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SIMULATION MODEL OF THERMAL WATER DISCHARGE EFFLUENT FROM THE STEAM ELECTRICAL GENERATING POWER PLANT "TAMBAK LOROK" AT TANJUNG EMAS HARBOR POND SEMARANG

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ABSTRACT

Simulation model is built for simulating the residual chillier which has now become hot water discarded through an outlet to Tanjung Emas harbor pond. The discarded water is called "thermal effluent" and will cause changes in sea temperature in the surrounding areas.

The figuring of the causal relationship among those factors is carried out by developing a subsystem model and building it from the model's subsystems to make a big system. It shows the complexity of the water effluent model. To know the immensity of the effects of each factor and relationship with the simulation of the model. one chooses an approach in the analytical method of dynamic system which uses the program "Powersim version 2.01" copyright 1993 - 1995 by ModellData U.S.A.

The result of model simulation showed that the temperature effect on the physical-chemical characteristics will improve the water condition with diversity index and will decrease according to the temperature condition with respect to time.

Keywords : Simulation model, thermal effluent, diversity index.

I. INTRODUCTION

The policies in the energy sector are an integral parts of national policies as a whole, and are closely related to the growth of the economy, population and the supply of energy.

The growth of economics, the demand for electricity continuously grows from year to year, especially in Java and Bali areas which consumes 80% of Indonesian electricity (Bakoren, 1991). The growth is in accordance to the forecast of electricity growth in the average of 15.5% per year during the fifth Repelita (National five year development planning) and the increase to 17.7% during the sixth Repelita before it decreases to 14.1% in the seventh Repelita.

To fulfill the growing demand of electricity and to improve the service to users, the government of Indonesia had build several steam generated electrical power plant (PLTU), one of which is "*PLTU Tambak Lorok Semarang*".

PLTU Tambak Lorok is a power plant which uses steam as the main force to move the turbine to create electricity. The system is functioning by using sea water as the working liquid. The clean water is turned into steam in the boiler and out from turbine, then being put into a condenser with the chillier from sea water and to turn its thermal water discharged effluent back to sea water. The residual chillier which has now become hot water is discarded through an outlet to Tanjung Emas harbor pond (Sudibyo, et al, 1993). The discarded water is called "thermal effluent" and it will cause changes in sea temperature in the surrounding areas (Burhanuddin. 1988).

In this research, the problem is emphasised on simulation of the dynamic models of thermal effluent system on the physical and chemical characteristics of sea water and aquatic biota in the waste outlet region. If the water effluent is discarded excessively so that it exceeds the tolerance of surrounding sea water body, the waste will be poisonous. It brings the declines in quality of the water in terms of physical-chemical characteristics its, and diversity index of aquatic biota (plankton).

II. STUDY OBJECTIVE

This research intends to capture the idea or to formulate the model of water effluent effect on the physical-chemical characteristic of the water and aquatic biota in a simple way. Furthermore, this research can be used as an inputs for the policy of good management to the Steam Power Plant, so that its environmental impact can be minimised.

III. METHODOLOGY

By way of the simulation of the model, one chooses an approach with the analytical method of dynamic system which uses the program "Powersim version 2.01" copyright 1993-1995 by ModellData, U.S.A. to know the immensity of the effects of each factor and relationship. The relationship among each interacting and affecting factors behaves differently. This shows the complexity of the water effluent model.

To validate model, one uses unit analysis, model simulation in graphics and tables and verifications. In the model simulation on parameters as the starting value one choose the standard quality value according to Kepmen KLH No.Kep.02/Men.KLH/1988 about the sea pollution for fishery. Model verification is done by measuring on the field with 2 samplings at 6 stations in the water at harbor Tanjung Emas (Table 1 and 2).

