Journal of Green Engineering (JGE)

Volume-10, Issue-12, December 2020

Minimize Effluents of Aeration Process in Wastewater Treatment Plant

[1]Mei Wyin Yaw, [2]*Kok Hen Chong,[3]Chin Hock Goh, [4]Kamil Karmila

[1]College of Electronics & Communication Engineering, Universiti Tenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia.
[2,3]Department of Electronics & Communication Engineering, Universiti Tenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia
[4]Department of Electrical Power Engineering,UniversitiTenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia.

Abstract

The aim for this paper is to optimize the water quality indicator which is the sewage effluent from aeration process in Wastewater Treatment Plant (WWTP) process by using hybrid Artificial Immune System (AIS) algorithm. The effluents are including dissolved oxygen (DO) and other effluents such as biochemical oxygen demand (CBOD), concentration of suspended solids (TSS), dissolved phosphorous (TDP) and suspended phosphorous (TSP). The proposed algorithms will be applied into model of aeration process in practical of WWTP process in this paper. The proposed AIS algorithms are named as Transform of Artificial Immune System (TRANSAIS) and Cross Three Parents of Artificial Immune System (X3PAIS). The two models are tested under the similar condition such as generation number, size of population, rate of cloning process, rate of mutation process, crossover rate and stopping condition. The concentration of the effluents will affect the water quality and energy consumption during WWTP process. The optimize indicators results from this paper will be used in the next research to optimize the energy consumption in WWTP process.

Journal of Green Engineering, Vol.10_12, 13520-13535.

Alpha Publishers

Keywords: Aeration Process, Artificial Immune System, Genetic Algorithm, Optimization, Wastewater Treatment Plant Process

1 Introduction

Aeration is important process of treating wastewater which including sewage effluent. Aeration process is adding air into wastewater to assign bio-degradation workout of the pollutant components. It is a fundamental part of most biological in WWTP systems which unlike as chemical treatment. Chemical treatment uses chemicals to react and stabilize contaminants in the wastewater stream while biological treatment uses microorganisms that occur naturally in wastewater to degrade wastewater contaminants. Aeration process is part of the stage in WWTP which known as the secondary treatment process in city or industrial wastewater treatment. To ensure efficiently and safety of nutrient removal, aeration in wastewater treatment tanks always monitoring carefully. In the aeration process, DO is a critical parameter compare to CBOD, TSS TDP or TSP because oxygen levels in the tank will influencing the health of the microorganisms or biomass decomposition of the nutrients.

1.1 Aeration Process in WWTP

There are different methods or process of wastewater treatment which used to clean wastewater from contaminants. In order to orient the water quality, WWTP optimal control system tends to slightly overpass the potential of energy saving consumption in the industries. Energy intensive equipment in WWTP process is included pumps and blowers to treat and process wastewater. From fig. 1, it shows that is a generic flow diagram of the WWTP process [11].

The aim of analysis presented in this paper is to enhance the aeration process. From fig. 1, it shows that centrifugal blowers provide the pure oxygen to each aeration tank through the bottom of the tank. In this paper, the two scenarios investigation models [1] were used to optimize the effluents such as dissolved oxygen (DO), biochemical oxygen demand (CBOD), concentration of suspended solids (TSS), dissolved phosphorous (TDP) and suspended phosphorous (TSP). The DO is used for indicate the energy consumption while effluent of CBOD, TSS, TDP and TSP are used to indicate water quality. All five metrics are optimized by developed a multi-objective model[5][9]. Next section will be explained on the AI algorithm which applies in this research to optimize the effluents.

