

## Forecasting of BOD<sub>5</sub> and COD from Waste water CPO Mill Using Neural Networks As a Basis for Forming Strategic Planning to Increase the River of Water Quality

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### Abstract

The objective of the research was to analyze forecasting BOD<sub>5</sub>-COD of wastewater CPO manufacture with Neural Network in 2017-2020 in order to determine strategic planning in order to increase the water quality of rivers. The results showed that BOD<sub>5</sub> have an architecture 2-10-1 and 2-11-1 for COD. The value was lower than the government policy standard and there is the trend for it to decrease until 2020. The Strategic Planning CPO mill was not entirely consistent with theory so the wastewater prediction cannot reach zero waste in 2020. Strategic planning based on theory were a review of the vision, mission, goal, and must relate to sustainability environment and have the SWOT/AHP analysis/Fishbone Diagram/Life Cycle Assessment conducted; practiced ISPO/RSP0/HACCP; having a Proper blue/gold level; core competency implemented; implementation of Green Supply Chain Management with Good Corporate Governance; implementation of eco efficiency and design for the environment; occupancy, safety and health implemented; and CSR implemented.

**KEYWORDS:** forecasting, neural network, BOD<sub>5</sub>, COD, strategic planning

### 1. INTRODUCTION

River water quality is often influenced by human activities. Waste from urban areas, households, and industrial sectors will go into water bodies, such as rivers, lakes, dams, and the sea. Nevertheless, humans need unpolluted water for daily activities. Although, nowadays, industrial wastewaters are treated to reduce pollution, and the treated wastewaters that go into the river still contain pollutants. One determining factor of river water quality are the pollutants contained in the river. Low quality of river water can be caused by pollutants from mills, such as the crude palm oil (CPO) mill.

CPO mills are mostly found in Riau Province, Indonesia. The high amount of CPO mills in Riau are one of the causes of low river water quality, such as Siak River. Siak watershed is 11.527 km<sup>2</sup> wide. Some of the area are a mining region. Using BOD and COD as pollution indicators, almost all spots of the river exceed the value limit (1).

Based on a study from *Badan Lingkungan Hidup (BLH)*, one of industrial activities in Siak River which has pollution causing potential is the CPO industry. As we know palm oil is an Indonesian top agricultural commodity that has developed really fast and has a great role in the national economy.

The bright prospect of palm oil in the world market is encouraging the Indonesian Government to expand CPO plantations (2). Waste produced from CPO are declared as one of main pollution causes because in CPO processing there will be by-products such as POME that is hard to be treated. The by-product of CPO production is called palm oil mill effluent (POME) which are difficult to be decomposed naturally (3). Waste from the

CPO mill process including POME are produced mostly from oil extraction and the cleaning process. POME contains cellulose, fat, and oil. CPO mill waste is a brownish liquid which contains solids, oils, and fats (4). Some technologies are used to treat the POME because the direct disposal of POME will negatively affect the environment. (5)

The quality of wastewater produced in the CPO process using BOD are around 8.200-35.000 mg/l with an average of 21.289 mg/l. Using COD, the quality is around 15.103-65.100 mg/l with an average of 34.720 mg/l. (6) The value of BOD and COD from the CPO mill can be forecasted for the next few years with the help of a forecasting model.

Times Series forecasting are forecasting events in the future by understanding previous data. A successful Times Series forecasting depends on the model that is used. Talib et al (2009) said that The Artificial Neural Networks (ANNs) model are often used to predict many ecological processes and phenomena that are related to water sources. ANN application can predict water quality using various environment parameters(7). The basic characteristic of the neural model is the association between application, problem formulation, algorithm analysis, neural model forming, architecture building, and implementation through application. Neural basic model are training and remembering phases. (8) Neural network application training and testing are done and finally, a prediction will be obtained.

Based on the background problem, the main problems of this research were:

1. How is the water quality of Siak River in 2016?
2. How is long term forecasting of Riau CPO M mill wastewater BOD<sub>5</sub> and COD in 2017-2020, using neural network based on 2013 and 2016 data?
3. How does the CPO M Company strategic planning compare to strategic planning theory for 'zero waste' in the next year based on the forecasting result to improve the Siak River water quality?