Table 1. Analysis Water Quality in the Pond of Tanjung Emas Harbor Semarang (Sampling I)

Variable	Dimen-tion	Quality in Station					
		I	II	III	IV	V	VI
1. P-total	mg/liter	0,2103	0,2125	0,0245	0,0522	0,2216	0,4873
2. N-total	mg/liter	2,0392	3,2752	1,1008	1,0962	2,2024	6,5666
3. pH	-	7,8	6,5	7,2	7,5	7,2	8,1
4. Dissolved Oxygen	mg/liter	6,0410	6,1212	5,6244	5,8854	6,0047	4,2164
5. CO2 free	mg/liter	4,2220	5,0624	4,7721	5,0243	4.2651	4,1654
6. BOD_5	mg/liter	2,5522	3,0520	0,8000	0,8000	3,0216	3,6658
7. COD	mg/liter	5,7120	6,8000	1,1160	3,3322	5,2520	9,1262
8.Chlor free	mg/liter	17,02	16,24	22,16	13,16	14,82	14,06
9. Temperature	^0C	30,7	30,7	34,3	29,4	32,4	32,6

Table 2. Analysis Water Quality in the Pond of Tanjung Emas Harbor Semarang (Sampling II)

Variable	Dimen-tion	Quality in Station					
		I	II	III	IV	V	VI
1. P-total	mg/liter	0,1976	0,2125	0,0314	0,0617	0,2664	0,5249
2. N-total	mg/liter	3,1865	3,2752	1,4266	0,9645	2,4353	6,8762
3. pH	-	7,7	6,5	7,5	7,5	7,2	7,8
4.Dissolved Oxygen	mg/liter	6,1467	6,0166	5,1422	5,3506	6,2122	5,0264
5. CO2 free	mg/liter	5,2560	5,1104	4,7428	4,4246	4,8105	5,0126
6. BOD_5	mg/liter	2,6452	3,0520	1,2260	1,2260	3,1954	4,0124
7. COD	mg/liter	8,4216	6,8000	3,1652	3,1652	6,5524	9,7882
8.Chlor free	mg/liter	17,21	16,24	23,08	23,08	14,02	15,11
9. Temperature	^0C	32	32	36,5	31	36	32

Note : Station I : East of harbor pond
Station II : Harbor pond
Station III : Outlet
Station IV : Mouth of outlet
Station V : Intake
Station VI : Near Syah-Bandar

The figuring of the causal relationship among those factors is carried out by developing a subsystem model and building it from the model's subsystems to make a big system. (Figure 1 and 2). From the assumptions in equation taken from several simulation, the model can support the concept of water effluent pollution cycle which affects various the forming of some kind of pollution system (Appendices 1).

