WATER QUALITY FOR AQUATIC LIFE IN CIMANUK RIVER, WEST JAVA

(Kualitas Air Bagi Kehidupan Organisme Perairan di Sungai Cimanuk, Jawa Barat)

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ABSTRACT

A survey on water quality was conducted in Cimanuk river in 1999/2000 representing the upstream down to estuary region. Twelve sampling stations were chosen along the river. At each station, we sampled three times, in August, October, and January, to represent three different seasons of the year. Some parameters were measured *in situ*, while the other were analyzed at laboratory in Bogor Agricultural University. The results of this study indicated that, in general, water quality in Cimanuk river is still suitable for aquatic life. This condition is reflected by water quality indices, which are in the range of 50 to 80 or from moderate to good. Cimanuk river is typical of tropical flood river, in which the discharge fluctuate according to the rainfall. The rain water flushing on surface land in the early wet season decreases sharply the water quality of the river. Therefore, although the water quality of the river is still good for aquatic organisms, there is potential pollution from its watershed, especially in early rainy season.

Key words: water quality, Cimanuk river, seasonal.

ABSTRAK

Sebuah survei kualitas air dilakukan di Sungai Cimanuk pada tahun 1999-2000 mulai dari hulu sungai hingga ke daerah estuari. Dua belas stasiun pengambilan contoh ditetapkan di sepanjang aliran sungai. Pada setiap stasiun, pengambilan contoh dilakukan tiga kali waktu pengambilan, yaitu pada bulan Agustus, Oktober, dan Januari untuk dapat mewakili tiga musim yang berbeda pada periode tahun tersebut. Beberapa parameter diukur *in situ*, sementara beberapa yang lainnya dianalisis di laboratorium di Institut Pertanian Bogor. Hasil studi ini menunjukkan bahwa secara umum kualitas air di Sungai Cimanuk masih sesuai bagi peruntukan kehidupan organisme perairan. Kondisi tersebut tercermin pada indek kualitas airnya yang berada pada selang 50 hingga 80 atau dari kategori sedang ke baik. Sungai Cimanuk adalah satah satu contoh khas sungai tropis, dimana volume aliran sungai berfluktuasi menurut besarnya curah hujan. Air hujan menggelontor permukaan tanah pada awal musim hujan yang berakibat menurunkan secara tajam kualitas air sungai. Oleh karena itu walaupun kualitas air sungai masih baik bagi kehidupan organisme perairan, terdapat potensi pencemaran dari daerah aliran sungai tersebut, terutama pada awal musim hujan.

Kata kunci: kualitas air, Sungai Cimanuk, musiman.

INTRODUCTION

River basin or river system closely related to human development activities. The ancient civilizations usually were associated with a river system. The reason is that the river makes a human being easy to access the necessities of life-reliable sources of food and water (Awachie, 1981). Fisheries, drinking water, and transportation may be the first triple-use of rivers. Now, as human activities and the needs of life increase, a river is used multiply. Despite the vital role of river system for human life that has been recognized for centuries, relatively few studies have been carried out on the broad aspects of river characteristics. Compared with lakes, rivers have for some time been neglected, partly because limnologists prefer to study relatively closed systems (Bayley, 1979). The concept of sustainable development, introduced in 1992 by UNCED (United Nations Conference on Environment and Development) for the world's resource use (Cicin-Sain and Knecht, 1998), has not been seriously applied on river basin management in Indonesia. The failure contributed to the Jakarta massive flooding in the beginning of 2002 and astonished the government, experts, and even the people of the whole nation.

Cimanuk is one of the six major rivers in West Java, (the others are Citarum, Ciliwung, Ci-

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sadane, Cimandiri, and Citandui), flowing from hilly area of Garut, the Cikurai mountain, passing through Sumedang and Majalengka areas and ended in the coastal area of Indramayu (the Java Sea). The length of this river is approximately 175 *km* with the width varies from about 6 *m* upstream to about 150 *m* downstream. Water quality study in this river is very limited. The last spatially extensive study on water quality in this river was in 1979 done by a team of PUSDI-PSL-IPB (1979). The river is used mainly for irrigation purposes while traditionally it is for fishing, washing, bathing, and waste discharging activities as well. Since fisheries and wild life are not the priority in this river system, decisions to maintain a healthy quality of the river's biological life depends on compromising with the users outside to the fisheries and wild life affairs. This often retards regular water quality monitoring and evaluation of the river system.