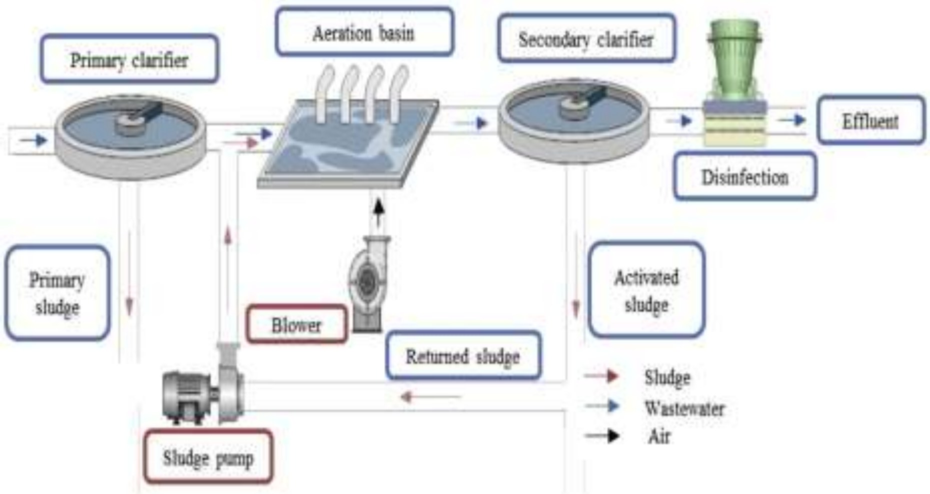


Figure 1 Wastewater treatment process flow diagram

There are two optimization AI was selected in this research which is Artificial Immune System algorithm (AIS) and Genetic Algorithm (GA). AIS algorithm good at improve global searching but it easy to have degeneration appear in optimization process which cause to the convergence quality lower. GA has good ability in optimize complex problems but it has poor search ability. Therefore, in this paper the optimization ability was enhanced by hybrid of between crossover operator of GA and AIS algorithm.

The hybrid optimization methods developed in this paper are known as Transform of Artificial Immune System (TRANSAIS) and Cross Three Parents of Artificial Immune System (X3PAIS). The next section of paper will describe on AIS, GA, TRANS-AIS and X3PAIS. The proposed optimization algorithm will be applied into two DO models which used [1].

1.2 Artificial Immune System – Clonal Selection

AIS are inspired by nature biological immune system. It used to solve engineering problem with immunology theory, immune principles, models or function [2,3]. The operation of optimization in this paper is using optimization technique in AIS which is known as clonal selection algorithm (CSA). The CSA is using the fundamental of clonal expansion and affinity maturation in AIS [2,3].

In the CSA process, antibodies which can best recognize the antigen detected will proliferate by cloning process. Each antigen will have the specific immune response. The antigen will be replicating with reproduce immune cells in tandem. These processes will success when immune cells can recognize and fight against the specific antigen. The newly cloned cells will be characterized as plasma cells and memory cells. The plasma cells are responsible to produce antibody under mutation process to boost up the genetic variation while the memory cells in charge for invasion of antigen in the future for immunologic response.

Hereafter, the best cells which have the best affinity to the specific antigen will be select in the next mechanism population. Hyper mutation will go into inactive mode for the high affinity cells while the low affinity receptors will disappear through apoptosis process if mutation process continue going on [10][4].Fig. 2 explained the theory of CSA process.

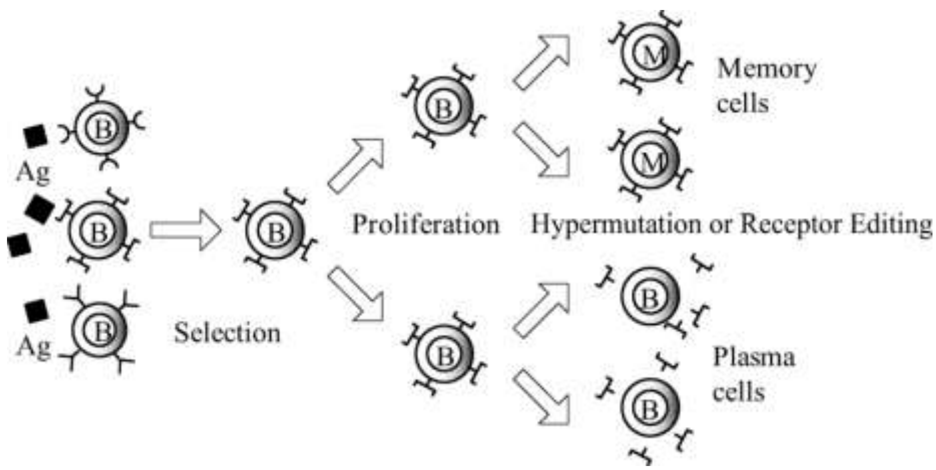


Figure 2 The Clonal selection theory

De Castro and Timmis [2][3]created SA in year 2002. Standard CSA process has simplified into seven steps where listed below: -

Step 1: Random populations generate process
Step 2: Fitness calculation process
Step 3: Cloning process
Step 4: Mutate process
Step 5: Evaluation process
Step 6: The best population selected for next generation
Step 7: Before stopping condition is met, step 3-6 is repeated.