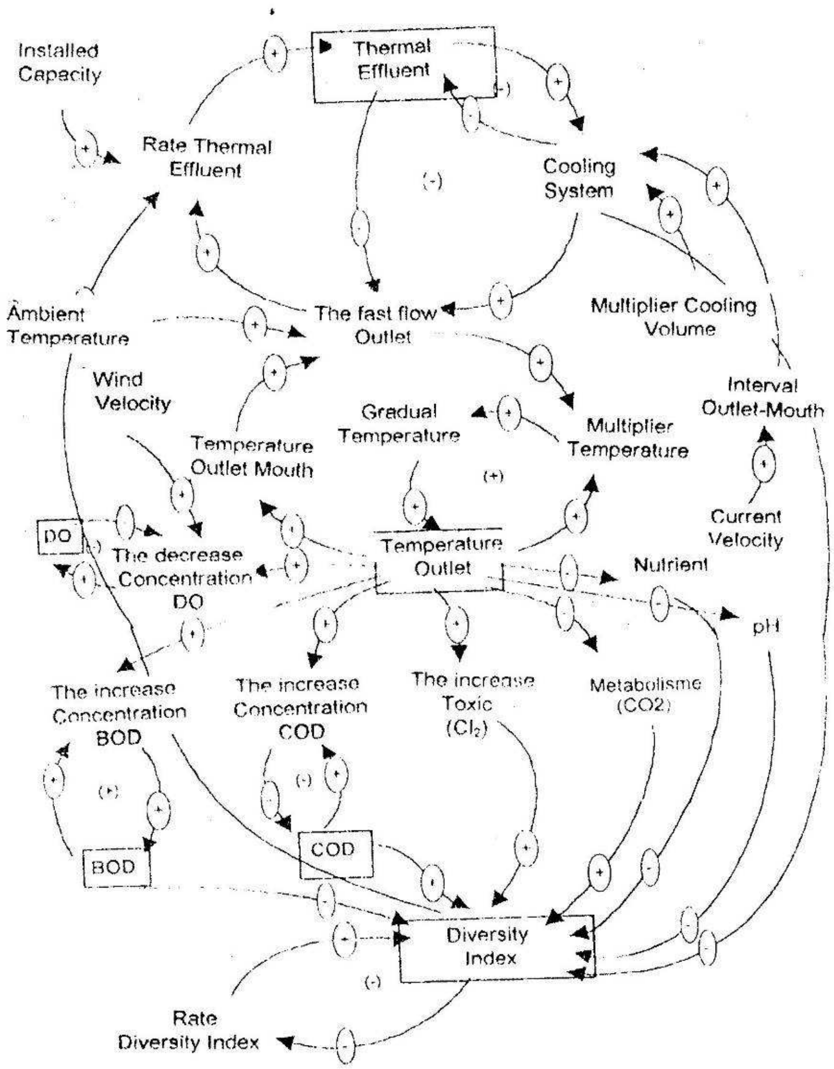

Figure 1. Causal loop diagram of thermal water discharged effluent from the steam electrical generating power plant "Tambak Lorok".

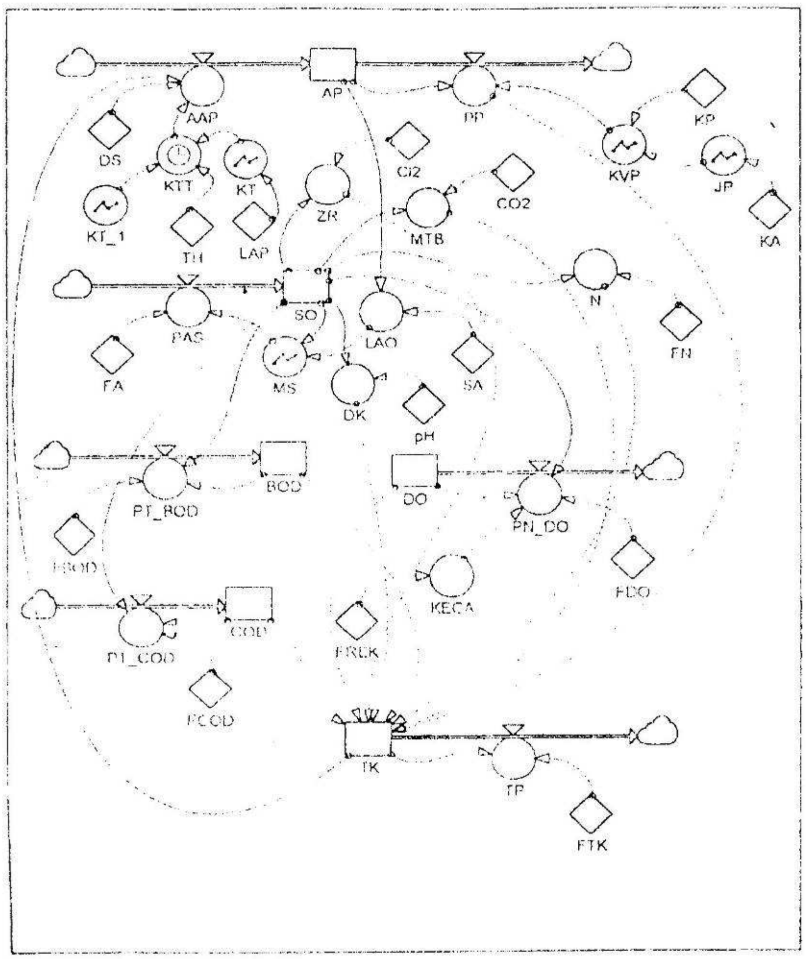

Figure 2. Flow diagram of the relationship of thermal effluent from the steam electrical generating power plant "Tambak Lorok"

IV. RESULTS AND DISCUSSION

Analysis result shows that water effluent discarded into water can change its temperature and becomes higher than the ambient level (30^{0}C) at about 7^{0}C. The water temperature increase affects the oxygen solvability. The higher the temperature, the lower the oxygen solvability, so that the oxygen in the water is weak.

In the dynamic system model simulation produced will be repeated from time to time, at waste temperature equal to 37^{0}C and solved oxygen (DO) equal to 7 mg/l, the diversity index acquired from the simulation is 2.63. It shows the polluted water condition at the middle level (Figure 3.).