With the increasing understanding of the importance of the sustainable development concept, all users ultimately have to be more concern with the river's water quality, not only to maintain the health of biological life in the river but also to indicate sustainability of the development in the basin. The assemblage of characteristics of a river summarizes the geology, geography, and development in its basin. All activities taking place on earth are eventually reflected in the river waters (Welcomme and Henderson, 1976). This study is intended to figure out some water quality characteristics in Cimanuk river and evaluate the environmental condition based on that. Water quality parameters measured in this study is limited to parameters related to organic pollution since that matter is the dominant form of water pollution in the area. This study does not include measurements on heavy metal concentrations due to shortage of fund available. However, source of heavy metals as pollutant in the river basin seems to be still very limited. Hopely, this paper will be taken as a consideration for the Cimanuk river management toward sustainable management of the river use.

MATERIALS AND METHODS

The study was conducted from June 1999 to January 2000 in Cimanuk river, including its major tributary, Cipeles river or "Sungai Cipeles". In this study, the river basin was divided into three segments from upstream toward downstream, which were Garut segment, Sumedang segment, and Indramayu segment. Every segment of the river had four measurement stations where nearby stations had approximately the same distances. The stations were named refering to the initial segment names, which were G1, G2, G3, G4, S1, S2, S3, S4, I1, I2, I3, and I4. Station S2 was in the tributary and the I' stations located downstream of Rentang weir. Therefore, water quality characteristics of the I' stations may not relate directly with its upper stations. Figure 1 shows the locations of the stations along the river.

Some important water quality parameters were measured at the stations in three different months expected to reflect condition in three different seasons. Measurements were done in August 1999 to reflect the condition of dry season, in October 1999 as a representation of transition season (early wet season), and in January 2000 as a representation of wet or rainy season.

Water quality parameters measured; and will be discussed in this paper; were water flow, river depth, turbidity, temperature, pH (acidity), alkalinity, dissolved oxygen (DO), five-day biochemical oxygen demand (BOD_5), ammonia, and orthophosphate. Some of the parameters were measured in the field and the others were analyzed at the "Laboratorium Produktivitas dan Lingkungan Perairan (ProLing)", Faculty of Fisheries and Marine Sciences, Bogor Agricultural University. Measurements and analyses were based on standard methods on freshwater quality analyses.

This paper will discuss the water quality condition of the river based on water quality standard for fisheries or aquatic life. Additionally, the overall water quality will also be analyzed using the water quality index (WQI) developed by Ott (1978). The index of each station is calculated with the formula of:

$$WQI = \sum_{i-1}^{n} W_i I_i$$

where I_i is sub-index of the i-th parameter referring to water quality standard for fisheries; W_i is the weight of the i-th parameter reflecting its importance and strength to indicate and drive the water quality change; and n is the number of parameters. The sub-index has value from 0 to

100. The weigths are as follows: 0.25 for BOD and ammonia, 0.20 for DO, 0.10 for turbidity and orthophosphate, 0.05 for pH and temperature.

