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THE POTENTIAL USED OF EPIPELIC DIATOM AS BIOINDICATOR OF WATER QUALITY: part I

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ABSTRACT

Biomonitoring methods for water quality, such as coli form content, diversity and evenness indices of macrobenthic invertebrates and plankton which are recently used, actually have some weaknesses. Escherichia coli *only indicated pollution caused by faecal coli; macrobenthic invertebrates have not ability to live in all substratum, whereas the population of phytoplankton are affected by current as they are floating in the surface water. Therefore, the method which are more effective have to be developed. Epipelic diatoms have potential characteristics as bioindicator of water quality because they have ability to accumulate physico-chemical component of aquatic ecosystem and respond it immediately.*

This research is conducted in order to find out a new alternative of biomonitoring method (: species indices of diatoms) which are more significant, effective and efficient by determine water quality map based on diatoms and determines the species which responsible to the grouping.

Sediment samples were taken from 7 rivers in the Northern Coast of Central Java (called Pantura): Karanggeneng-Rembang, Juana-Pati, Banjir Kanal Timur-Semarang, Banjir Kanal Barat-Semarang, Banger-Pekalongan, Pekalongan-Pekalongan and Gung-Tegal. Temperature, dissolved oxygen, salinity, pH and turbidity were measure in-situ. *Analysis of water and sediment samples include total nitrogen, total phosphorous, silica, heavy metals of Cu, Cr and Cd. Extraction, preparation and identification of diatoms followed Wetzel & Likens (1991) and Round (1993). The data were then analysed using Primer package programme version 4.0 which is produced by Plymouth Marine Laboratory, United Kingdom (Carr, 1997). The Multi Dimentional Scaling (MDS) ordination was done to make grouping and was followed by SIMPER analysis to determine responsible species (Clarke & Warwick, 1994).*

Based on diatom community, 7 rivers in Pantura could be divided into 3 groups: Group I, consisted of Gung and Pekalongan Rivers, Group II of Banjir Kanal Timur, Barat and Banger Rivers and Group III of Karanggeneng and Juana Rivers. Synedra ulna *was responsibled for those grouping and are therefore could be promoted as bioindicator of water quality in the Indonesian river. Research still should be developed, especially for diatoms in the bottom layer of sediment samples to reconstruct ecological condition in the past and to predict the condition in the future.*

Keywords: diatom, epipelic, bioindicator, water quality

I. INTRODUCTION

Monitoring on the environmental changes has been carried out using indicators, which change when environmental conditions are altered. Traditional indicators of water quality have been the physical and chemical parameters of the water column. Physical parameters, such as water temperature, water flow, pH, hardness have marked impacts on the expression of toxicity and obviously site specific (Cairns & van der Schalie, 1980; Horowitz, 1990; Loeb, 1994). Furthermore, the chemical characteristics such as turbidity, pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nutrients and heavy metals only provide an information of water quality at a given time. The value of physico-chemical indicator are therefore, affected by time and sampling site (Horowitz, 1990). Many pollutants are however, often present through synergism, their effects can be cumulative, exacerbating the impact of individual pollutants on biological systems. Potential pollutants can adversely affect biological processes below level detectable by chemical analysis and this analysis can not assess the biological consequences of these toxicants on the environment (Root, 1990; Loeb, 1994). Therefore, biological indicators have to be applied as they were more express ecosystem stability in a longer period.

Biomonitoring is important since the communities of organisms integrate the effect of all physical and chemical characteristics of waters and might be able to indicate the type of pollutant. However, up to this time, biomonitors being used: macrobenthic organisms, plankton and *Escherichia coli* (Government regulation No. 20, 1990 about Environmental Standard) have some weaknesses. Macrobenthic organisms only found in the specific substrate (Nybakken, 1988; Astuti, 1990), plankton are floating on the water, current are, therefore, very influence their population (Reynolds, 1990; Soeprobowati *et al.*, 1994; Soeprobowati, 1996). The diversity indices of macrobenthics and plankton reflect the changes in ecosystem structure only in a stress period and could not differ stress and health community (Ramade, 1995). The domination of one species will drop diversity index value (Soeprobowati *et al.*, 1993; 1994). *Escherichia coli* expresses coli-form concentration in the water (Suryawiria, 1991). Those weaknesses induce ineffective and inefficient monitoring program, therefore a significant method have to be fully developed to accurately identify the water quality and in turn to protect or to restore the ecosystem health.