The standard CSA process is represented in pseudo code format as shown in Fig. 3, while the summarized flow chart of CSA is shown in Fig. 4.

```
begin AIS
  c:=0  { counter }
  Initialize  population
  Do:
    Compute affinity
    Generate clones
    Mutate clones
    Replace lowest affinity Ab with a new randomly generated Ab
   c:=c+1
  end
end AIS
```

Figure 3 Pseudo-code of the standard CSA

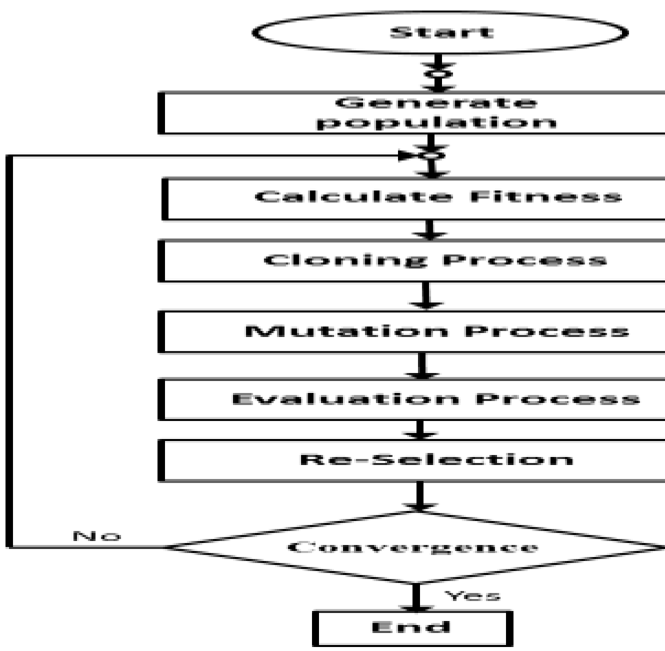


Figure 4 Flow chart of standard CSA

1.3 Genetic Algorithm

GA firstly found by John Holland in 1960's[4][6][7][8] and certifies that it is strong in optimization problem approach which used to optimize different type of problems. One of the GA operators which is crossover process which inspired as an idea of conjugation of cell bacterial in the immune system. This operator will be used to hybrid with the AIS algorithm to enhance the optimization results. Crossover process will generate new antibody by providing a set of selected members of antibody parents. The selected genetic cells will crossover between two or more genes of parents. In this paper, the technique of single point and cross three parents' will be used to improve the proposed algorithm results.

1.3.1 Single Point Crossover

The idea of single point crossover is shown in fig. 5. Minimum of two parents of antibody parents, antibody A and antibody B needed for this single point crossover process. The first step of single point crossover process is a crossover point is selects randomly, which is represents by the dashed line shown in fig. 5. At the end of crossover process is completed, from beginning of the genes to the crossover point from one antibody will conjugate with the rest after this point to the end of genes from the second antibody. As shown in fig. 4, the genes of both antibodies were exchange to born out two new antibodies A and antibody B where they have different genes compare to parents. These two new antibodies are hoped to take over the good genes of the parents' antibody after the crossover process.

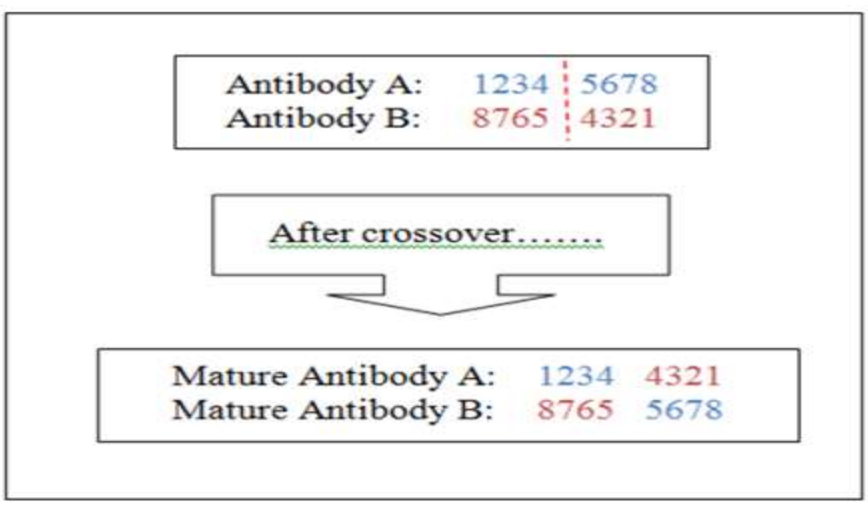


Figure 5 Summarized of single-point crossover process

1.3.2 Three Parents Crossover

In the three parent's crossover process, three antibodies are been chosen as parents. The idea of it is hoped to maintain the better cell from each antibody parents and conjugate them to create a new mature antibody. During the crossover process, each bit of the first two parents will be compare. During the comparison, the bits will be used for generation if bits are same or else the bits of the third parent will be used. The proposed comparison of each bit of the three parents in this paper by using AND and OR logic gate as summarized and shown in fig. 6. The truth table of the process is express in table 1 below.