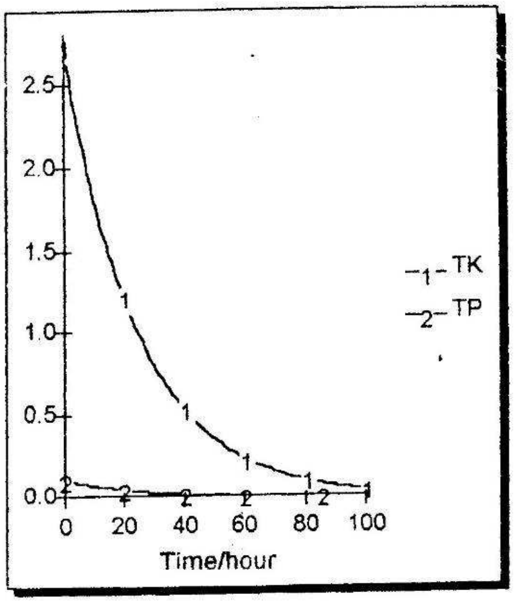

Figure 3.

Curve Diversity Index (TK) and Rate Diversity Index (TP) acquired from the simulation with time

The increase of water temperature causes solved oxygen to decrease, biology oxygen demanded (BOD) to increase, and chemical oxygen demanded (COD) to increase, too. The system of dynamic model simulation with respect to time shows that diversity index affected by information flow from DO, BOD, and COD with the existence of the cooling system is very small, close to 0 (zero). (Figure 4, 5 and Table 3).

This shows that the water biota in the outlet were all died, although when sampled, several kinds of plankton were still found. Considering that plankton is floating, the capture of the plankton may start from the outlet.

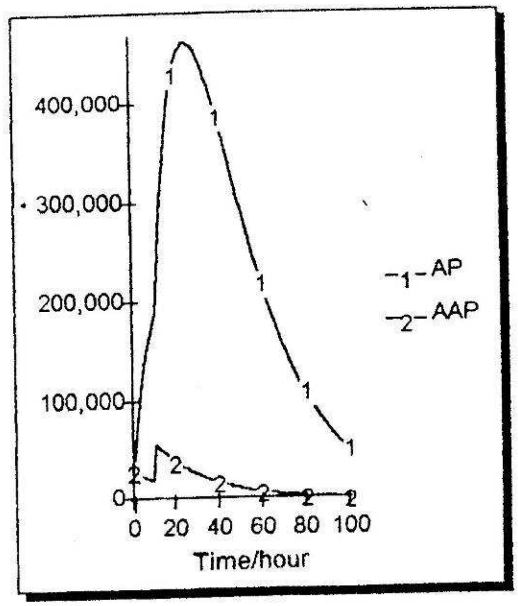

Figure 4.

Curve Thermal Effluent (AP) and Fast Flow Outlet (AAP) with time

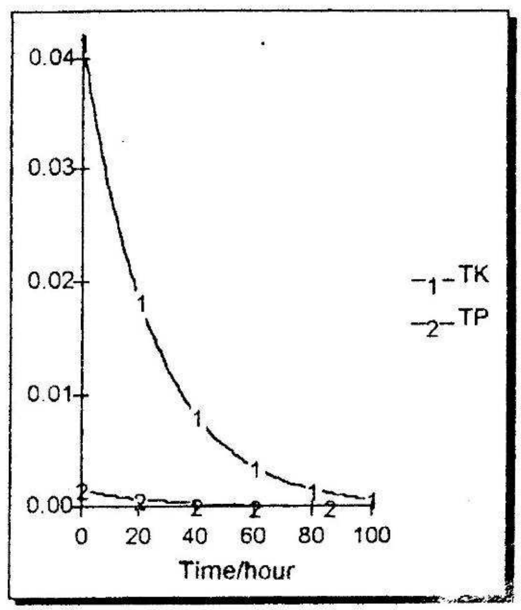

Figure 5.

Curve Diversity Index (TK) and Rate Diversity Index (TP) with ime affected by information flow from DO, BOD, and COD with the exixtence of the cooling system

