WATER QUALITY IN MADURA STRAIT, INDONESIA

M. Saleh Nugrahadi and Tetsuo Yanagi

ABSTRACT

Observations on water quality based on physical chemical and biological properties of sea surface water were conducted on 13-14 September 2000 and on 14-15 May 2001 in Madura Strait, Indonesia. Particular emphasis has been placed on Surabaya and Porong estuaries and its surrounding coastal water, where rivers carry contaminated load from land and debouch. The observation showed that Madura Strait received a lot of pollutant from the rivers.

Key words: *water quality, Madura Strait, Porong river, Surabaya river, estuary*

I. INTRODUCTION

Madura Strait lies between East Java, Madura Island, and Bali Strait (Fig. 1). It is connected to the Java Sea through the narrow, shallow channel around 20 km long, less than 15 km wide and four meter deep, and Surabaya Harbor is situated at the center of this channel. Surabaya is the second biggest city in Indonesia and the main harbor in the eastern part of Indonesia. In the southern part there is an electric power plant. Madura Strait is a shallow water area with depth ranging between 1-60 m. The water depth near land is 1-5 meters, and deepens toward eastward. The steep area exists between Madura and Kambing islands (Fig. 2).

This strait has been used for fishing, sea transportation, and shrimp cultivation. Madura Strait is located at the downstream area of the Brantas river that diverges into the Surabaya river which passes through the heart of city of Surabaya and the Porong river which is built as flood control canal. The freshwater discharge of these two rivers varies seasonally. The Surabaya river input in 1997 (Fig. 3) was 19.4 m^3/s during the dry season (average from April to September) and 45.9 m^3/s during the wet season (average from October to April). Meanwhile, the Porong river input was 15.4 m^3/s during the dry season and 106.0 m^3/s during the wet season.

Wrigley and Widjanarko (1999) reported that there were many domestic and industrial sources of pollution in the Brantas river catchment. A total 13.72 million people or 42% of East Java population presently live in the basin. Additionally, there are numerous industries in the Brantas river basin, and many of them are potential polluters of the river. Due to the pressure from industry, agriculture and urbanization, the Brantas River becomes heavily polluted, threatened by flood and draught. Afterward, the water that flows into the estuary causes pollution of heavy metal (esp. mercury). However, Rochyatun (1999) showed that the environmental quality of the Porong estuary became better based on 3 years (1992-1994) investigation. During those years, DO increased but COD decreased. On the other hand, there are several fish and shrimp ponds along the coast between the Surabaya estuary and the Porong estuary. At the moment those ponds were abandoned due to fish disease called "white spot disease ".

In this work the impact of river discharge on the estuary area and its adjacent waters is investigated.

II. METHOD OF RESEARCH

Field observations were carried out on 13-14, September 2000, and on 14-15, May 2001 in the Madura Strait, East Java Indonesia. The sampling period represented the transition period between wet and dry season (May) and the end of dry season (September). Eleven points were selected around the two estuaries of Surabaya and Porong rivers and its surrounding coastal water for collecting sea surface water (Fig. 1). Those samples were analyzed in the