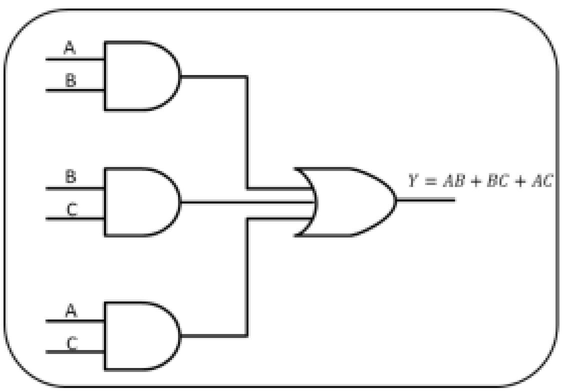


Figure 6 Summarized of cross three parents

Table 1 Truth table for proposed cross three parents

A	B	C	Y
0	0	0	**0**
0	0	1	**0**
0	1	0	**0**
0	1	1	**1**
1	0	0	**0**
1	0	1	**1**
1	1	0	**1**
1	1	1	**1**

1.3.3 Hybrid of AI Algorithm – AIS and GA

The optimum results can be enhanced by using hybrid AI algorithm, the concept of fusion of two antibodies was used which explain in previous section. This understanding was inspirited from newly enhanced germ cells which bring new and stronger sickness happened around us. The revolution of the new bacteria is the genetic modification of genes develops by directly contact or unfamiliar and strange genes material from surroundings. Revolution or conjugation process can also exist in naturally with same species of bacteria or affected by other species or artificial bacteria.

1.3.3.1 Transform of Artificial Immune System (TRANSAIS)

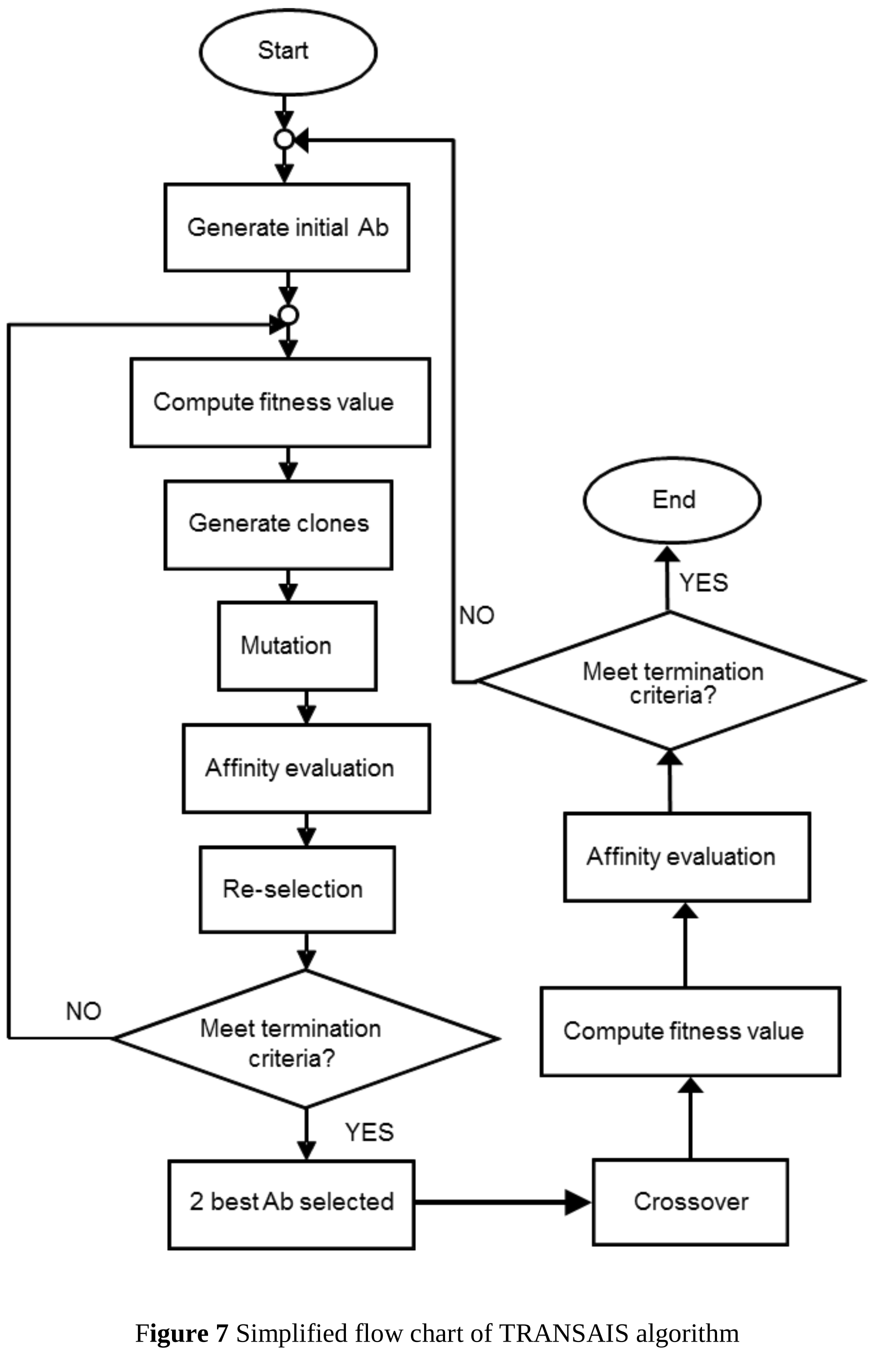
TRANSAIS algorithm is includes of AIS algorithm and single point crossover operator. Each algorithm was explained in previous section. The transformation of new antibody process will be started after two superior antibodies were choosing after AIS algorithm process. The transformation of new antibody process is conjugation of that two chosen antibody cells. These chosen genetic cells are transfer between two antibodies that are in direct contact under a random crossover point. The revolution of antibody in this paper is used the concept of crossover operator to obtain the better optimum results. Therefore, to establish the two chosen superior parents' genes obtain have the best antibody with AIS algorithm, the better principle of genes will be going for cloning process while others will be going for mutation process. The simplified flow chart of TRANSAIS algorithm was described in Fig. 7.