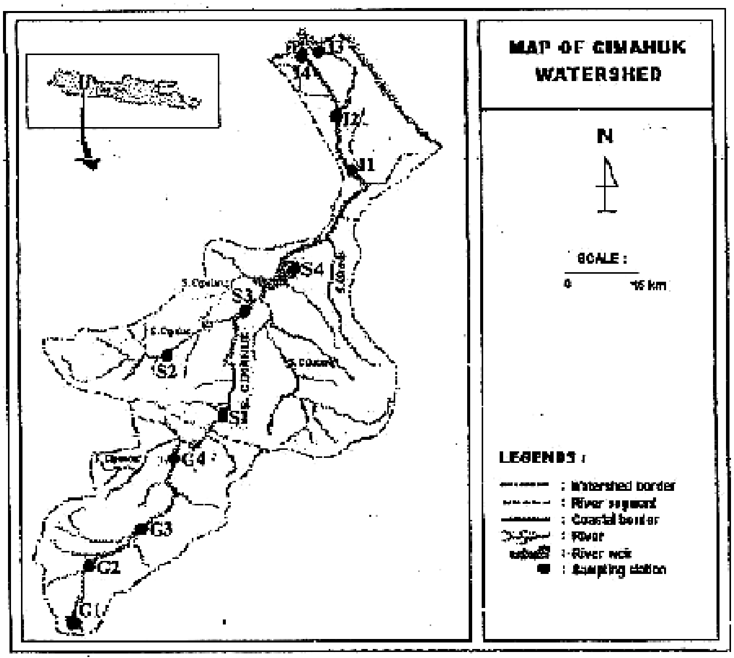

Figure 1. Cimanuk River Basin and Sampling Stations.

The WQI of each station will have value ranging from 0 to 100. The value will determines the water quality level according to the following criteria: 0 - 25 as very bad, 26 - 50 as bad, 51 - 70 as moderate, 71 - 90 as good, and 91 - 100 as very good

RESULTS AND DISCUSSION

Water quality characteristics in Cimanuk river measured in 1999 - 2000 are presented on Table 1. According to Welcomme (1979), rivers may be classified into two types, reservoir and flood rivers. Reservoir rivers have a stable flow throughout the year while flood rivers have large seasonal variations in the flow. Considering the above categories, Cimanuk river belongs to the flood river or the rainfall river. This can be characterized by seasonal flow (Figure 2) and seasonal depth of the river (Figure 3). Only few natural springs are found in the watershed so that the flow depends mostly on rainfall spill. In dry season (August), the flows are less than 20 m^3/s for all stations. In early rainy season (transition season, October), the flows begin to increase before achieving the peak in January. Similar flow characteristics were recorded in Solo river (DGWRD, 1983). Hickling (1961) said that, in general, tropical rivers undergo great seasonal variations in level.

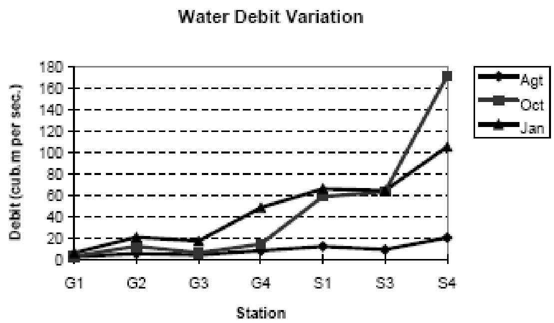

Figure 2. Flow Characteristics of Cimanuk River

Figure 2 also tries to show spatial variation of flow from upper reach down to lower reach of the river, and therefore, station S2 is excluded from analysis since this station located in a tributary. Station I1, I2, I3, and I4 are also excluded because there is a weir just below station S4 so that the flow at the I' stations have no longer represented natural flows. A river dam violates the river continuum concept as described by Vannote *et al.* (1980). In general, there is apparent that the flow is increasing downstream, except in dry season, which is fairly constant. The increasing flow transmitted downriver has also shown on the depth characteristics (Figure 3).

Table 1. Water Quality Characteristics in Cimanuk River.