Fig. 1. Situation site of Madura Strait

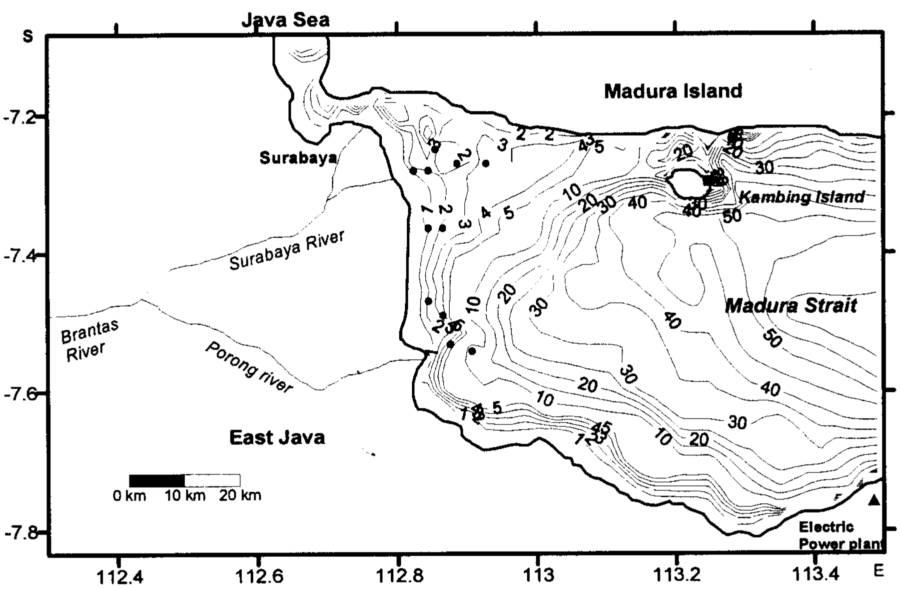

Fig. 2. Study area and bottom topography. Numbers show the depth in meter

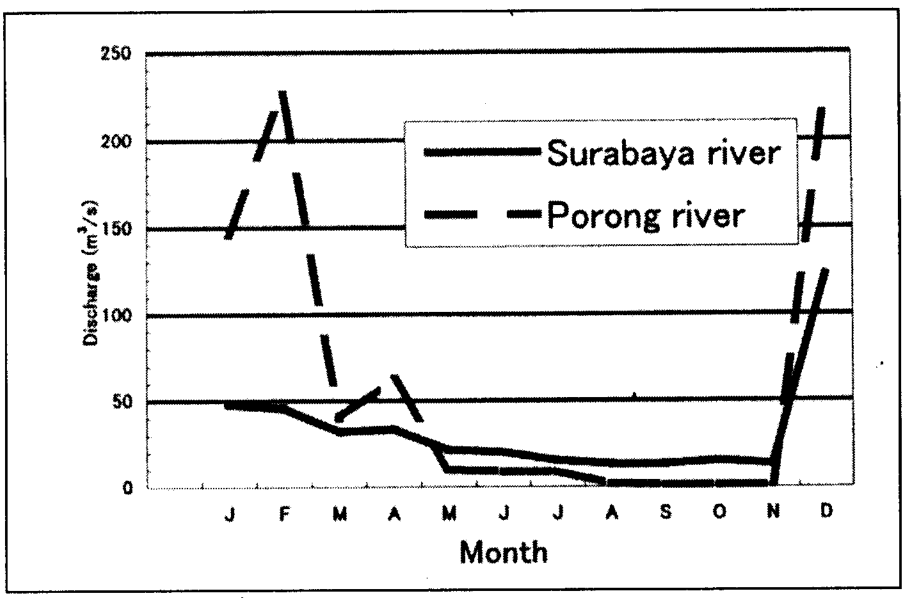

Fig. 3. Discharge of Surabaya River and Porong River in 1997

field or laboratory. Water temperature was measured directly in the field by thermometer, salinity by salinometer and density was calculated from temperature and salinity by using the program based on UNESCO Sea Water Properties Standard. Chemical and biological parameters were measured in the laboratory. Total suspended solid (TSS) was measured by gravimetric method. Nitrate (NO_3), silicate (Si) and phosphate (PO_4) were measured by spectrophotometric method (Parson et al., 1984). Chromium (Cr) was measured by atomic absorption spectrophotometer method (Ernest and Billings, 1967).

III. RESULT

3.1 Water Temperature and Salinity

Sea surface water temperature (SST) distributions in both periods (Fig. 4) show relatively high SST in offshore area and low SST in near shore area. This is obviously due to the effect of freshwater discharge from both rivers. SST in September 2000 that was ranging between 27 and 31°C, was higher than that in May 2001 that was ranging between 26 and 30°C. 0In September 2000, salinity was between 10 and 35 psu and that in May 2001 was between 5 and 27 psu. Temperature and salinity distributions affected density distribution. Water density in September 2000 was higher than that in May 2001. In September 2000, density was between 4 and 20 and that in May 2001 was between 14 and 17. In Indonesia, September is the end of dry season or transition season between dry to wet monsoon. The daily average air temperature in Surabaya is between 28°C-33°C in September. In contrast, May is the end of wet season hence the air temperature was lower than that in September. This situation also happened to SST in the Madura Strait. In addition, freshwater discharge from the Surabaya and Porong rivers decreased salinity in May 2001. It is clearly visible in salinity and density levels in the area near the mouths of Surabaya and Porong rivers, which were lower than those in the other area of the coastal water.