1.3.3.2 Cross Three Parents of Artificial Immune System (X3PAIS)

The next transformation antibody process is by revolution of three antibody genes was proposed. The revolution of three antibodies idea apply in this paper is the three parents crossover operator which explained in previous section will be tested to obtain a better results and improving optimization of AIS algorithm. The better criteria of the genetics of the antibody will be cloning to produce the part of new genetic in AIS algorithm to ensure the three selected antibody parents have superior genetics to go for conjugation process.

The genes of the three antibodies was exchanged and highly hoped to produce a new antibodies Y which is more mature after the three parent's crossover process completed. The new antibody was come by through three parents' crossover process which is hoped to take over the superior genes. The simplified flow chart of X3PAIS algorithm was described in Fig. 8.

\



F**igure 7** Simplified flow chart of TRANSAIS algorithm

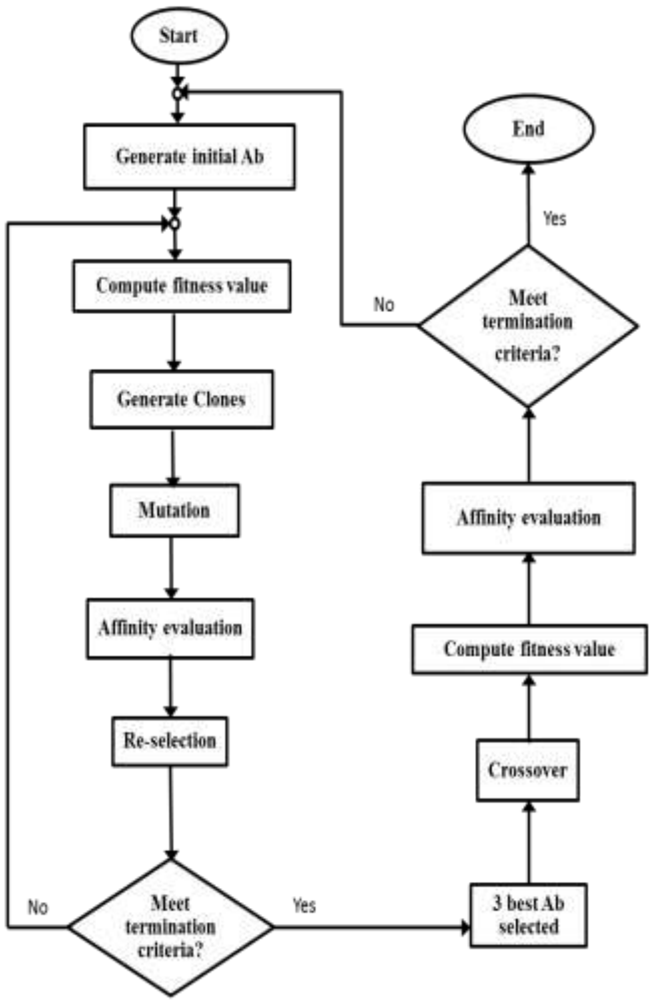


Figure 8 Simplified flow chart of X3PAIS algorithm

2 Simulation

The optimization model developed with the DO models and individual effluents formulated from multi-adaptive regression spline (MARS) algorithms [1]are shown in below. During the plant is process, process data is collected and the constraint limits for the two models are formulated from there.