Water Quality	Stations and Sampling Months											
	G1			G2			G3			G4		
Parameters	Agt	Oct	Jan	Agt	Oct	Jan	Agt	Oct	Jan	Agt	Oct	Jan
Temperature	20	22	20	25	23	21	22	24	23	21	23	23
Turbidity	8	8	24	40	55	29	24	75	47	27	49	45
Depth	45	50	60	55	80	90	50	50	60	50	70	100
Flow	2.295	2.745	5.871	5.096	12	20.592	3.85	5.9	17.04	7.92	14	48
pH	5	6	6	6	6	6	6	6	6	6	6	6
DO	6.86	6.68	5.24	7.26	6.45	5.65	6.45	9.67	6.86	3.2	8.45	5.24
BOD	5.85	6.86	1.62	5.45	6.05	6.86	5.52	6.45	6.05	6.45	5.65	5.64
Alkalinity	40	54	54	40	54	58	64	58	88	108	54	84
NH3	0.0099	0.01	0.0072	0.0089	0.08	0.0088	0.01	0.1	0.869	0.0067	0.03	0.0666
Ortho-P	0.1192	0.1021	0.05	0.0586	0.0826	0.0586	0.0723	0.08	0.0564	0.1053	0.0274	0.0666
	S1			**S2**			**S3**			**S4**		
	Agt	**Oct**	**Jan**	**Agt**	**Oct**	**Jan**	**Agt**	**Oct**	**Jan**	**Agt**	**Oct**	**Jan**
Temperature	24.5	27	24.5	26.5	29	25.5	28	26.5	25	28	27.5	26
Turbidity	29	74	60	14	50	39	32	75	68	15	80	62
Depth	50	100	150	50	80	100	150	180	200	500	600	700
Flow	11.85	58.45	65.62	4.16	7.92	9	9	63	64	20	171	105
pH	6	6	6	6	5	6	6	6	6	7	6	6
DO	5.65	6.45	4.84	5.24	5.65	4.84	6.45	5.24	7.06	5.24	4.84	6.86
BOD	6.05	5.85	4.84	6.66	5.64	4.84	6.46	4.84	6.86	5.29	6.05	5.45
Alkalinity	52	85	62	68	80	45	112	60	70	120	80	75
NH3	0.16	1.735	0.0095	0.492	0.93	0.0119	0.121	1.091	0.0089	0.254	1.021	0.0092
Ortho-P	0.089	0.129	0.082	0.0672	0.064	0.047	0.0695	0.05	0.0614	0.057	0.063	0.0515
	I1			**I2**			**I3**			**I4**		
	Agt	**Oct**	**Jan**	**Agt**	**Oct**	**Jan**	**Agt**	**Oct**	**Jan**	**Agt**	**Oct**	**Jan**
Temperature	30	27.5	26	30	30	25	28	31.5	26	30	31	27
Turbidity	11	75	44	10	69	30	14	35	54	17	83	70
Depth	200	200	600	300	300	500	100	120	400	500	500	500
pH	7.5	6.5	6.5	8	6.5	6.5	6	7	7.5	7.5	7	7
DO	6.03	3.23	4.03	6.85	2.8	4.03	6.45	3.23	6.05	4.03	2.8	4.03
BOD	4.8	6.44	7.66	6.86	11.29	4.03	7.26	10.48	8.07	6.05	8.08	5.24
Alkalinity	40	40	56	220	184	16	100	200	20	100	132	76
NH3	0.037	1.07	0.012	0.409	1.23	0.086	0.598	0.94	0.008	0.355	0.63	0.012
Ortho-P	0.096	0.0593	0.0645	0.07	0.0395	0.0547	0	0.0549	0.0372	0	0.0712	0.008

Turbidity is also physical characteristic of river affecting aquatic life that is influenced by rainfall in the basin. Effendi (2000) noted that an increase of turbidity by 5 NTU may reduce primary productivity of 3 - 13 %. Turbidity restricts light penetration and limits photosynthesis although it may not be harmful to fish (Boyd, 1979). Turbidity variations in Cimanuk river may be inspected on Figure 4. In dry season (August), turbidity in the river commonly is less than 30 NTU, which is the allowable turbidity for fisheries based on Indonesian Ministry Decree Number Kep-02/MenKLH/I/1988. Accumulation of suspended solid from domestic discharge along the river is not obvious in all seasons, causing a relatively constant turbidity downstream with small fluctuations. However, when early rain falls and flushes land materials to the river, turbidity achieves the highest. In the middle of rainy season (January), the land in the basin is relatively cleaner than in the beginning of rainy season (October) and the solid material content in the runoff water is lower. Turbidity in rainy season surpass its allowable upper limit for fisheries. This temporal variation of turbidity is observable on Figure 4.