## 2. LITERATURE REVIEW

Claude E. Boyd (2000) (9), any physical, chemical, or biological property that influences the use of water is a water quality variable, and that the term water quality refers to the suitability of water for a particular purpose. Richard Helmer and Ivanildo Hespanhol (1997) (10) said that water quality criteria have been widely established for a number of traditional water quality variables such as pH, dissolved oxygen, and biochemical oxygen demands for periods of five or seven days (BOD<sub>5</sub> and BOD<sub>7</sub>), chemical oxygen demand (COD) and nutrients. Such criteria guide decision makers, especially in countries with rivers that are affected by severe organic pollution, in the establishment of control strategies in order to decrease the potential for oxygen depletion and the resultant low BOD and COD levels. Water quality standard is an objective that is recognized in enforceable environmental control laws or regulations of a level of Government.

Francis X. Diebold (2013)(11) forecasts are constantly made in business, finance, economics, government, and many other fields, and they guide many important decisions. Jeffrey M. Wooldridge (12) said that various criteria are used for choosing among forecasting methods. The most common performance measures are the root mean squared error and the mean absolute error.

Drucker et al (1999)(13):strategic planning is the continuous process of making present risk-taking decisions systematically with the greatest knowledge of their futurity; organizing systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organized, systematic feedback.

Henze, M and Comeau, Y(2008)(14) said that BOD analysis measures the oxygen used foroxidation of part of the organic matter. The COD analysis measures through chemical oxidation by dichromate the majority of the organic matter which are present in the sample.

### 3. METHODS

The data used were CPO M Riau mill wastewater quality parameter from July 2013 until May 2016 and strategic planning CPO M mill. This research were explorative research and a comparative study, using the Times Series method and ANN model. In this research, forecasting was done with Excel software and Matlab R2015a. The model that used were ANN (Artificial Neural Network) with NARX Network, NAR Network, and Neural Network application. The ANN model consists of 3 layers. The first is the input layer. The middle one is the hidden layer. The last one is the output layer. Before doing the training, the amount of hidden layer was determined. Normally, the hidden layer amount is one or two. The next parameter are the neuron amounts in each layer, activation function in each layer and the ANN model training algorithm.

During the training, validation and the data test were set at:

- 70% data used for training
- 15% data used for general network validation and stopping the training before over fitting happens
- 15% used as complex independent test from network.(15)

Data consisted of training data and test data. Training data were actual (target) input and output normalization data that were given to the network in order to train the pattern. In this research, the writer divided the total data assuming that 80% data were used for training and 20% used for testing. Data used for training were CPO mill wastewater data in the July 2013-December 2015 period. Data in January 2016-May 2016 were used for testing.

The best prediction was obtained when the trial and error had the lowest MSE. MSE is the difference between the average square of output and the target. Zero MSE value means no error.

The pattern used in this research was:

- Input the first and second year data to predict the third year;
- Input the second and the third year data to predict the fourth year; and
- Input the third and the fourth year data to predict the fifth year.

In long term forecasting, the normalization process is done by neural network using syntax.

[inputn,meaninput,stdinput,targetn,meantarget,stdtarget] = prestd (input,target)

While, for the simulation data to be obtained in future prediction, sim function was used with the following syntax:

output\_network = sim(network,inputn)

For denormalization, returning the output value to the real value, syntax were used as follows:

```
network_outputs = poststd(network_outputs, meanT, stdT)
```

Steps in forecasting:

- ✓ Normalization of the initial weight
- ✓ Determining the network architecture determining the amount of hidden layers and neurons
- ✓ Neural network process in the first step, the data from July 2013 until December 2015 were put into training and the results compared to the BOD and COD actual data. In the second step, testing was done.
- ✓ Doing feed forward back propagation. The type of training that was used re Levenberg-Marquardt. Trial and error of the layer amount, neuron amount, and transfer function (logsig, tansig, purelin), epoch. Too few epoch will make the training short, while too many will make the training too long. In this research, the writer set the epoch at 10.000 which meant that the computer network would do the maximum of 10.000 training.
- ✓ Doing the forecasting simulation. The best model is the one with the smallest MSE value.