Model 1

$$Z_1 = \min[(w_1 * y_1) + (w_2 * y_2) + (w_3 * y_3) + (w_4 * y_4) + (w_5 * y_5)] \quad \text{(Eq.1)}$$

Where

$0 \leq y_1 \leq 6.5$ (Eq.2)

$0 \leq y_2 \leq 25$ (Eq.3)

$0 \leq y_3 \leq 30$ (Eq.4)

$0.2 \leq y_4 \leq 1$ (Eq.5)

$0.2 \leq y_5 \leq 1$ (Eq.6)

$0 \leq w_{1,} w_2, w_3, w_4, w_5 \leq 1$ (Eq.7)

Model 2

$$Z_2 = \min[(w_1 * y_1) + (w_2 * y_2) + (w_3 * y_3) + (w_4 * y_4) + (w_5 * y_5)] \quad \text{(Eq.8)}$$

Where

$0 \leq y_1 \leq 0.21$ (Eq.9)

$0 \leq y_2 \leq 1$ (Eq.10)

$0 \leq y_3 \leq 0.39$ (Eq.11)

$0.2 \leq y_4 \leq 1$ (Eq.12)

$0.2 \leq y_5 \leq 1$ (Eq.13)

$w_1 = w_2 = 0.4$ (Eq.14)

$w_3 = 0.2$ (Eq.15)

$0 \leq w_4, w_5 \leq 1$ (Eq.16)

y_1- y_5 are the objective functions corresponding to DO, effluent of CBOD, TSS, TSP and TDP respectively. The w_1-w_5 are the weights for each individual objective. The constraints in eq. 2-6 are the elemental objectives limits. After normalization process for the data points as mention in [1]for each objective in is done, each corresponding constraints and objective function would be change into eq. 9-13. In model 1, all weights are assigned to be the same while in model 2; weights are reallocated to each effluent are modified after normalization.

3 Results and Discussions

In the direction of minimize the effluents of aeration process, AIS algorithm and proposed algorithm (TRANSAIS and X3PAIS) will applied into two optimization models which explain in previous section. Matlab programming language is used in simulation in this paper. The two models are testing under the similar condition such as generation number, size of population, rate of cloning process, rate of mutation process, crossover rate and stopping condition for all algorithms.

Fig. 9 and Fig. 10 shown the results of 100 simulations for the two models with optimize by using AIS, TRANSAIS and X3PAIS algorithm. As shown in the results, the minimum value for each model is nearer to value 0 by using X3PAIS algorithm compare with other algorithm.

Minimize of Z value, mean and standard deviations that obtain in 2 models were shown in Table 2. By using X3PAIS algorithm in this paper, it shows that X3PAIS obtained a better result (but not superior) compare to others algorithm. Fig. 11 and Fig. 12 summarize the minimum, mean and standard deviation of Z value for the 2 models.

As shown in the results, X3PAIS algorithm managed to obtain the minimized of effluents produce during aeration process by under the constraint limits. The efficiently and safety of nutrient removal can be under control after optimization of the sewage effluents. Water quality after this aeration process is guarantee since the five indicators concentration was optimized.

The results get from this research is the average optimizes results for the water quality indicators which are DO, effluent of CBOD, TSS, TSP and TDP. The results obtained in this paper will be used in the next research to optimize the energy consumption in WWTP system. It affects the water quality and vice-versa for optimized the water quality scenario.