3.2 TSS and Cr

The effect of seasonal variation of precipitation on Total Suspended Solid (TSS) is obviously visible in Fig. 7. TSS was ranging between 50-350 mg/l in September while in May it was ranging between 110-350 mg/l. Such high value in May can reduce the penetration of sunlight through the water column and may reduce the biological activity of aquatic organism. General value of TSS concentration in East Java rivers is below 100 mg/l (Wrigley and Widjanarko, 1999). Causes of high turbidity in East Java are as follows: unconsolidated nature of the surface soils of East Java, lost of forested areas particularly on critical lands, high agricultural activity in the catchment and high rate of disturbance by human settlement.

The major source of water and sediment for the Surabaya and Porong estuaries is the Brantas river.

The Porong river is almost entirely controlled by man because it was build as a flood control during the wet season.

In the dry season the water is diverted to the city of Surabaya through the Surabaya river, while in the wet season the flow is concentrated to the Porong river in order to avoid flood in Surabaya. Therefore, the freshwater discharge between two rivers varies seasonally. This fact is shown by the distribution of TSS. In May, high concentration of TSS is only seen near the Porong river, while in September, high concentration of TSS is seen not only in the Porong river but also in the Surabaya strait. However if we notice the high concentration of TSS existed during both season around Porong estuary even though river discharge in Porong river during dry season was low. Since the coastal water area in the study area is shallow and muddy, the coastal water becomes turbid due to wind waves that make resuspension of the sediment occurred.

The only heavy metal that was analyzed is Chromium (Fig. 8). Cr distribution in September was ranging between 0.03 and 0.06 mg/l while in May it was ranging between 0.12 and 0.15 mg/l. Cr concentration in May was higher than that in September. Even though Cr concentration in September was lower than that in May, it was distributed widely in the vicinity of the Surabaya estuary.

3.3 Nutrients

As mentioned before, the freshwater load from two rivers varies seasonaly. Therefore it also affects the distribution of nutrients in the western part of Madura Strait. Wrigley and Widjanarko (1999) stated that sources of nutrient in the rivers of East Java were from untreated or septic sewage. The other source of phosphate is the phosphorus attached to the soil particles or river sediments. Nutrients distributions revealed significant differences in both periods (Fig. 9,10,11). In September 2000 nutrients distribution varied in 10-28 mM for nitrate (Fig.9), 20-100 mM for silicate (Fig. 10) and 40-140 mM for phosphate (Fig. 11). Nutrients distributions in May 2001 showed variation in 30-80 mM for nitrate (Fig.9) and 50-200 mM for silicate (Fig. 10) and 50-250 mM for phosphate (Fig. 11). Nutrient concentration in May was higher than that in September. The river discharge into the Madura Strait brings more organic waste in May than in September and nutrient concentration in May was higher than that in September. Only the phosphate concentration in May shows higher concentration in offshore but the reason is not clear.