#### 4. RESULTS and DISCUSSION

The water quality of the Siak river were: H<sub>2</sub>S: 0,002 – 0,095 mg/l; BOD: <2,515 – 119 mg/l; COD: <1,9 – 395 mg/l; oil and fat: 200 – 5600 mg/l . This illustrated that the water quality of the Siak River in 2016 was heavily polluted at all points of monitoring.

Long term BOD<sub>5</sub> and COD in the next 4 year were done using nntool application in Matlab2015a software. The architecture result in forecasting CPO M Riau mill wastewater BOD<sub>5</sub> reached the lowest trial and error with MSE in neuron 10 and epoch 10000, while the COD in neuron 11 and epoch 10000.

There are many forecasting methods, but the chosen method was adjusted with the current data. Time-Series method with neural network was used in this research. According to the BOD<sub>5</sub> and COD data, the graph was nonlinear and random, so we did the forecasting with a neural network. This research were in line with Talib A. Y, et al (6) study about BOD prediction as a river pollution indicator using Artificial Neural Network (ANN). While Abyaneh, H.Z. 2014 (16) found that the ANN model with minimum parameter input; temperature, pH, suspended solid, and total suspense; can be used to predict BOD and COD concentration in waste treatment.

The best BOD<sub>5</sub> prediction is generated in neuron 10 and the best COD prediction is generated in neuron 11. BOD<sub>5</sub> havean architecture 2-10-1 and 2-11-1 for COD. The highest BOD<sub>5</sub> value (July 2016 - June 2020) was 78.6863 in February 2017 and the lowest 12.8470 in June 2019. This value is still below the threshold value determined by the government. The highest COD value (July 2016 – June 2020) was 203.9218 mg/l in July 2016 and the lowest was 95.4232 mg/l in November 2016. This values are still below the 350 mg/l threshold value as determined by the government.

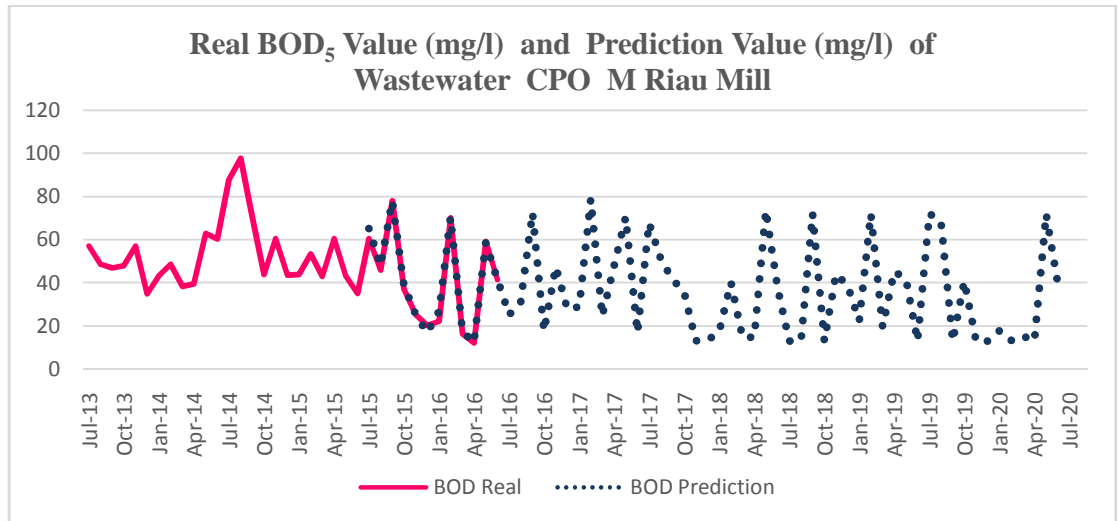


Figure 1. Real BOD<sub>5</sub> Value and Long Term Prediction Value of wastewater in CPO M Riau Mill Graph.