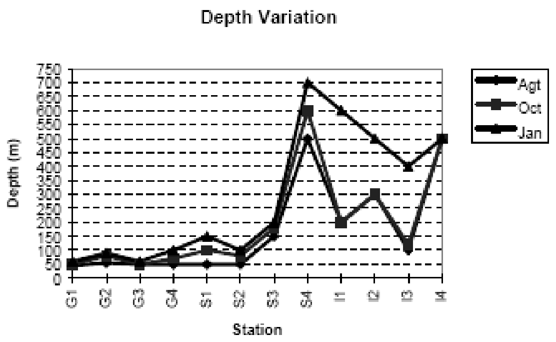

Figure 3. Water Depth in Cimanuk River.

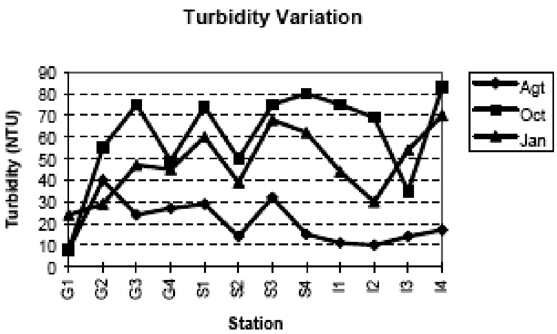

Figure 4. Turbidity Characteristics of Cimanuk River.

Water temperature in tropical region usually is not a problem for organisms. Huet (1971) noted that aquatic organisms live well in 20 - 30°C of water; and according to Hariyadi *et al.* (1992), fish will grow optimally at temperature of about 27°C. Figure 5 shows the temperature variation along the river in three different seasons. In general, temperature in Cimanuk river varies from 20°C to 30°C, except for station I3 in October, which is 31°C. It means that temperature in the river in all seasons is in allowable range. Temperature difference among seasons is not prominent although in January the temperature seems to be the lowest (Figure 5). Temperature exhibits a tendency to decrease downriver and may correlates with altitude of the river base. Goldman and Horne (1983) concluded that substrate composition, ground water temperature, rain temperature, and air temperature influence the surface water temperature.

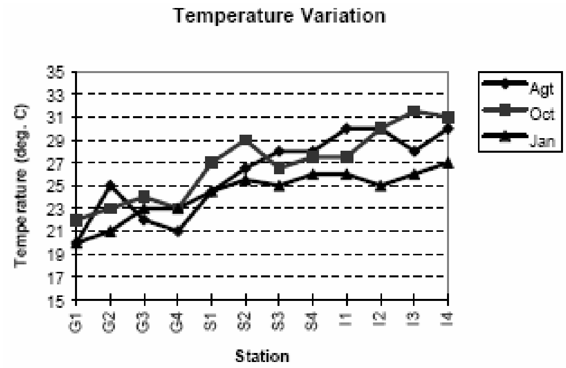

Figure 5. Temperature Variation in Cimanuk River.

Acidity and alkalinity are two water quality parameters important for fish. Acidity measures concentration of hydrogen ions in water and represented by pH, while alkalinity measures concentration of bases in water and expressed as *mg/liter* equivalent calcium carbonate ($CaCO_3$). The two parameters relate each other closely. Acid and alkaline water will be indicated by low value and high value of pH respectively. The acid and alkaline death points for fish are approximately pH 4 and pH 11 (Boyd, 1979). This author also mentioned that suitable pH for fish production is from about 6.5 to 9. Pescod (1973) suggested that ideal pH for fisheries is 6.5 - 8.5. The allowable pH for fisheries according to Indonesian Ministry Decree Number Kep-02/MenKLH/I/1988 is 6 - 9. The suitable alkalinity for fisheries is 30 - 500 *mg/liter*. Acidity or alkalinity, along with temperature, may be used to estimate ichthyomass of a river (Holcik, 1979).