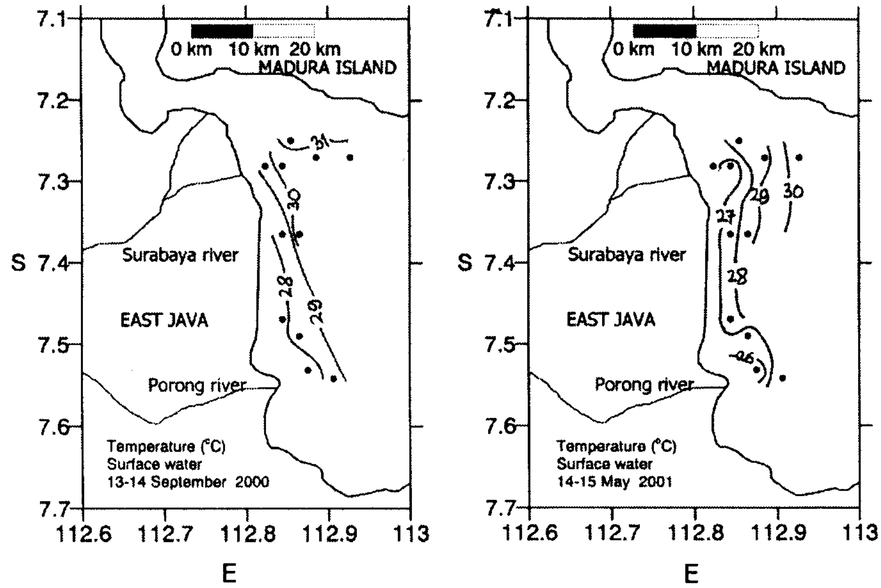

Fig. 4. Temperature of surface water

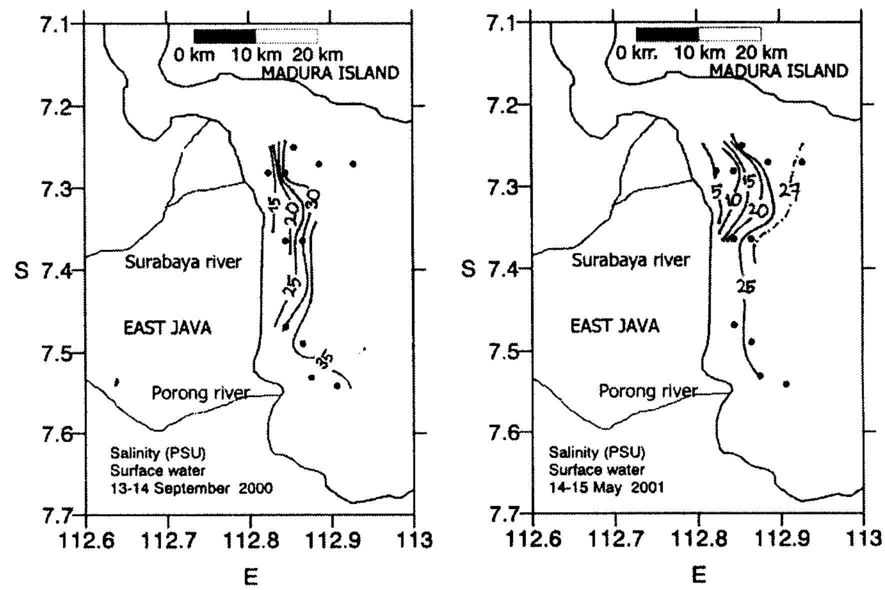

Fig. 5. Salinity of surface water

IV. DISCUSSION

If we notice Figs. 4-12, it is clearly visible that the distribution pattern of water quality changes seasonally. Monsoon wind generates a seasonal flow pattern arounds the island of Java and Madura (Hoekstra et al., 1989). During the dry season, southeasterly wind is dominant and drives the westward flow. In the contrary, during the wet season, northwesterly wind is dominant and drives the eastward flow. The southeastern or eastern monsoon (May-September) creates a western drift with residual flow. However, the observation data that we have here did