To answer this challenge, research on biological indicator has to be developed. Diatoms meet all requirement to be used as bioindicator because diatoms are the most abundant algae, have wide spread distribution, have the important role in the food web, have diverse assemblages, colonising in all available surface therefore record habitat history, have simple life cycles stage, some species are sensitive to environmental changes and therefore reflect the changes in water quality both in a short or longer period, easily in taking and handling samples and identifiable (Round, 1993; Patrick, 1994; John, 1996; Lowe & Pan, 1996; Stevenson *et al.*, 1996). Research on the use of diatom as bioindicator of water quality have been developed recently (Patrick, 1994; House *et al.*, 1995; John, 1996;

Nomboro, 1996; Stevenson *et al.*, 1996).

Diatoms monitor the aquatic ecosystem continuously as they integrate physical and chemical parameters shortly, therefore all the weaknesses of methods that have been used (as state in Indonesian Environmental Standard) could be eliminated. No doubt of the potential use of diatoms in monitoring changes in water quality because they integrate physical and chemical parameters of the water (Sabater *et* al., 1987; John, 1993; Progiel & Coste, 1993; Round, 1993; van dam & Mertens, 1993; Soeprobowati, 1998). A study of epipelic diatoms community in relation to their niches and water quality should be conducted to establish indicator species for all type of rivers (Round, 1993).

II. MATERIAL AND METHODS

2.1. Sites Area

Sediment samples have been collected from seven in the Northern Coast of Central Java (Called Pantura), including Gung (Tegal), Banger (Pekalongan), Pekalongan (Pekalongan), Banjir Kanal Barat (Semarang), Banjir Kanal Timur (Semarang), Juana (Pati) and Karanggeneng (Rembang) rivers (Figure 1).

Industrial development in the Northern coast areas of Central Java sharply increased since 1980s. In Tegal, food, leather, textile, metal plating industries discharge the waste to the Gung River. Gung River had been moderately polluted by organic and heavy metals pollutant (Bappeda Tk I Jawa Tengah & Balai Penelitian dan Pengembangan Industri Semarang, 1988). Pekalongan and Banger Rivers flow to the Pekalongan city, which receive discharge mostly from textile industries.

Banjir Kanal Barat and Banjir Kanal Timur Rivers flow throw Semarang city have 37,333.83 ha of catchment area. There are a lot of industries in Semarang, such as pharmaceutical, textile and electroplating industries as well as domestic and city sewage, all contribute on high heavy metals concentration.

Juana River in Pati and Karanggeneng River, Rembang are chosen as reference sites as their condition are more pristine than others. Sewage that discharge to these rivers are mostly from agriculture industries and domestic sewage.

This research was conducted for 2 years. Three sampling periods were on April 1998, August 1998 and April 1999. However, in this paper only presented data of April 1998 on surficial sediment sample.

Sediment samples were collected using modified core barrel approximately 20 cm in 2 sites at each river. The sites were chosen in the area which had the best of sedimentation process, no effect of tide, low turbulent and had lacustrine conditions. *In-situ* measurement of physical and chemical parameters including pH, salinity, temperature, dissolved oxygen and turbidity.

The organic matters in sediment were eliminated with nitric acid and potassium dichromate (Wetzel & Likens, 1991). Distilled water was added to neutralise acid until the pH was 7. The washed frustules were mounted in Naphrax and examined by optical microscope at 400 - 1000 magnification. In each sample, an average of 100 valves were counted in order to establish the relative abundance of the species (Round, 1993).

Phosphate, ammonia, Silica, heavy metals of cadmium, chromium and cooper concentrations were measured in the Laboratory both in the water column and sediment (American Public Health Association, 1992). Water, dry matter percentages, the amount of organic matter concentrations were determined as well as sedimentary pigment degradation units (Wetzel & Likens, 1991).

