the start to the conclusion of the treatment period. The oxidation process is relative to the quantity of organic matter added, indicating a rise in DO consumption (Dissolved Oxygen) [19]. Despite the fact that it appeared to decline, it exhibited a significant increase when contrasted to the quantity of DO in CP1 point as mentioned in [10]. When aerobic decomposers consume more oxygen than the rate of reaeration, the DO concentration decreases, and some species are eliminated. Anaerobic species may populate the water if aerobic decomposers remain to function [20]. Due to changes in species composition, the DO decreases. After all, chemical reactions have influenced the oxygen level. The stream dissolved oxygen content decreased when connected to the pond outflow, indicating that the stream was polluted by sewage effluents [21]. As organic matter in sewage oxidizes, a demand is imposed on the available dissolved oxygen, resulting in decreased dissolved oxygen content. Therefore, dissolved oxygen tests are critical for preventing pollution of natural waters, especially streams that receive sewage effluent discharges. The maximum amount of oxygen dissolved is determined by water temperature. Warmer water can have less dissolved oxygen than colder water [22]. Nevertheless, Ficklin et al. [23] noted in their paper that the longer summer daylight hours and warmer temperatures mean that DO concentrations will rise higher and remain higher during the day than they would in winter. Aerobic bacteria absorb oxygen during the night, resulting in a significant decrease in DO concentrations.

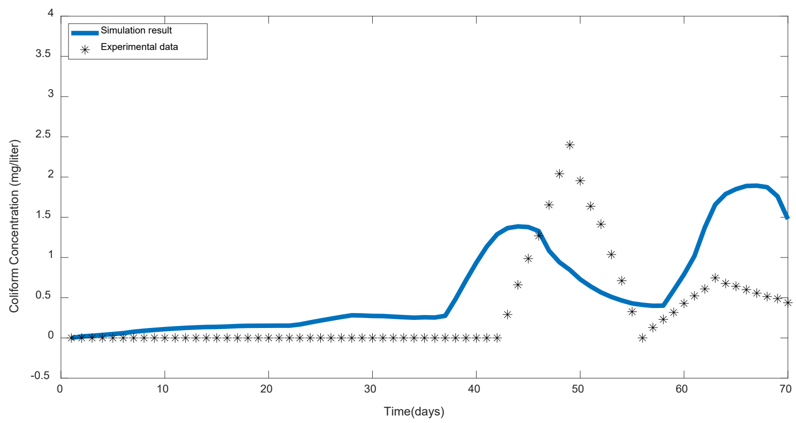

Figure 2. Simulation result with regards to microbe's experimental data and coliform concentration opposing time.

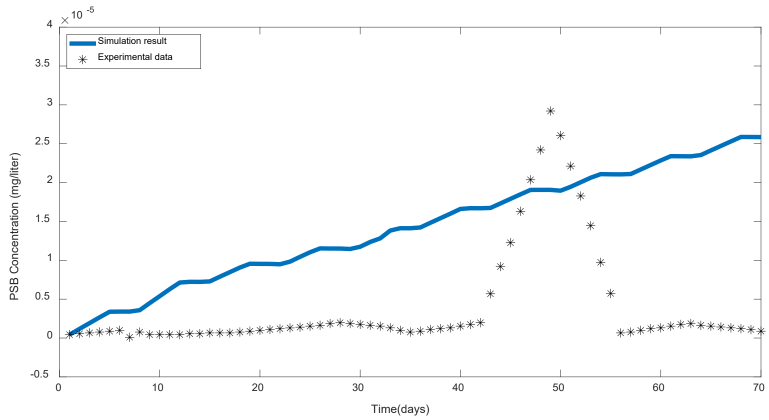

Figure 3. Simulation result with regards to PSB experimental data and concentration opposing time.

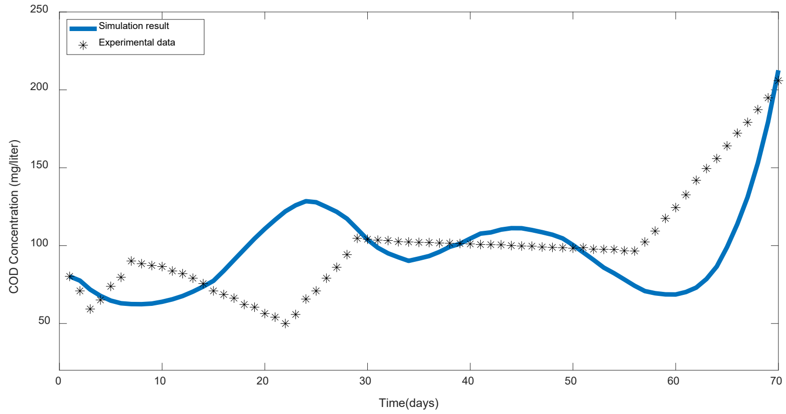

Figure 4. Simulation result of COD experimental data and concentration opposing time.