Table 3. Thermal Effluent, Temperature, DO, BOD, COD and Diversity Index

Time	SO	DO	PN_DO	BOD	PT_BOD	COD	PT_COD	TK	TP
0	37.00	7.00	0.00118	25.00	0.0203	40.00	0.0324	2.7	0.11
1	37.00	7.00	0.00118	25.02	0.0203	40.03	0.0325	2.6	0.11
2	37.02	7.00	0.00118	25.04	0.0203	40.06	0.0325	2.5	0.10
3	37.04	7.00	0.00118	25.06	0.0203	40.10	0.0325	2.4	0.10
4	37.05	7.00	0.00118	25.08	0.0203	40.13	0.0325	2.3	0.09
5	37.07	6.99	0.00118	25.10	0.0203	40.16	0.0325	2.2	0.09
6	37.09	6.99	0.00118	25.12	0.0203	40.19	0.0325	2.1	0.09
7	37.11	6.99	0.00118	25.14	0.0203	40.23	0.0325	2.1	0.08
8	37.12	6.99	0.00118	25.16	0.0203	40.26	0.0325	2.0	0.08
9	37.14	6.99	0.00118	25.18	0.0203	40.29	0.0325	1.9	0.08
10	37.16	6.99	0.00118	25.20	0.0203	40.32	0.0326	1.8	0.07
11	37.18	6.99	0.00118	25.22	0.0204	40.36	0.0326	1.8	0.07
12	37.19	6.99	0.00117	25.24	0.0204	40.39	0.0326	1.7	0.07
13	37.21	6.98	0.00117	25.26	0.0204	40.42	0.0326	1.6	0.06
14	37.23	6.98	0.00117	25.28	0.0204	40.46	0.0326	1.5	0.06
15	37.25	6.98	0.00117	25.30	0.0204	40.49	0.0326	1.5	0.06
16	37.26	6.98	0.00117	25.33	0.0204	40.52	0.0326	1.4	0.06
17	37.28	6.98	0.00117	25.35	0.0204	40.55	0.0326	1.4	0.05
18	37.30	6.98	0.00117	25.37	0.0204	40.59	0.0326	1.3	0.05

The increasing temperature in the pond of Tanjung Emas Harbor because of water effluent, PLTU was thought the main culprit of the decrease of number and kinds of planks in the water. The diversity index measured in the outlet are 1.43 and 1.44 (Table 4 and 5).

Table 4. Kinds of Plankton in the Observed Stations (Sampling I)

No	Organisme	Total Individu per liter					
		I	II	III	IV	V	VI
1.	*Skeletonema sp.*	32	29	11	20	6	8
2.	*Nitzschia sp.*	14	14	3	6	30	9
3.	*Chaetoceros sp.*	8	8	-	5	5	4
4.	*Pleurosygma sp.*	8	8	-	-	-	-
5.	*Rhizosollenia sp.*	7	8	-	4	3	6
6.	*Oscilatoria sp.*	7	7	-	2	2	-
7.	*Surirella sp.*	6	6	-	-	1	-
8.	*Ceratium sp.*	6	5	-	1	2	5
9.	*Thalassiothrix sp.*	3	4	-	-	-	1
10	*Asterionella sp.*	3	-	-	-	-	-
11.	*Peridinium sp.*	2	3	-	-	-	-
12.	*Cyclops sp.*	2	2	-	-	-	-
13.	*Dunalliela sp.*	-	-	2	-	-	-
14.	*Ulothrix sp.*	-	-	1	-	-	-
15.	*Chlorella sp.*	-	-	1	-	-	-
16.	*Melosera sp.*	-	-	1	-	-	-
17.	*Lauderia sp.*	-	-	-	1	1	1
18.	*Rhopaloidea sp.*	-	-	-	-	1	-
19.	*Hemidiscus sp.*	-	-	-	-	1	-
Kinds Total (t)		12	11	7	8	10	7
Total Individu (N)		98	94	20	44	52	35
Diversity Index (H')		2,12	2,10	1,43	1,58	1,49	1,77
Average Index (J)		0,85	0,87	0,73	0,75	0,64	0,90

Table 5. Kinds of Plankton in the Observed Stations (Sampling II)