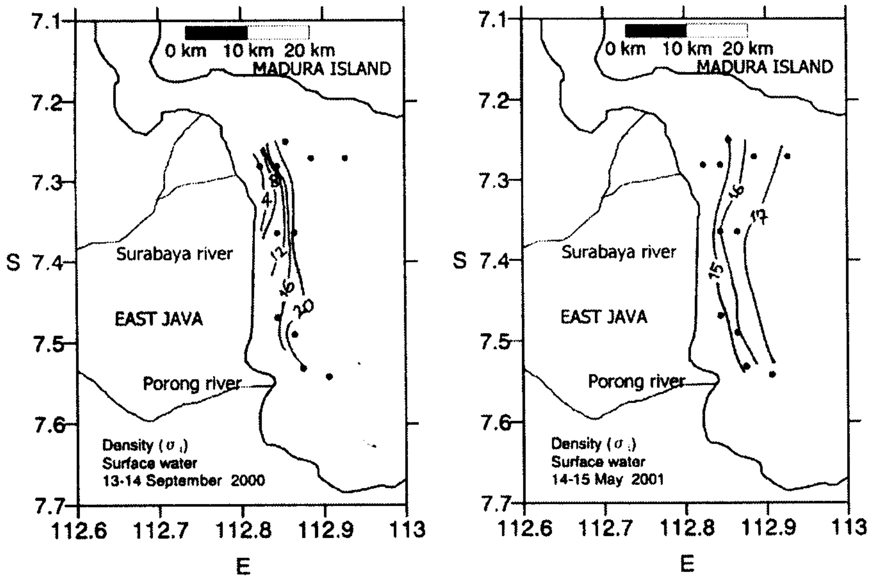

Fig. 6. Density (o_1) of surface water

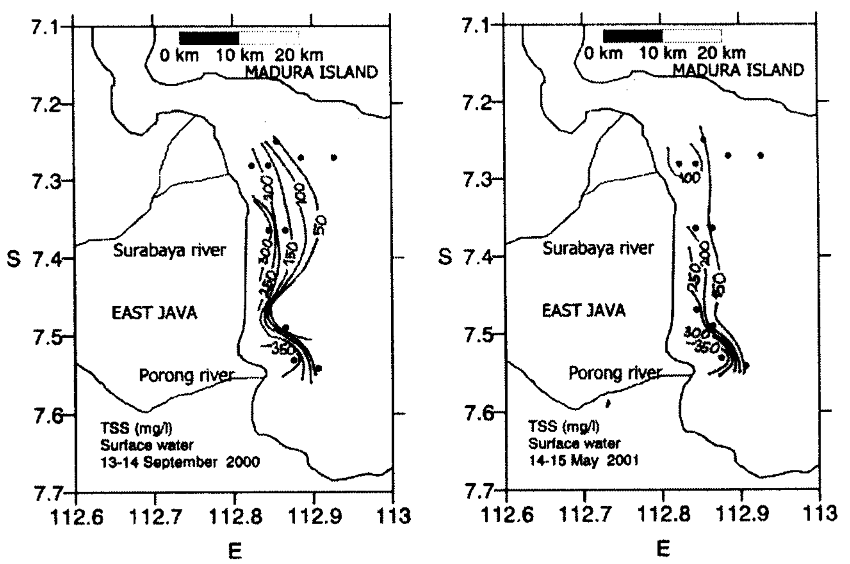

Fig. 7. Total suspended solids (mg/1) of surface water

not represent the both monsoons. Therefore, the distribution patterns spread eastward, and the alteration between May and September patterns depended only on freshwater discharge from the Surabaya and Porong rivers. Considering river discharge in 1997, during both measurement periods, the river discharges are expected to be lower than 30 m^3/s (Fig. 2). Discharges of the Surabaya river from May to September are always higher than that of the Porong river. Therefore, high concentrations near to the strait of Surabaya and the Surabaya estuary are believed to the result of the local source, namely the city of Surabaya. On the other hand, the influence of the Porong river remains in the western part of Madura Strait and restricted to the coastal zone.

In the ocean, the mean concentrations of phosphate, silicate, nitrate and carbon in phytoplankton generally correspond with the Redfield molar ratio C:N:P:Si and it is 106:16:1:15 (Redfield et al, 1963). N/P ratio in May that was ranging within 0.4 and 3.8 is higher than that in September that was ranging within 0.1 and 0.6(Fig. 13). The reason of high N/P ratio in September is that much nitrogen is loaded by river discharge. N/P ratio OV0Tÿ both periods showed value much lower than the Redfield ratio of 16. This indicates that nitrate may act as a limiting nutrient for primary production in the Madura Strait. N/Si ratio in May ranged between 0.1 and 1.5 and in September ranged between 0.1 and 0.8 (Fig. 14). N/Si ratio in September showed value lower than the Redfield ratio of 1.01, but in May showed value higher than the Redfield ratio in small area. This indicates that nitrate may act as a limiting nutrient for primary production of diatom too in large areas of the western part of the Madura Strait.