The data were than analysed using Primer programme version 4.0 which is produced by Plymouth Marine Laboratory, United Kingdom (Carr, 1997). The distribution mapping of diatoms based on the relative abundance is shown by Multi Dimentional Scaling (MDS) ordination. SIMPER (Similarity percentage) analysis was than run to determined the species that responsible for sample groupings observe in a MDS ordination (Clarke, 1993).

III. RESULT AND DISCUSSION

3.1. Water Quality

Gung River has the worst water quality than the other rivers (Table 1). The dissolved oxygen (DO) and cooper concentrations exceed Indonesian water quality standard for all purposes in Central Java. Chromium (Cr) concentration exceeds Standard for drinking water. NH_4-N and turbidity in Gung River show the highest concentrations (3,11 mg/L and 18.01 NTU, respectively).

High phosphorus concentration is found in Banjir Kanal Timur, Banir Kanal Barat and Banger Barat Rivers (more than 25 mg/L) and categorised as eutrophic, whereas the other rivers are mesotrophic (Forsberg & Ryding, 1980).

Table 1. Water quality of some rivers in the Northern Coast of Central Java, April 1998.

PARAMETER	UNIT	KRG	JUANA	BKT	BKB	BANG	PKL	GUNG
Conductivity	µS/cm	62.30	38.90	22.10	21.60	53.21	10.00	32.60
Temperature	°C	31.00	30.50	32.00	28.00	30.00	28.00	28.00
DO	mg/L	6.98	6.00	3.15	7..13	2.9	8.30	1.53
pH		7.89	7.60	7.62	8.31	7.9	7.50	7.45
Salinity	ppt	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Turbidity	NTU	16.60	16.52	16.85	18.79	5.93	11.80	18.01
Velocity	det/m	3.33	6.67	5.33	5.33	5.12	4.60	2.60
Transparency	cm	25.00	15.00	5.00	10.00	10.00	45.00	15.00
Nitrogen	mg/L N	2.00	2.13	2.19	2.48	1.43	2.03	3.110
Phosphorus	mg/L P-PO_4	16.72	21.02	33.87	31.54	32.54	24.53	20.04
Silica, SiO2	mg/L SiO_2	17.00	25.00	48.00	30.00	29.14	12.00	15.00
Cooper	mg/L Cu	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	0.012
Chromium	mg/L Cr	<0.02	<0.02	0.04	0.020	<0.02	0.030	0.110
Cadmium	mg/L Cd	<0.002	<0.002	0.008	<0.002	<0.002	<0.002	<0.002

Figure 1. Location of the sampling sites.

3.2. Sediment Chemistry

The concentrations of nitrogen, phosphorus, silica, cooper, chromium and cadmium on the sediment are higher than in the water column as result of accumulation process. Banjir Kanal Timur River has the highest accumulation of N, Cu and Cd of 499.85 mg/L, 22.3 mg/kg and 0.8 mg/kg, respectively. Gung River has the highest Phosphorus and Chromium concentrations of 226.09 mg/kg and 14.2 mg/kg. The highest Cadmium concentration (1.05 mg/kg) is found at Banger River, is followed Banjir Kanal Timur, Pekalongan and Gung Rivers (0.8 mg/kg, Table 2).

Table 2. Sediment concentrations of Nitrogen, Phosphorus, cooper, chromium and cadmium of some rivers in the Northern Coast of Central Java, April 1998.

	Unit	KRG	JUANA	BKT	BKB	BANG	PKL	GUNG
Nitrogen	mg N / kg	145.11	109.72	499.85	195.06	85.3	217.01	487.66
Phosphorus	mg P / kg	143.48	165.22	147.83	104.35	134.67	191.30	226.09
Silica, SiO_2	% SiO_2	35.41	35.71	31.40	34.79	71.32	51.02	33.72
Cooper	mg Cu / kg	8.00	13.20	22.30	11.50	4.7	11.90	16.90
Chromium	mg Cr / kg	4.20	5.50	7.20	6.70	1.6	6.50	14.20
Cadmium	mg Cd / kg	0.20	0.60	0.80	0.60	1.05	0.80	0.80
water content	%	23.05	40.65	42.55	57.80	38.6	38.86	52.97
ash	%	71.19	54.27	51.88	33.67	51.99	54.82	39.39
organic matter	%	5.77	5.08	5.66	8.53	9.93	6.31	7.64
SPDU	gr/dry weight	3.14×10^{-6}	3.93×10^{-6}	4.12×10^{-6}	5.97×10^{-6}	2.88×10^{-5}	2.9×10^{-6}	3.24×10^{-6}