Generally, pHs along the Cimanuk river in all seasons are in the range of suitability for fisheries, except for station G1 in August and station S2 in October (Figure 6). The station G1 that is the uppermost station of this river receive mostly spring water just has flown through humid land. Therefore, in August the water of this station tends to be more acid. Acidity at station S2 probably is affected by early flushing rain in October on some tapioca and tofu (soybean cake) industries in its basin. This station is in a tributary of Cimanuk river, with some home industries in its basin.

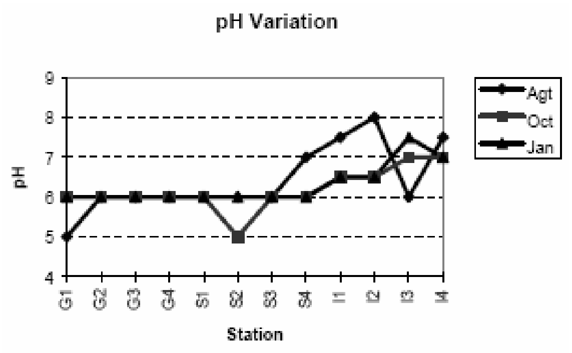

Figure 6. Acidity Characteristics of Cimanuk River.

The alkalinity of the river commonly is also in the range of suitability for fisheries, except at station I2 and I3 in January (Figure 7). Exceptional fluctuation on pH and alkalinity at I' stations needs more detail data on land use to explain, which is not available right now. Water quality characteristics at those stations may not connect directly with their upper stations since a weir exists just above station I1.

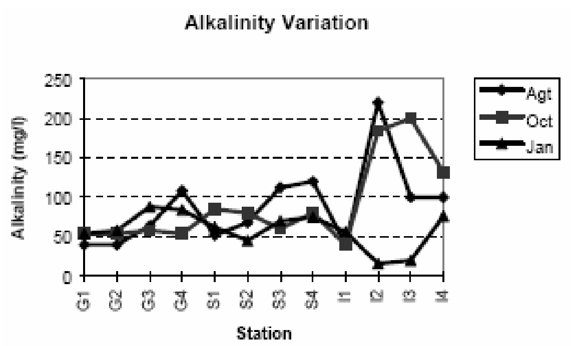

Figure 7. Alkalinity in Cimanuk River.

Dissolve oxygen (DO) in the water is vital for aquatic organisms for respiration. However, the DO in river usually is not a limiting factor since a lot of oxygen may be injected from air in flowing water. Huet (1971) mentioned that minimum physiological activity of fish needs no less than 3 *mg/liter* of DO, and for normal growth, fish needs more than 5 *mg/liter* of DO in the water. Based on various sources of information, Indonesian Ministry Decree Number Kep-02/MenKLH/I/1988 uses 4 *mg/liter* as the lower limit DO of fisheries water quality standard. DO variation in Cimanuk river may be inspected on Figure 8. Although some values of DO on Figure 8 are bellow 3 *mg/liter*, it should be realized that DO may change quickly.

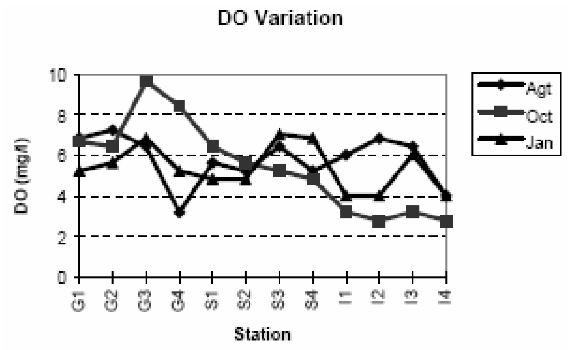

Figure 8. DO (Dissolved Oxygen) Variation in Cimanuk River.