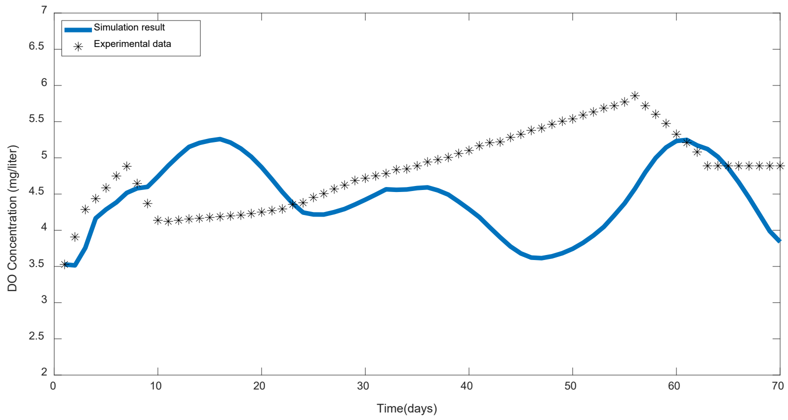

Figure 5. Simulation result of DO experimental data and concentration opposing time.

Model validation

The current model of Ockendon et al. [10] and the modified model relying on the derived root mean square error (RMSE) value were quantitatively evaluated in the ongoing investigation. The modified predictive model's RMSE value fitted the data along the regression line better than the old model, as indicated in Table 3. The reason for this was that the modified model had a reduced RMSE than the existing model. Equation (3) to (5) which combined with Monod equation were shown to deliver an improved outcome than the existing model. Between the two models, there were substantial differences, implying that the suggested model was much better. The projection graph of proposed model was consistent with the trend behavior of the experimental data as visualized in Figure 4 to Figure 7, qualitatively.

Table 3. Comparison of RMSE values of the existing model against modified predictive model.

RMSE value of Ockendon's model	RMSE value of the modified model
$1.484152171240465 \times 10^2$	$1.382880393769406 \times 10^2$

GUI simulation tool

The objectives of this research were to produce a GUI for a predictive model of the wastewater treatment process in an oxidation pond, and the development of a GUI in MATLAB by using GUIDE. MATLAB is a famous mathematical programming language used extensively for numerical computation, algorithm development, visualization, and data analysis [24]. A GUI collects user input in the form of events such as mouse clicks, selections, and text entered in text fields and then modifies the state of its widgets [25]. The GUI is simple and convenient to use for all.

This study developed a MATLAB-based GUI to predict the dynamic of concentration in an oxidation pond as shown in Figure 6. The application of mPHO was divided into two phases which were intensive during the Week 1 and Week 2, and continuously during the Week 3 until Week 10. A user must enter the amount of mpHO for the intensive and continuous phase as shown in the input panel on the right side of the GUI. After the GO button was pressed, the projection graphs for the four species will appear, as depicted in Figure 7. The data were plotted as (*) for the mPHO applied in the oxidation pond, which 25 litres on the Week 1, 30 litres on the Week 2 and 20 litres on the Week 3 until Week 10 as implemented in a study by Ockendon et al. [10]. The flow chart in developing the GUI for wastewater treatment process of an oxidation pond is illustrated in Figure 8.

As a simulation example, Figure 7 shows that the amount of mPHO for Week 1 is 150 litres, while Week 2 was 200 litres. Meanwhile, the amount of mPHO for Week 3 until Week 10 was 50 litres. The figure predicts the concentration of four species that which were investigated in this study. In Figure 7, coliform bacteria and COD did not show any changes from the used in Ockendon et al. [10] controlled values. However, the other two species showed very significant changes in the concentrations of oxidation pond. As you can see in Figure 7, the number of simulations for PSB concentrations is seen to increase dramatically. This is because the amount of mPHO used during the experiment (mentioned above) is very different when compared to the amount of mPHO used for the simulation. Due to that, for the simulation the amount of PSB is very high due to the excessive use of mPHO. The excessive use of mPHO will cause PSB to increase sharply, whereas the DO was decreased. Long-term exposure to low dissolved levels of oxygen cannot destroy the organisms directly but increased its vulnerability to other environmental stresses [26]. According to Figure 7, oxi-P GUI can predict the behaviour of four species in the oxidation pond through changes in the amount of mPHO.