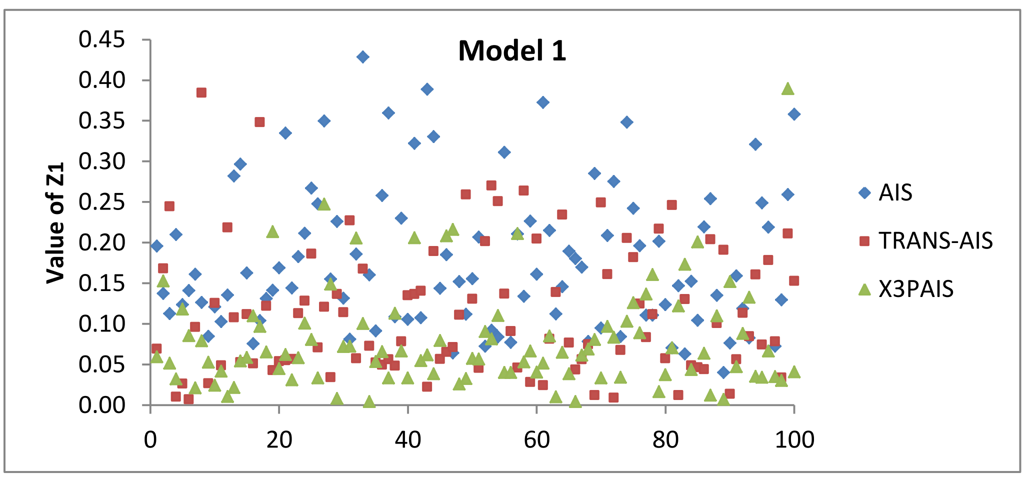


Figure 9. 100 Experiments data collected for model 1

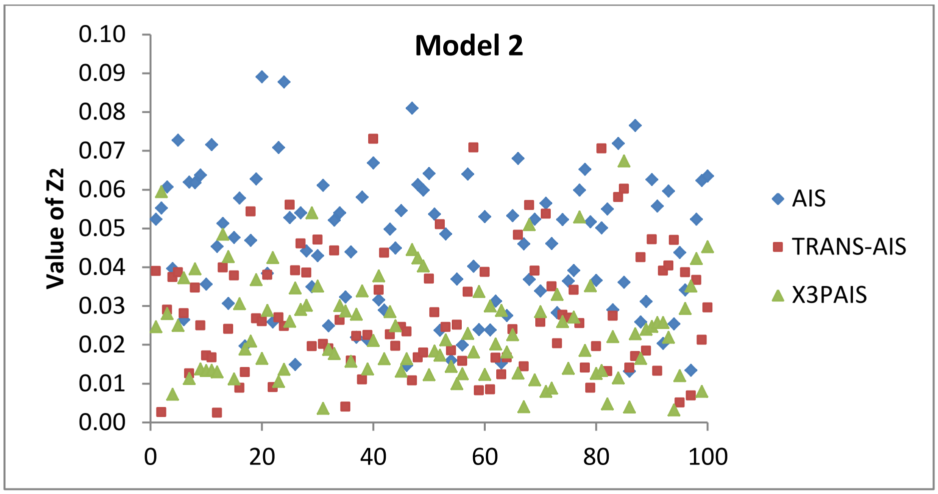


Figure 10. 100 Experiments data collected for model 2

Table 2 Comparisons Results for AIS, TRANSAIS and X3PAIS for Each Model

	Minimum			Mean			Standard Deviation		
	AIS	TRANSAIS	X3PAIS	AIS	TRANSAIS	X3PAIS	AIS	TRANSAIS	X3PAIS
Model 1	4.023619E-02	6.937100E-03	4.189711E-03	1.778157E-01	1.138973E-01	7.992620E-02	8.722443E-02	7.908630E-02	6.275595E-02
Model 2	1.315971E-02	2.409314E-03	3.211680E-03	4.566688E-02	2.855950E-02	2.405296E-02	1.762106E-02	1.564926E-02	1.311263E-02

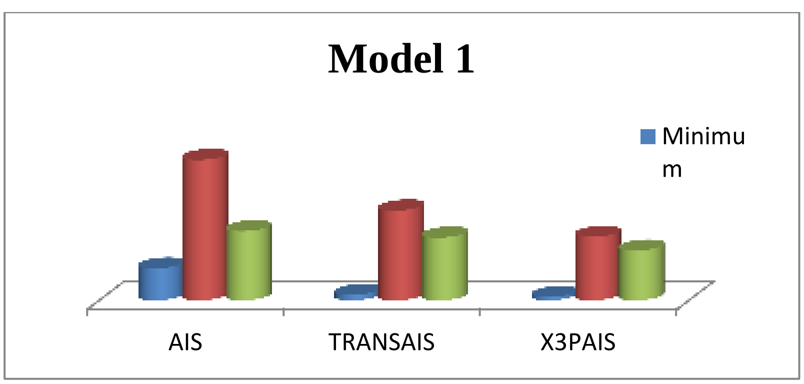


Figure 11. Comparisons Minimum, Mean and Standard Deviation Z_1 value of Model by using AIS, TRANSAIS and X3PAIS