V. CONCLUSION

Some conclusions can be drawn from the combined measurement results and previous publications on the same sites. In general, water quality distribution in the Madura Strait, especially near the Surabaya river and the Porong river estuaries is highly affected by the load from the river.

1. Madura Strait clearly show an example that coastal environment is affected by the flow of freshwater, sediment and nutrient contaminant from the river. As a result of the presence of monsoon, the distribution pattern and load vary between two observation periods.
2. High precipitation and river discharge at the end of the wet season (May) cause salinity and density levels lower than those in the dry season (September). They also caused TSS, NO_3, PO_4, Si, and Cr concentrations higher than those in the dry season as well.
3. In the dry season, Porong river discharge is almost zero, hence Surabaya River transports sediments and nutrients through the city of Surabaya (Fig.3). Therefore, the contaminant was concentrated at the Surabaya estuary and Surabaya channel in the dry season.
4. N/P ratio in the western part of the

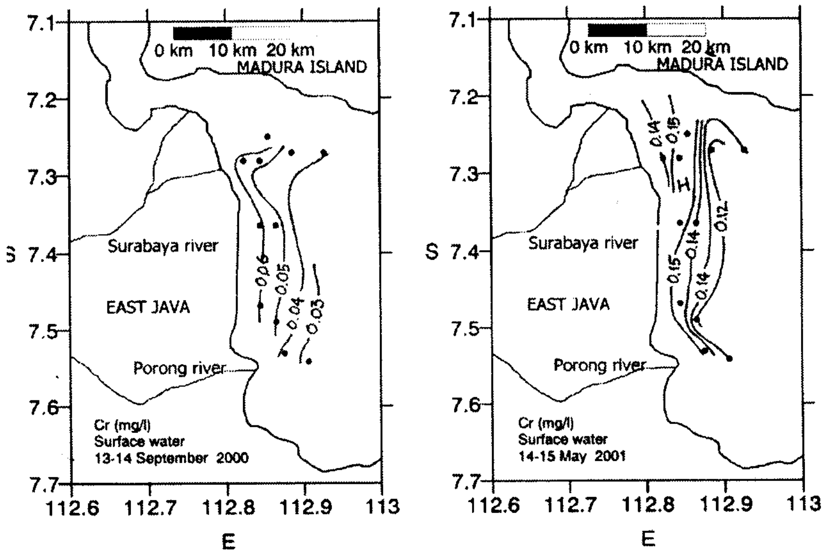

Fig. 8. Chromium (mg/1) of surface water

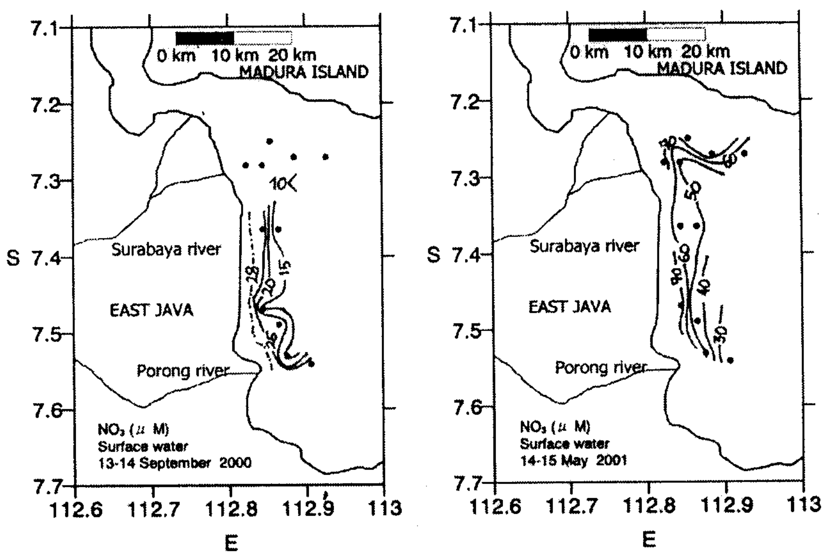

Fig. 9. Nitrate (μ M) of surface water

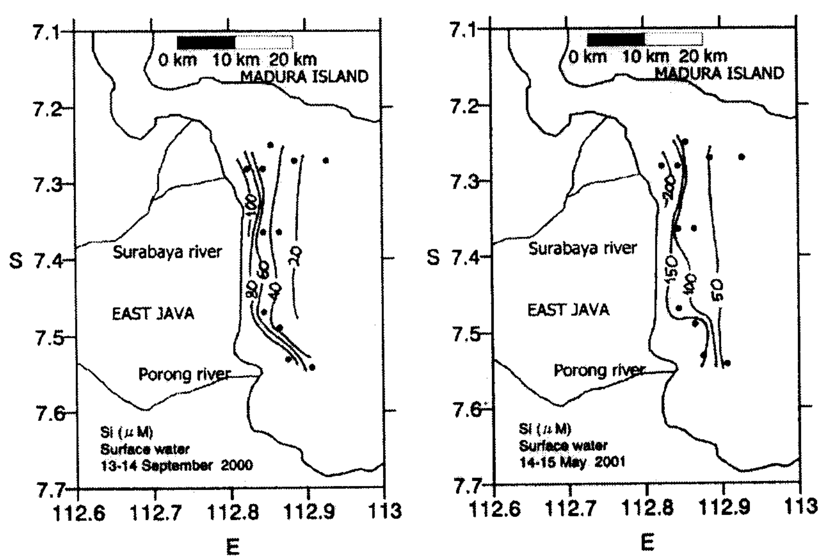

Fig. 10. Silicate (μ M) of surface water

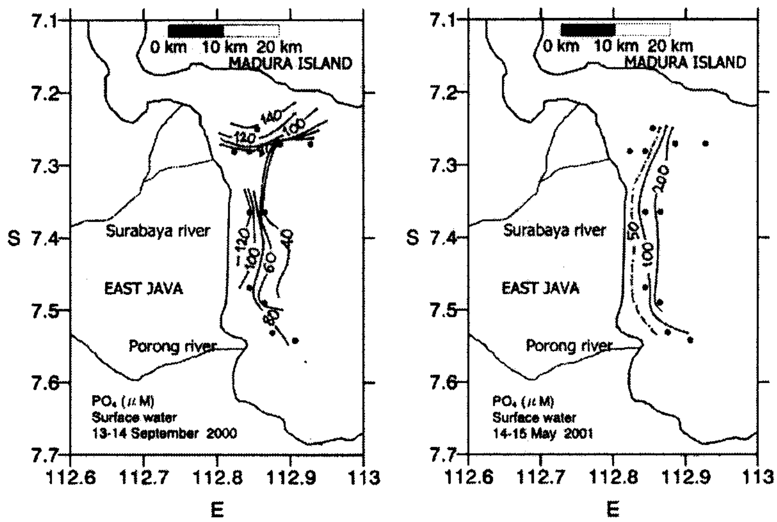

Fig. 11. Phosphate (μ M) of surface water

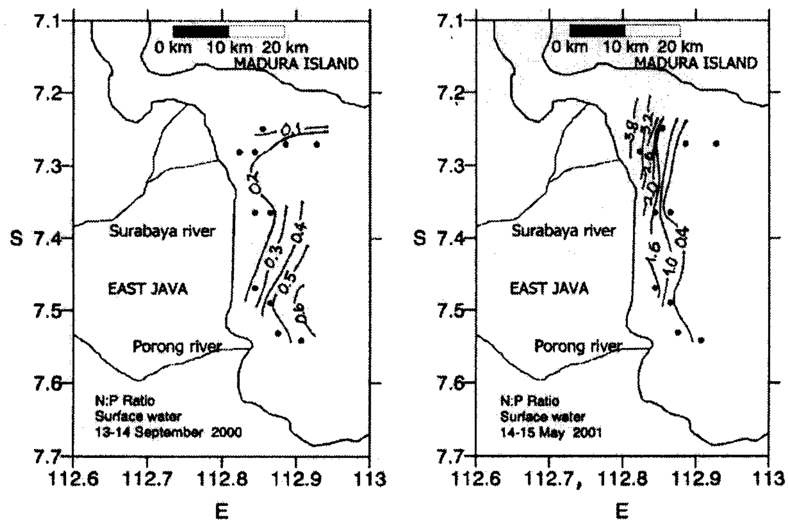

Fig. 12. N:P ratio

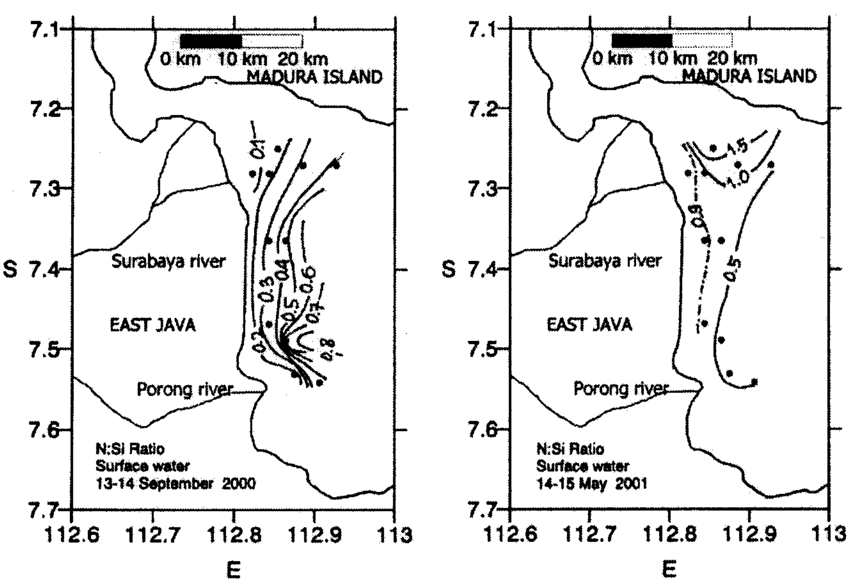

Fig. 13. N:Si ratio

Madura Strait coastal water is lower than 16, hence, nitrate may act as the limiting factor for the primary production within this region.

ACKNOWLEDGMENTS.

The authors thank to Mr. Seno Adi of Agency for the Assessment and Application of Technology,, Jakarta, Indonesia for the field observation data used in this work.

REFFERENCES

Ernest, E.A and K.B. Billings (1967): *Atomic Absorption Spectrometry in Geology,* Elsevier, Amsterdam, 144p.