SPDU = sedimentary pigment degradation units.
KRG = Karanggeneng River - Rembang
JUANA = Juana River - Pati
BKT = Banjir Kanal Timur River - Semarang
BKB = Banjir Kanal Barat River - Semarang
BANG = Banger River - Pekalongan
PKL = Pekalongan River - Pekalongan
GUNG = Gung River - Tegal

3.3. Diatoms Communities

Gung and Pekalongan Rivers cluster into Group I as well as Banjir Kanal Barat and Banger Rivers as Group II. Banjir Kanal Timur River is positioned in between Group I and II. Karanggeneng and Juana Rivers are mapped in a distance with others (Figure 2). Karanggeneng and Juana Rivers are far from the others. As reference sites, it supposes to be differed with others. Those rivers are in the opposite direction as the uses of catchment area are different. Most of Karanggeneng catchment are rural and agricultural areas, whereas Juana River are fisheries area. Forty diatoms species which have the relatives abundance more than 1% are found at 7 rivers in Northern Coast of Central Java. The communities of *Achnanthes lanceolata, A. minutissima, Caloneis bacillum, Cocconeis placentula, Mastogloia elliptica, Navicula binodis, Rhoicosphen ia curvata* and *Surirella biseriata* are only found at Karanggeneng and Juana Rivers.

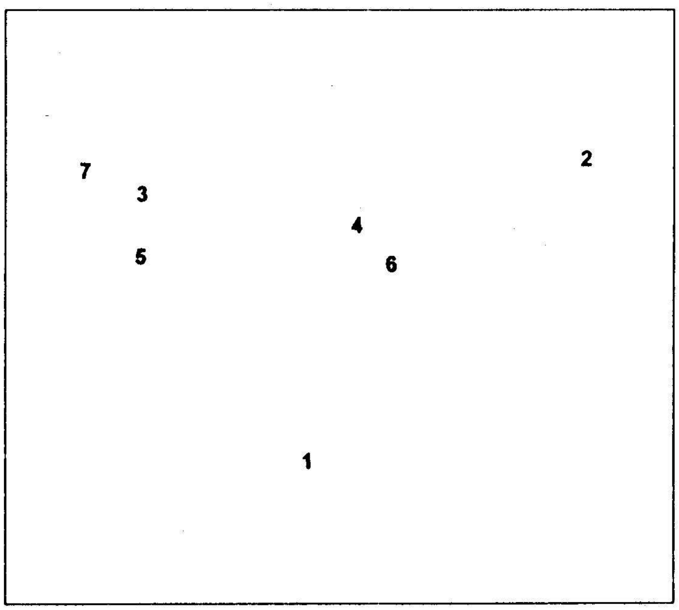

Figure 2.

Two dimentional ordination of 7 rivers in Northern Coast of Central Java from non-metric multi-dimentional scaling (MDS). Stress = .06.

Table 3. Species that responsible on grouping sites of 7 rivers in the Northern Coast of Central Java.