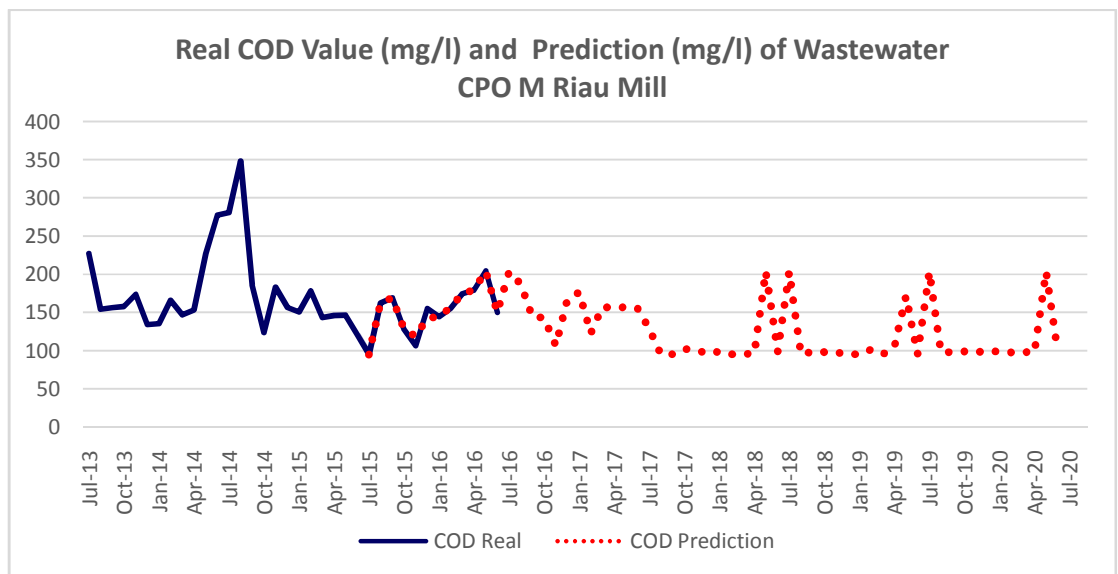


Figure 2. Real COD Value and Long Term Prediction Value of wastewater in CPO M Riau Mill Graph.

Using the neural network to forecast BOD<sub>5</sub> and COD, they were parallel with Chu et al study's (17) about water quality parameter prediction using BPANN (Back Propagation Artificial Neural Networks) and Hopfield Neural Networks, using 3 layers and 7 nodes with one input and one output.

Based on the forecasting result, CPO mill strategic planning are made. The strategy must be advantageous for the company, but still keep environment sustainability. Table 1 describes CPO M Company's strategic planning compared to the strategic planning theory for 'zero waste' in the next year based on the forecasting results to improve the Siak River water quality.

Table 1. Strategic Planning M CPO Mill in Riau vs Theory

No	Strategic Planning of M CPO mill in Riau	Basic Theory of Strategic Planning	Match/Not Match
a	Vision, Mission, Value and Objectives of M CPO mill linked to the sustainable environment	<p>Five elements comprise a strategic plan:</p> <ul style="list-style-type: none"> <li>a. Define mission, vision, activities and values</li> <li>b. Scan the environment using aSWOT analysis</li> <li>c. Identify and prioritize strategic issues</li> <li>d. Define strategic goals and objectives</li> <li>e. Establish an implementation plan and schedule</li> </ul> <ul style="list-style-type: none"> <li>• (Rouse, J and Rouse, P, 1999)(18)</li> </ul> <p>Strategic planning requires adopting a vision for the future. Businesses must heed to the need to protect the natural environment. Manufactures must be environmentally conscious.</p> <ul style="list-style-type: none"> <li>• (Madu, 2007)(19)</li> </ul>	Match
b	Secret	<p>Forecasting is an integral part of the decision making activities of management. There are 3 categories typical of the short, medium and longterm forecasting</p> <ul style="list-style-type: none"> <li>• (Spyros Makridakis <i>et al</i>, 1998) (20)</li> </ul>	Secret
c	SWOT analyze/AHP/Fishbone Diagram (optional based on competency) Life cycle assessment	<p>Scan the environment using aSWOT analysis</p> <ul style="list-style-type: none"> <li>• Rouse, J and Rouse, P (1999)(18)</li> <li>• (Madu, 2007)(19)</li> </ul> <p>SWOT analysis is an acronym for the internal strengths and weaknesses of a firm, and the environmental opportunities</p>	Match