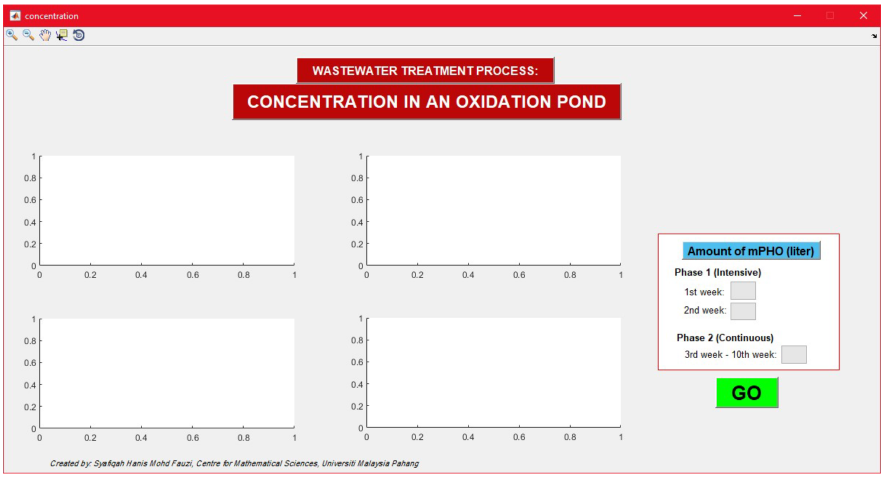

Figure 6. Interface of oxi-P GUI.

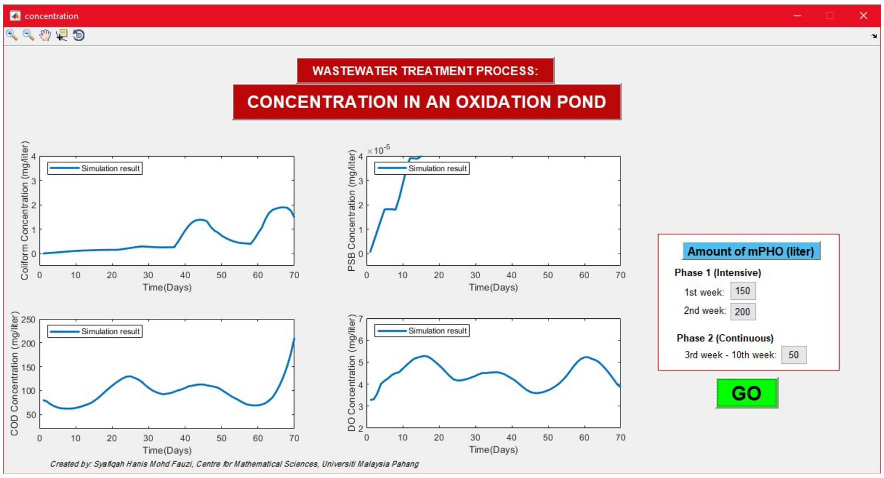

Figure 7. Predictive model appears in oxi-P GUI.