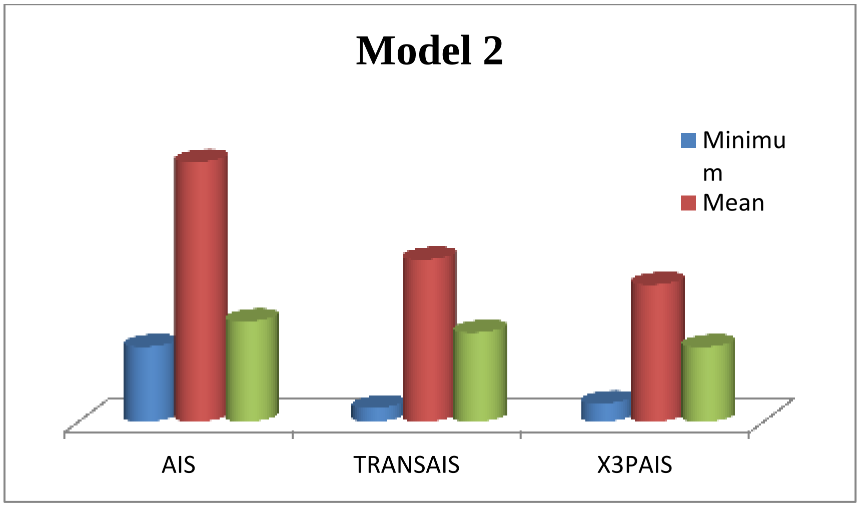


Figure 12. Comparisons Minimum, Mean and Standard Deviation Z_2 value of Model 2 by using AIS, TRANSAIS and X3PAIS

4 Conclusion

In this paper, two effluents models of WWTP is tested to minimize of the effluents produced by applied the proposed AI algorithm which is TRANSAIS and X3PAIS. The results are comparing with the standard AIS algorithm. Its show that proposed algorithm is better than the standard AIS algorithm approaching optimum value. The performance of TRANSAIS and X3PAIS algorithm is better but not superior comparing by each other. These performances can be improved by reconsider the parameters and selection criteria to enhance TRANSAIS and X3PAIS. The optimum value obtained from this paper can be used for further energy consumption calculation in WWTP model.

Acknowledgement

This research work in Universiti Tenaga Nasional (Uniten) and Institute of Sustainable Energy (ISE) is supported and funded by Innovation and Research Management Centre.

References

[1] Ali Asadi, Anoop Verma, Kai Yang, Ben Mejabi, "Wastewater treatment aeration process optimization: A data mining approach", Journal of Environmental Management, Vol. 203, pp. 630-639, 2016.

[2] De Castro L. N., Von Von Zuben F. J., "Artificial Immune System: a novel paradigm to pattern in artificial neural networks in pattern recognition", International Conference on Soft Computing Models in Industrial and Environmental Applications, SOCO, pp. 67-84, 2002.
[3] De Castro L. N., Von Zuben F. J., "Learning and Optimization using clonal selection principle. IEEE Transactions on Evolutionary Computation, Vol. 6, no.3, pp. 239-251, 2002.
[4] Hussain, A., Manikanthan, S. V., Padmapriya, T., Nagalingam, M., "Genetic algorithm based adaptive offloading for improving IoT device communication efficiency", Wireless Networks, Vol.26,no.4, pp. 2329-2338,2020.
[5] H.Inbarani J.Savithri, "Comparative Analysis Of K-Means, Pso-K-Means, And Hybrid Psogenetic K-Means For Gene Expression DataAuthors", International Journal Of Innovations In Scientific And Engineering Research (IJISER),Vol.1,no.1,pp.43-50,2014.
[6]A. Korejo, S. X. Yang, "A comparative study of adaptive mutation operators for genetic algorithms", Proceedings of 8th Metaheuristics International Conference, Hamburg, Germany, pp. 1-10, 2009.
[7] J. H. Holland, "An introductory Analysis with Application to Biology, Control and Artificial Intelligence", Adaption in Natural and Artificial Systems, United States of America: MIT Press. pp. 211.1992.
[8] Sue Ellen Haupt, "Introduction to Genetic Algorithms", Artificial Intelligence Methods in the Environmental Sciences, pp.103-125,2009.
[9] T. B. Kepler, A. S. Perelson, "Somatic hypermutation in B cells: An optimal control treatment", Journal of Theoretical Biology, Vol. 164, no.1,pp. 37-64,1993.
[10] Xiupeng Wei, Kusiak Andrew, "Short-term prediction of influent flow in wastewater treatment plant", Stochastic Environmental Research and Risk Assessment, vol. 29, pp. 241-249,2015.
[11] Nadia Matter Almhana, Seroor Atallah Khaleefa Ali, Shahad Z. AlNajjar, Zainab T. Al-Sharify "Assessment of Cobalt Ions Removal in Synthetic Waste water using Broad Bean Peels", Journal of Green Engineering,Vol.10,no.11,pp.10157 - 10173,2020.

Biographies

Mei Wyin Yaw,College of Electronics & Communication Engineering, Universiti Tenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia**.**

Kok Hen Chong, Department of Electronics & Communication Engineering, Universiti Tenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia.

Chin Hock Goh, Department of Electronics & Communication Engineering, Universiti Tenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia.

Kamil Karmila,Department of Electrical Power Engineering,UniversitiTenaga Nasional (UNITEN), Jalan Ikram-Uniten, Kajang, Selangor Darul Ehsan, Malaysia.