		<p>and threats facing that firm. SWOT analysis is a technique through which managers create a quick overview of a company's strategic situation.</p> <ul style="list-style-type: none"> <li>• (Pearce and Robinson, 2013) (21)</li> </ul>	
		<p>Analytic Hierarchy Process (AHP). The use of AHP as a decision support which can help to clarify problems when comparing alternative choices since it will attach relative importance to different environmental impacts. AHP is a multi-criteria decision method that uses hierarchic or network structures to represent a decision problem and then develops priorities for the alternatives based on the decision makers' judgments throughout the system.</p> <ul style="list-style-type: none"> <li>• (Madu, 2007) (19)</li> <li>• (Saaty, 2008)(22)</li> </ul> <p>Fishbone Diagram. An efficient planning process must include consideration of man, materials, machines and methods and how they could potentially influence environmental burden.</p> <ul style="list-style-type: none"> <li>• (Madu, 2007)(19)</li> </ul>	
		<p>Life cycle assessment is a structural approach to define and evaluate the total environmental load associated with providing a service. It also incorporates development of an inventory of data, impact of materials, products and processes, and improvement analysis aspects.</p> <ul style="list-style-type: none"> <li>• (Madu, 2007)(19)</li> </ul>	Match
d	No Good Corporate Governance	The corporate governance framework should promote	Not Match

	document	<p>transparent and efficient markets, be consistent with the rule of law, and clearly articulate the division of responsibilities among different supervisory, regulatory and enforcement authorities.</p> <ul style="list-style-type: none"> <li>• (Johnston,2004) (23)</li> </ul>	
e	Green Supply Chain Management hasn't entirely practiced	<p>A number of environmentally conscious practices are evident throughout the supply chain ranging from green design (marketing and engineering), green procurement practices(e.g., certifying suppliers, purchasing environmentally sound materials/products), total quality environmental management (internal performance measurement, pollution prevention), environmentally friendly packaging and transportation to the various product end-of-life practices defined by the "Re's" of reduction, reuse, remanufacturing, and recycling. GSCM performance measurement and metrics are critical to all these dimensions of life cycle assessment.</p> <ul style="list-style-type: none"> <li>• Hervani <i>et al</i> (2008) (24) Recycling is a process of converting materials that could have been treated as wastes into valuable resources.</li> <li>• (Madu, 2007)(19)</li> </ul>	Not Match



f	M mill has not practiced ISPO/RSPO/HACCP	<p>Practiced ISPO/RSPO/HACCP</p> <ul style="list-style-type: none"> <li>Peraturan Menteri Pertanian Nomor :19/Permentan/OT.140//3/2011 (Indonesian government policy)</li> </ul> <p>RSPO is a not-for-profit association that unites stakeholders from the seven sectors of the palm oil industry - oil palm producers, palm oil processors or traders, consumer goods manufacturers, retailers, banks and investors, environmental or nature conservation NGOs and social or developmental NGOs - to develop and implement global standards for sustainable palm oil.</p> <ul style="list-style-type: none"> <li><a href="http://www.rspo.eu">www.rspo.eu</a>(25)</li> </ul>	Not Match
	ISO has practiced	<p>ISO 9000 series or ISO 14000 series has been practiced.</p> <ul style="list-style-type: none"> <li>(Madu, 2007)(19)</li> </ul>	Match
	M Mill has Proper Blue Level	<p>Has Proper Blue/gold Level (Indonesian government policy)</p>	Match
g	M Mill has CSR	<p>CSR is concerned with what is –or should be – the relationship between global corporations, governments of countries and individual citizens.</p> <ul style="list-style-type: none"> <li>(Crowder and Aras,2008) (26)</li> </ul>	Match
h	Secret	<p>Core competence implemented.</p> <p>Core competence is a capability or skill that a firm emphasizes and excels in doing, while in pursuit of its overall mission.</p> <ul style="list-style-type: none"> <li>(Pearce and Robinson, 2013) (21)</li> </ul>	Not Known
i	Occupancy, safety and health has not done	Occupancy, safety and health	Not Match

	completely	have been done completely.  (Indonesian government policy)	
j	<i>Eco Efficiency</i> practiced has done	Eco Efficiency practiced. Eco Efficiency are company actions that produce more useful goods and services while continuously reducing resource consumption and pollution. (Pearce and Robinson, 2013) (21)	Match
k	<i>Design for environment</i> practiced has done	Design for the environment is a strategic response to achieving sustainable production. There are designs for recycling, energy efficiency, remanufacture disassembly, disposability, and minimize hazardous material. • (Madu, 2007) (19)	Match