Biochemical oxygen demand (BOD) is a measure of organic matter in the water. The BOD measures the strength of waste discharges and therefore is widely used as an organic pollution indicator in bodies of water (Ortolano, 1984). High BOD levels have been frequently reported in urbanized river basins due to direct effluent discharge from industrial premises and sewage effluent from domestic homes, while natural rivers in general maintain low BOD levels (Lai, 1983). According to Effendi (2000), natural waters have 0.5 - 7.0 *mg/liter* BOD and waters with BOD level more than 10 *mg/liter* can be considered as polluted waters. Lai (1983) classified river water quality in Selangor, Malaysia, with respect to BOD concentration as very clean (< 1 *mg/liter*), clean (2 *mg/liter*), fairly clean (3 *mg/liter*), doubtful (5 *mg/liter*) and bad (> 10 *mg/liter*). Higher level of minimum water quality standard for fisheries based on BOD concentration has been used by Indonesian Ministry Decree Number Kep-02/MenKLH/I/1988, which is 45 *mg/liter*.

In general, the difference of BOD level either along the Cimanuk river or among the seasons is not sharp (Figure 9). Again, an exception occurs at station G1 and the I' stations. Low BOD level at G1 in August is obviously because the cleanly spring water not contaminated yet by waste effluent from its surrounding basin. Higher BOD levels at station I2, I3, and I4 in October are due to land flushing of the early rainfall. All BOD values on Figure 9, however, are less that 12 *mg/liter* and mostly bellow 10 *mg/liter*. These data indicate that the river is not polluted badly yet.

Ammonia (NH3) concentration is another widely used indicator for water quality. Ammonia mostly comes from deaminated process of organic matter. Ammonia is always in equilibrium with ammonium ion ($NH4^+$). Ammonia is toxic to fish but ammonium ion is not (Boyd, 1979). Effendi (2000) noted that natural water usually contains less than 0.1 mg/liter of ammonia. Higher level of ammonia indicates organic pollution of the water. Pescod (1973) suggested that ammonia concentration should be less than 1 *mg/liter* in order to be suitable for fisheries. The same value has been adopted by Indonesian Ministry Decree Number Kep-02/Men KLH/I/1988.

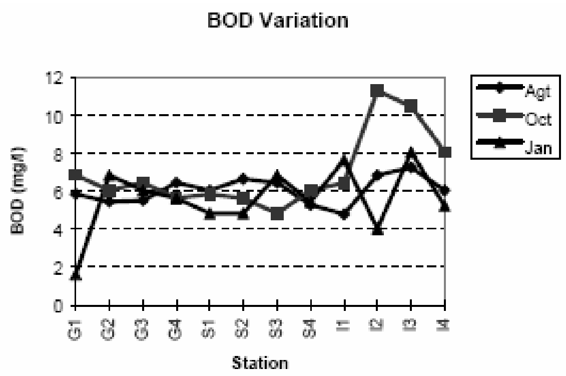

Figure 9. BOD (Biochemical Oxygen Demand) in Cimanuk River.

Figure 10 shows that, in October, NH3 level increases markedly especially at stations in Sumedang and Indramayu area. This is normal because early rain falls in October and the runoff is loaded with the dry season accumulated nitrogen from land. This nitrogen pollution is therefore not worrying since in the other seasons reveal low concentration of ammonia.

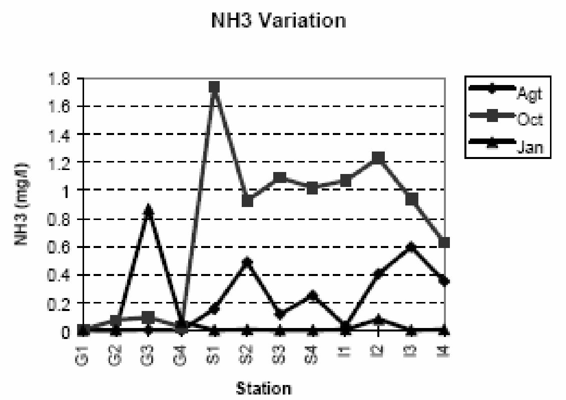

Figure 10. Ammonia (NH3) Concentrations in Cimanuk River.