No	Organisme	Total Individu per liter					
		I	II	III	IV	V	VI
1.	*Skeletonema sp.*	33	30	10	19	6	9
2.	*Nitzschia sp.*	18	16	2	6	28	9
3.	*Chaetoceros sp.*	9	9	-	4	5	4
4.	*Pleurosygma sp.*	9	7	-	-	-	-
5.	*Rhizosollenia sp.*	8	8	-	2	3	5
6.	*Oscilatoria sp.*	7	6	-	1	2	-
7.	*Surirella sp.*	7	-	-	-	1	-
8.	*Ceratium sp.*	7	4	-	-	1	2
9.	*Thalassiothrix sp.*	5	3	-	-	-	1
10	*Asterionella sp.*	6	5	-	-	-	1
11.	*Peridinium sp.*	3	2	-	1	-	-
12.	*Cyclops sp.*	2		-	-	-	-
13.	*Dunalliela sp.*	-	-	2	-	-	-
14.	*Ulothrix sp.*	-	-	1	3	-	-
15.	*Chlorella sp.*	-	-	1	3	-	-
16.	*Melosera sp.*	-	-	-	-	-	-
17.	*Lauderia sp.*	-	7	1	4	3	5
18.	*Rhopaloidea sp.*	-	-	-	-	1	-
19.	*Hemidiscus sp.*	-	-	-	-	1	-
20	*Euchampia sp.*	-	-	1			
Kinds Total (t)		12	11	7	9	10	8
Total Individu (N)		114	97	18	43	51	36
Deversity Index (H')		2,20	2,25	1,44	1,75	1,55	1,83
Average Index (J)		0,88	0,96	0,74	0,80	0,67	0,88

Note : Station I : East of harbor pond
Station II : Harbor pond
Station III : Outlet
Station IV : Mouth of outlet
Station V : Intake
Station VI : Near Syah-Bandar

There were two kinds of plankton found in all the observation stations, namely Skeletonema and Nitzchia which can survive at 37^{0}C. The dynamic system model simulation showed that the temperature effect on DO, BOD, COD, Cl_2, CO_2, nitrogen and pH will improve the water condition with diversity index equal to 1.57, and will decrease according to the temperature condition with respect to time (Figure 6).

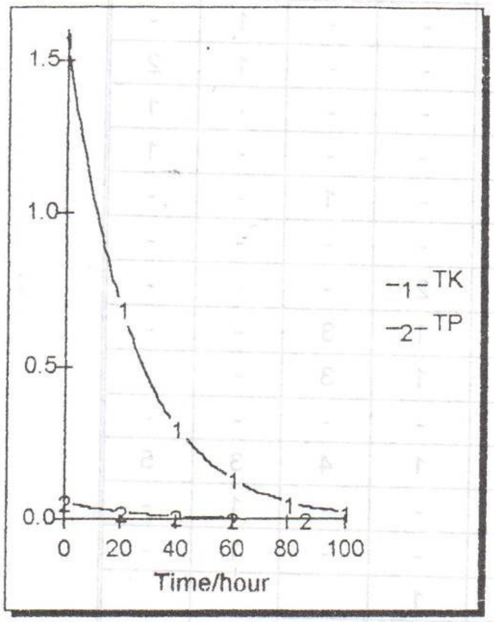

Figure 6.

Curve Diversity Index (TK) and Rate Diversity Index (TP) versus time with that the temperature effect on DO, BOD, COD, Cl_2, CO_2, nitrogen and pH

Increasing the installed capacity to 500 MW causes the water effluent debit to increase 250% which accelerates the increase of water temperature. The increase temperature by 2^{0}C, means that the temperature will be 39^{0}C. This condition causes a re-circulation to the intake. The system of dynamic simulation model shows that the heat increase from the water effluent was faster than before the installed capacity had been increased. In the mean time, the hot water flow shows the stability or "goal seeking" for a relatively long time (Figure 7).

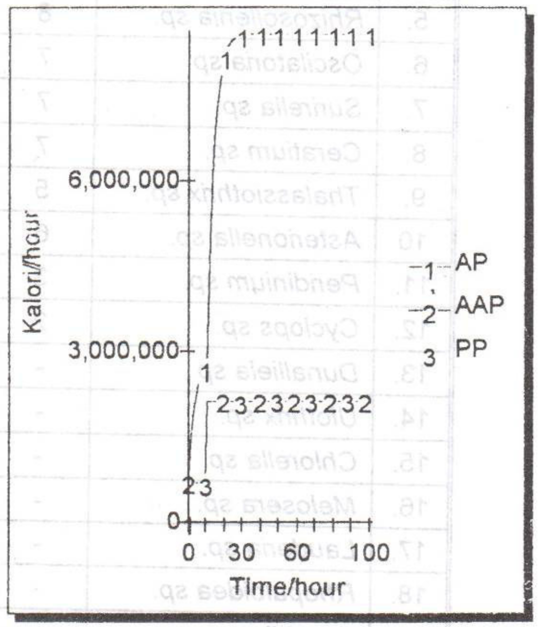

Figure 7.