Strategic planning can be started by making a SWOT analysis or scanning the environment by the CPO company. In this analysis, internal and external research of strengths, weaknesses, opportunity, and threat were done. Similarly with what is explained by Madu (2017), determining a policy can be done through making a SWOT analysis/benchmarking by forming teams led by top management, identifying consumer needs through market surveys, and designing consumer needs through Quality Function Deployment (QFD) to convey the consumer aspiration systematically in production planning and the product development phase.

In the CPO company, the implementation of QFD should be integrated with product planning so that green products will be achieved. The management should also pay attention to life cycle assessment. Life cycle assessments are done in order to know how far the CPO mill wastewater will harm the environment or in making environment degradation. For example, a manager's decision to increase CPO production will increase the fresh fruit bought by the company. This matter will have an impact on people's interest in planting palm trees, so the palm plantation area will increase. The opening of palm plantations in swamps, peatland, or forest areas will cause forest degradation. Especially, if the opening is done by burning forest or peatland either intentionally or accidentally. The air pollution will decrease environment quality. Moreover, the amount of waste from the CPO company will either be solid or water and will increase too.

If the wastewater containing BOD<sub>5</sub> and COD are not maintained, the terrestrial and aquatic ecosystem around the mill location will undergo degradation. Therefore, every CPO company must bring a wastewater sample to the agency appointed by the government to be tested (wastewater quality test) every month. The test report will be reported to *BLH (Badan Lingkungan Hidup)* every three months.

Besides the SWOT analysis, the CPO company can make an Analytic Hierarchy Process (AHP). The CPO company can also create a Fishbone Diagram. According to Madu's (2007) statement that a Fishbone Diagram is a cause-effect diagram and can be used to identify the main cause of environment weight from a product or process. This problem solving method is based on the reason that the known main causes are 4 M; man, material, machine, and method. The existence of wastewater containing BOD<sub>5</sub> and COD in CPO mills can be analyzed from the 4 M factors.

After receiving the analysis results, the company can make a strategy to overcome the problem. For example, a company can implement Eco-Efficiency. Pearce *et al* said that there are four key characteristics of eco efficient corporations: eco efficient firms are proactive, not reactive; design in, not added on; flexibility is imperative for eco-efficient strategy implementation; encompassing, not insular (24). Eco-efficiency can be done by the CPO mill in decreasing wastewater amounts during the production process and by improving the recycling process. Wastewater containing high amounts of BOD<sub>5</sub> must be treated, so the company needs to have an IPAL tank with quantity and quality proportional to production capacity.

There are many kinds of wastewater waste treatments that can be done so the water that goes from the outlet to the water body will not harm the ecosystem. However, the mill management must have competence in waste treatment technology chemically and biologically. Application of some treatments must be decided by considering many factors, such as economic income and social welfare. Wastewater treatment technology are quite expensive, so the management must allocate large amounts of money. The high amount of IPAL pools that the company must make requires a high budget and a large area.

Therefore, the company should update their treatment technology to new technology with affordable costs and maximum results. This kind of technology should be informed to all stakeholders, so that in strategic decision making, they have knowledge about environment sustainability.

The CPO M Riau Company have not fully implemented the strategic planning according to the theory, so in the next year, the company cannot achieve 'zero waste'.

## 5. CONCLUSION

- ❖ Neural network can forecast BOD<sub>5</sub> and COD value in CPO millwastewater. BOD<sub>5</sub> have an architecture 2-10-1 and 2-11-1 for COD. In the long term for BOD<sub>5</sub> and COD forecasting, there is a decreasing trend but this has not reached 'zero waste'.
- ❖ Forecasting closely related with the strategic decision-making in the CPO company to increase river water quality.

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