Phosphorus (P) is a key metabolic nutrient and the supply of this element often regulates the productivity of natural waters. Although phosphorus is a minor constituent of water, its biological importance is considerable, and it is usually considered to be the element that most frequently limits productivity in aquatic ecosystem (Boyd, 1979). Hariyadi *et al.* (1992) and Boyd (1979) explained that phosphorus occurs in water as soluble inorganic form (ortho-P), particulate inorganic form, and organic forms (poly-P). Plant only assimilates the soluble ortho-P. Boyd (1979) also mentioned that concentrations of ortho-P in water are quite low, and seldom exceed 0.1 mg/liter even in highly eutrophic waters. Wetzel (1983) categorizes fertility of water based on orthophosphate concentrations as follows: olygotrophic for 0.003 - 0.01 mg/liter of ortho-P, mesotrophic for 0.011 - 0.03 mg/liter of ortho-P, and eutrophic for 0.03 - 0.1 mg/liter of ortho-P. It should be noted, however, most phosphorus input entering the stream during high discharge may be flushed out without entering biogeochemical cycles of the ecosystem (Meyer and Likens, 1979).

Soluble orthophosphate (ortho-P) in Cimanuk river can be seen on Figure 11. The figure shows that in general Cimanuk river may be classified as a eutrophic water. Variation of ortho-P in this river either among stations or among seasons cannot be explained easily but excessive amount of ortho-P at some stations may indicate the use of phosphorus fertilizer in nearby agricultural land. Nevertheless, ortho-P has never been toxic to fish.

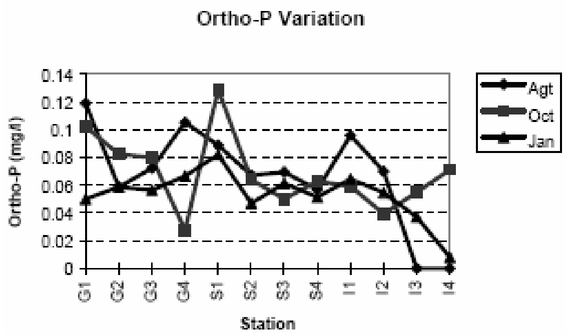

Figure 11. Orthophosphate (ortho-P) in Cimanuk river.

The overall water quality in Cimanuk river is reflected in water quality indices drawn on Figure 12. In general, the indices are more than 50 indicating that the water quality is moderate to good. Although this may be considered as a good news, potential pollution due to degrading watershed and domestic effluent should be alerted. Moderate pollution occurs in early rainy season when the rain water carries considerable pollutant from land. The cleansing process gradually weakens in rainy season because of fewer materials remaining.

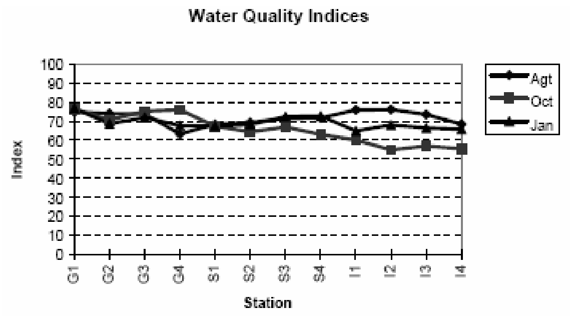

Figure 12. Water Quality Indices in Cimanuk River.

The use water quality indices to to figure out some water quality characteristics in Cimanuk river has the advantage mainly in term of easiness for interpretation. The water quality indices presented in this paper, however, are not complete indinces to measure water quality of the Cimanuk river sinces not all water quality parameter are included in the analyses. Parameters analyzed in this study mainly are limited to things that related to organic pollution. Furthermore, analysis water quality is focused on aquatic life needs.

Without forgetting the weakness of the study, the result of this study may be used as an early warning indicator for pollution potential of the river. Some parameters indicate pollution potential in the river in early rainy season. The potential will build up greater and greater and pollute the water even in dry season if management on the watershed fails. There are various methods and models that can be used to manage the watershed in relation to the water quality of a river. Mattikalli *et al.* (1996), for example, propose the soil conservation service and the export coefficient models integrated with GIS (Geographical Information System) to predict river discharge and water quality.

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