No.	Species	Average Abundance	Average	RATIO	Percent	Cumulative percent
1	*Synedra ulna*	15.96	10.7	2.17	34.00	34.00
2	*Nitzschia palea*	9.84	2.6	.71	8.19	57.33
3	*Navicula bacillum*	4.96	2.4	1.25	7.78	65.11
4	*Gomphonema ventricosum*	4.41	1.4	.59	4.54	69.65
5	*Nitzschia linearis*	4.77	1.4	.47	4.32	69.65
6	*Diatoma vulgare*	2.53	.9	.62	2.73	73.98
7	*Navicula cryptocenphala*	2.25	.8	.89	2.71	76.70
8	*Fragillaria virescens*	3.00	.8	.52	2.66	79.41
9	*Navicula mutica*	1.58	.6	.60	2.02	82.07
10	*Pinnularia gibba*	1.21	.6	.77	1.69	84.09
11	*Navicula fragillaroides*	2.98	.5	.34	1.33	85.78
12	*Navicula geoppertiana*	1.48	.4	.34	1.10	87.11
13	*Mastogloia elliptica*	1.73	.3	.28	1.03	88.22
14	*Tabellaria flocculosa*	1.20	.3	.59	1.02	89.25
15	*Amphora ovalis*	1.38	.3	.50	.98	90.27
16	*Gomphonema augur*	.63	.3	.69	.83	91.25
17	*Nitzschia spectabilis*	1.51	.3	.30	.80	92.08
18	*Pinnularia viridis*	1.95	.3	.51	.79	92.88
19	*Gyrosigma acuminatum*	.6	.2	.46	.56	93.68
20	*Cymbella tumida*	2.06	.2	.36	.50	94.23
21	*Gomphonema parvulum*	.78	.2	.45	.50	94.73
22	*Frustulia vulgaris*	1.04	.2	.51	.48	95.23
23	*Caloneis bacillum*	.82	.0	.52	.48	95.71
24	*Surirella ovata*	.79	.1	.44	.47	96.65
25	*Fragillaria cappucina*	.68	.1	.39	.44	97.09
26	*Cymbella minuta*	.81	.1	.27	.42	97.51
27	*Rhoicosphenia curvata*	.48	.1	.40	.42	97.93
28	*Eunotia exigua*	.48	.1	.53	.38	98.31
29	*Gomphonema lanceolatum*	.97	.1	.28	.37	98.68
30	*Navicula binodis*	.52	.1	.61	.28	98.96
31	*Cocconeis placentula*	.87	.1	.34	.22	99.18
32	*Gyrosigma scalproides*	.39	.1	.39	.20	99.38
33	*Meridion circulare*	.28	.1	.38	.16	99.55
34	*Cymbella affinis*	.79	.0	.22	.13	99.68
35	*Achnanthes minutissima*	.65	.0	.22	.11	99.80
36	*Navicula krasskai*	1.83	.0	.22	.10	99.90
37	*Surirella biseriata*	.35	.0	.22	.09	99.99
38	*Hatzschia amphioxus*	.10	.0	.22	.01	100.00