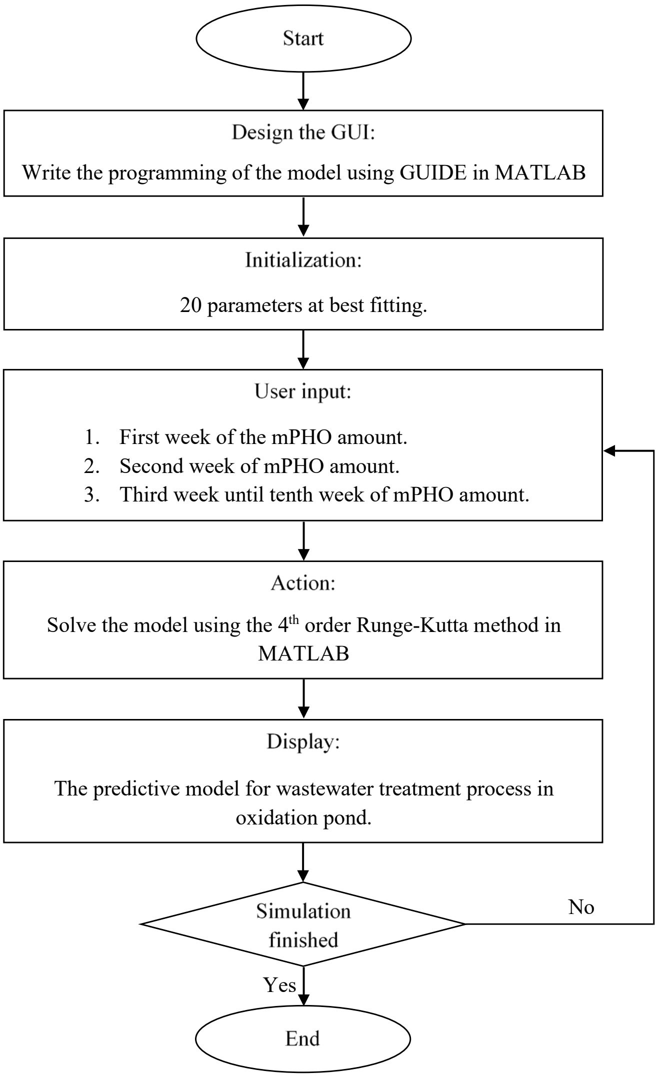

Figure 8. Flow chart of developing a graphical user interface (GUI).

CONCLUSION

A predictive model with respect to the wastewater treatment process in the oxidation pond in GUI is accessible to all, especially those who are studying the wastewater treatment process. The oxi-P GUI will predict the concentrations of four different species in the oxidation pond based on different amounts of mPHO added into the pond. By using the oxi-P GUI, the system will automatically determine the dynamic of concentration in the oxidation pond. The GUI compared simulation results to experimental data for non-expert mathematicians and programmers. The GUI simplifies simulation for user, particularly those with limited programming experience and a working knowledge of mathematics. In general, this study demonstrates how mathematical modeling can aid in designing a wastewater treatment system in an oxidation pond. Therefore, the quantity of mPHO can be simulated to guarantee that the overuse is avoided, its consistency is maintained, and appropriate dosage is added.

REFERENCES

[1] N. J. Horan, *Biological Wastewater Treatment Systems : Theory and Operation.* Chichester: Wiley, 1998.

[2] N.N. Muhammad, D.L.C. Ching, and A.S.S.S. Hamzah, "Mathematical modelling of wastewater treatment in oxidation pond," Journal of Computational and Theoretical Nanoscience, vol. 16, no. 11, pp. 4455–4460, 2019.

[3] T.A. Abdalhameed and J.S. Al Hassany, "The qualitative and quantitative composition of Epiphytic Algae on Ceratophyllum demersum L. in Tigris River within Wassit Province, Iraq," Baghdad Science Journal, vol. 16, no. 1, p. 0001, 2019.

[4] N. F. Gray, *Biology of Wastewater Treatment* (Vol. 4). World Scientific, 2004.

[5] A.S.S.S. Hamzah and A.H.M. Murid, "Nonlinear partial dierential equations model related to oxidation pond treatment system: a case study of mPHO at Taman Timor Oxidation Pond, Johor Bahru," MATEMATIKA, vol. 34, no. 2, pp. 293–311, 2018.

[6] M. Farzadkia, M.H. Ehrampoush, S. Sadeghi, M. Kermani, M.T. Ghaneian, V. Ghelmani, and M.E. Abouee. "Performance evaluation of wastewater stabilization ponds in Yazd-Iran," Environmental Health Engineering and Management Journal, vol. 1, no. 1, pp. 7–12, 2014.

[7] E. Butler, Y.T. Hung, M.S. Al Ahmad, R. Y.L. Yeh, R.L.H. Liu and Y.P. Fu, "Oxidation pond for municipal wastewater treatment," Applied Water Science, vol. 7, no. 1, pp. 31–51, 2015.

[8] F.S. Mjalli, S. Al-Asheh, and H.E. Alfadala, "Use of artificial neural network black-box modeling for the prediction of wastewater treatment plants performance," Journal of Environmental Management, vol. 83, no. 3, pp. 329–338, 2007.

[9] D. Winkler, M. Meister, M. Rezavand, and W. Rauch, "SPHASE—smoothed particle hydrodynamics in wastewater treatment.," World Environmental and Water Resources Congress 2016. American Society of Civil Engineers., pp. 303–311, 2016.