Hoekstra, P., R.F. Nolting, H. Hutagalung, and H.A. Van Der Sloot (1989): *Supply and dispersion of water and suspended matter of the rivers Solo and Brantas into the coastal waters of east Java, Indonesia.* Sea Research, 23(4), 501- 515.

Hoekstra, P. (1989): *River Outflow, Depositional Processes and Coastal Morphodynamics in a Monsoon-dominated Deltaic Environment, East Java Indonesia.* Netherland Geographic Studies, 209p.

Parsons, T.R., Y. Maita and C.M. Lalli (1984) : *A Manual of chemical and Biological Methods for Seawater Analysis.* Pergamon Press, 179p.

Redfield, A.G., Ketchum, B.H., Richards, F.A. (1963): *The influence of organism on the composition of sea-water.* In:Hill, M.N. (ed), The Sea, Vol. 2, Inter science, New York, 26-77.

RochyatunÿE. (1999): *Perkembangan kondisi lingkungan perairan muara Kali Porong antara tahun 1992-1994 ditinjau dari DO dan COD.* Pusat Penelitian Pengembangan Oseanologi LIPI, 9-14.

Wrigley, T. and D.A. Wijanarko (1999): *Surface water quality issues in east Java.* Bapedal and East Java Pollution Control Implementation (PCI) Project, Surabaya, 28p.