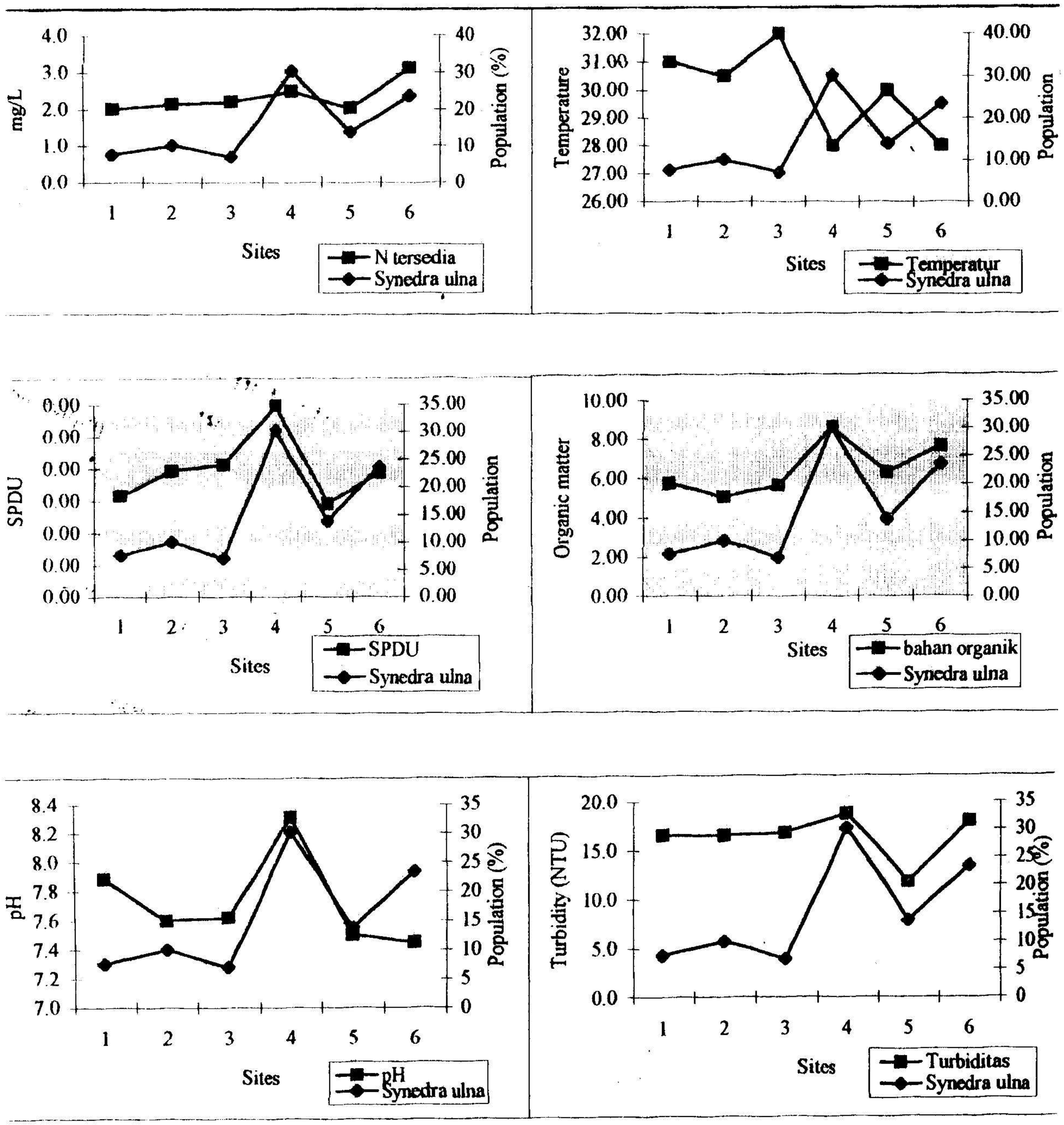

Figure 3.

The relationship of the relative abundance of *Synedra ulna* with water quality

Pekalongan and Gung Rivers are clustered into Group I as well as Banjir Kanal Barat and Banger Rivers as Group II. It seems to be that Banjir Kanal Timur River is closer to Group I rather than Group II. The stress of 0.06 in MDS indicate a good ordination with no real risk of inferences (Clarke, 1993). Those grouping is related to the qater quality (Table 1).

Synedra ulna was responsible on that grouping as it has the ratio of 2.17 (Clarke & Warwick, 1994) in the SIMPER analysis (Table 2). There is a relationship of *Synedra ulna* and water quality (Figure 3). An increase on Total N, turbidity, SPDU and organic matter followed by an increase of *Synedra ulna* population. However, an increase of temperature causes a decrease in its population.

The result presented was rough as it was the earlier result gain from 2 years research and the analysis that had been done was focused on the surficial layer of sediment. However, based on the SIMPER analysis and trend from Figure 3, it seems to be that *Synedra ulna* could be used as bioindicator of water quality as stated by Soeprobowati *et al.* (1993). *Synedra ulna* is one of the most tolerant species to pollution (Lange-Bertalot, 1979) and indicates mesotrophic condition of the waters (Leclercq, 1988; Round, 1993). Such species are, however, have to be considered although their ratio less than 1.4. Those algae are *Nitzschia palea, Navicula bacillum, Gomphonema ventricosum, Diatoma vulgare, Navicula cryptocephala, Fragillaria virescens, Navicula mutica, Pinnularia gibba, Tabellaria flocculosa, Amphora ovalis, Gomphonema augur, Pinnularia viridis, Frustulia vulgaris, Caloneis bacillum, Eunotia exigua* and *Navicula binodis.* Soeprobowati *et al.* (1998) found that *Pinnularia, Meridion* dan *Cymbella* are the dominant species at Banjir Kanal Barat estuarine Semarang.

IV. CONCLUSION

Monitoring program of water quality may use diatoms as bioindicator. Gung and Pekalongan Rivers cluster into Group I, Banjir Kanal Timur, Barat and Banger Rivers as group II. Meanwhile Karanggeneng and Juana Rivers are in a distance with others. It seems that *Synedra ulna* is tolerant species and could be used as bioindicator of water quality.

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