[10] J.R. Ockendon, G. Wake, K.L. Teo, R. Loxtan, A. Araújo, B. Widodo, A.H.M. Murid, Y.S. Hoe, A. Banitalebi, F. Johar and F. M. Siam. "Mathematical Modeling and Optimization for Biological-based Treatment of Taman Timor Oxidation Pond, Johor," Malaysian 2nd Mathematics in Industry Study Group (MISG 2014), pp. 1-37, 2014.

[11] M.Samer (Ed.). *Wastewater treatment engineering*. BoD–Books on Demand, 2015.

[12] M. Zamxaka, G. Pironcheva, and N. Muyima, "Microbiological and physico-chemical assessment of the quality of domestic water sources in selected rural communities of the Eastern Cape Province, South Africa," Water SA, Vol. 30, No. 3, 2004.

[13] M. Mishra, A.P. Arukha, A.K. Patel, N. Behera, T.K. Mohanta, and D. Yadav, "Multi-Drug Resistant Coliform: Water Sanitary Standards and Health Hazards," Frontiers in Pharmacology, vol. 9, Jun. 2018

[14] A. Talaiekhozani and S. Rezania, "Application of photosynthetic bacteria for removal of heavy metals, macro-pollutants and dye from wastewater: A review," Journal of Water Process Engineering, vol. 19, pp. 312–321, 2017.

[15] T. Noor, T.K. Ralebitso-Senior, M. Sarker, and D. Wright, "Characterisation of indigenous microbial community isolated from wastewater treatment phases Baghdad/Iraq," IOP Conference Series: Materials Science and Engineering, vol. 871, p. 012016, 2020.

[16] M.T. Bankole, A.S. Abdulkareem, J.O. Tijani, S.S. Ochigbo, A.S. Afolabi and W.D. Roos, "Chemical oxygen demand removal from electroplating wastewater by purified and polymer functionalized carbon nanotubes adsorbents," Water Resources and Industry, vol. 18, pp. 33–50, 2017.

[17] D. Li and S. Liu, "Water quality detection for lakes," Water Quality Monitoring and Management, pp. 221–231, 2019.

[18] Y.D. Abdulwahab, A. Mohammed, and T. Abbas, "improving the performance of constructed wetland microbial fuel cell (CW-MFC) for wastewater treatment and electricity generation", Baghdad Sci.J, vol. 18, no. 1, p. 0007, 2021.

[19] H. Q. Ali, A. Farooq, and M. Ahmed, "Monitoring the wastewater treatment efficiency of oxidation ponds at Chokera, Faisalabad, " Mehran University Research Journal of Engineering and Technology, vol. 36, no. 4, pp. 987 - 994, 2017.

[20] E. Płuciennik-Koropczuk and S. Myszograj, "New Approach in COD Fractionation Methods," Water, vol. 11, no. 7, p. 1484, 2019.

[21] P.O. Olutiola, K.O. Awojobi, O. Oyedeji, A.D.V. Ayansina and O.O. Cole, "Relationship between bacterial density and chemical composition of a tropical sewage oxidation pond," African Journal of Environmental Science and Technology, vol. 4, no. 9, pp. 595–602, 2010.

[22] R.S. Bryan, S.E. William, Tom M, *Pond Facts #5 Water Quality Concerns for Ponds*. The Pennsylvania State University, 2006.

[23] D. L. Ficklin, I.T. Stewart, and E.P. Maurer, "Effects of climate change on stream temperature, dissolved oxygen, and sediment concentration in the Sierra Nevada in California," Water Resources Research, vol. 49, no. 5, pp. 2765–2782, 2013.

[24] S. He and P. Li, "A MATLAB based Graphical User Interface (GUI) for quickly producing widely used hydrogeochemical diagrams," Geochemistry, vol. 80, no. 4, p. 125550, 2020.

[25] I. Banerjee, B. Nguyen, V. Garousi, and A. Memon, "Graphical User Interface (GUI) testing: systematic mapping and repository," Information and Software Technology, vol. 55, no. 10, pp. 1679–1694, 2013.

[26] M. Radwan, P. Willems, A. El-Sadek, and J. Berlamont, "Modelling of dissolved oxygen and biochemical oxygen demand in river water using a detailed and a simplified model," International Journal of River Basin Management, vol. 1, no. 2, pp. 97-103, 2003.