Curve Thermal Effluent (AP), Fast Flow (AAP) and Cooling System (PP) with time

To maintain a good water condition, the policy taken should be by disconnecting the heat flow (material flow) in the model, which means the water effluent is not discarded in the outlet as is the case in the current situation. The flow disconnection means moving the outlet or the waste channel. Even, according to the result of study conducted together by PLN and UGM, to stop the re-circulation to the intake, the water effluent channel is to be moved to east of the harbor pond. From the natural environment, this is very beneficial because the water effluent will immediately be thinned out by the atmosphere, so that the value of diversity index shows an unpolluted water condition.

V. CONCLUSIONS

The increase of water temperature causes oxygen to decrease, biology oxygen demanded (BOD) to increase, and chemical oxygen demanded (COD) to increase. The system of dynamic model simulation with respect to time shows that diversity index affected by information flow from DO, BOD and COD with the existence of cooling system is very small.

With the increase of temperature in the pond of Tanjung Emas Harbor caused by water effluent, PLTU was thought to be the main culprit of the decrease of numbers and kinds of plankton in the water. There are two kinds of plankton found in all the observation stations, namely *Skeletonema* and *Nitzchia* which survive at 37^0C.

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Appendices 1.

```
init    AP = 0
flow    AP = -dt*PP
        +dt*AAP
doc     AP = Thermal Effluent
init    BOD = 25
flow    BOD = +dt*PT_BOD
doc     BOD = Biology Oxygen Demand
init    COD = 40
flow    COD = +dt*PT_COD
doc     COD = Chemical Oxygen Demand
init    DO = 7.8
flow    DO = -dt*PN_DO
doc     DO = Disolve Oxygen
init    SO = 30
flow    +dt*PAS
doc     SO = Temperature outlet
init    TK = 300/(BOD+COD+DO)+PP
flow    TK = -dt*TP
doc     TK = Diversity index
aux     AAP = (KTT*DS*1020*0.998)*TK
doc     AAP = The hot water flow
aux     PAS = MS*FA
doc     PAS = Temperature outlet flow
aux     PN_DO = (DO/SO)*FDO*KECA
doc     PN_DO = The decrease of DO
aux     PP = AP/KVP
aux     PT_BOD = (BOD/SO)*FBOD
doc     PT_BOD = The increase of BOD
aux     PT_COD = (COD/SO)*FCOD
doc     PT_COD = Fraction COD
aux     TP = TK*FTK
doc     TP = The decrease of diversity index
aux     JP = GRAPH(KA,0,100,[100,200,300,400,500,600,700,800"Min:0;Max:800"])
doc     JP = Gradual temperature
aux     KECA = 1.39*FREK
doc     KECA = Wind velocity
aux     KT = GRAPH(LAP*TIME,1978,2(100,100,100,300,300,300,300,300,300])
doc     KT = The installed capacity
aux     KT_1 = GRAPH(TIME,1997,2[500,500,500])
doc     KT_1 = Increasing the installed capacity
aux     KTT = IF(TIME>=TH,KT,KT_1)
doc     KTT = Addition the installed capacity
aux     KVP = GRAPH(JP*KP,0,2[3,5,7,9,11,13,15"Min:0;Max:20"])
doc     KVP = Multiplier volume
aux     LAO = SA
aux     MS = GRAPH(SO/LAO,0,1,[7,6,5,4,3,2,1"Min:0;Max:7"])
doc     MS = Multiplier temperature
aux     MTB = SO/CO2
doc     MTB = Metabolisme
```

aux	N = SO/FN
doc	N = Nitrogen
aux	ZR = SO/Cl2
const	Cl2 = 0.5
doc	Cl2 = Free chlorine
aux	CO2 = 12
doc	Carbon Dioksida
const	DS = 9
doc	DS = Delta temperature
const	FA = Fraction hot flow
aux	FBOD = 0.03
doc	FBOD = Fraction BOD
aux	FCOD = Fraction COD
const	FDO = 0.03
doc	FDO = Fraction DO
const	FN = 1
doc	FN = Fraction Nitrogen
const	FREK = 0.04
doc	FREK = Fraction diversity index
const	KA = 43.2
doc	KA = Current velocity
const	KP = 0.25
doc	KP = Cooling system
const	LAP = 193.5
doc	LAP = Rate hot water MW/hour
const	SA = 30
doc	SA = Ambient temperatur
const	TH = 1997
doc	TH = The year increasing the installed capacity