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Water quality of Laguna de Bay: status and trends*

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Results of water quality monitoring of Laguna de Bay, particularly from 1986 to 1992, show a worsening trend in the condition of the lake in terms of the values of important physico-chemical parameters. There is an increasing trend in the values of conductivity, chlorides, hardness, chemical oxygen demand, phosphorus, ammonia and other nitrogen fraction, while a decreasing trend in the values of alkalinity, pH, dissolved oxygen, and transparency have been observed. The mean values for most of the parameters have fallen below the water quality standard prescribed for "Class C" waters. The continued deterioration in the water quality of the lake reflects the cumulative impacts of different kind of pollution in the lake. The worsening turbidity or decreasing transparency of the lake waters reflects the effects of heavy siltation which include destruction of bottom rooted plants and decreased photosynthetic level. On the other hand, the high levels of nitrogen and phosphorus fractions make the lake highly eutrophic and susceptible to massive algal bloom once the water clears up during calm or sunny weather condition. If the present trend in the determination of its water quality due to the unabated influx of pollutants continues, it will not be long until the lake becomes dystrophic.

Key Words: water quality, Laguna de Bay, dissolved oxygen, dystrophic, turbidity

LAGUNA DE BAY IS THE LARGEST FRESHWATER LAKE IN THE PHILippines and in Southeast Asia. It has a surface area of about 900 km^2 and a shoreline of about 220 km. It is bounded by the provinces of Rizal and Laguna and part of Metro Manila. The lake is shallow with an average depth of 2.8 m in 1976. It has only one outlet, the Pasig River which joins it to Manila Bay. Inflow to the lake from its watershed is capable of flushing the lake once a year.

Laguna de Bay has a watershed area of 2,920 km^2. Land use in the watershed is varied. The northwestern portion is highly urbanized and industrialized while the southeastern portion is agricultural. There are 27 municipalities surrounding the lake and the total population in the watershed area was estimated at 4.0 M in 1992.

The main uses of Laguna de Bay are as fishery resource, for power generation, source of irrigation water, recreation and navigation and for waste disposal. It is projected to be a source of domestic water supply for Metro Manila and the basin communities in the near future.

In the 1960's, the lake abounded with about two dozen species of tropical fish, several mollusks and shrimps. Open water fishing was a main source of livelihood of the people. In 1972, fishpen aquaculture was introduced and started to proliferate until 1983 when more than one-third of the lake was covered by disorderly sites of fishpens. As a consequence of the uncontrolled spread of fishpens, the carrying capacity of the lake was exceeded and fish productivity declined markedly. The decline in the productivity of the lake can be attributed not only to over exploitation by fishpen operators but also to the increasing input of wasteloads from industrial effluents, domestic wastes, agricultural run-offs and soil erosion which caused its water quality to deteriorate. There are about a thousand factories which discharge their wastes into the lake, 60% of them highly polluting. Equally guilty of wanton exploitation of the lake are the unscrupulous fishermen who use illegal and ecologically damaging fishing methods which harvest both adult and juvenile fishes including their eggs.

At present, only a few species of fish can be found in good enough numbers and community fishing is in the down trend. There have been reports not only of decreasing harvest and productivity but slow growth of fish, fish kills, fish diseases, malodorous water, undesirable tastes of fish etc.

One aspect in the proper management of Laguna de Bay that needs continuing attention is its water quality. This report presents the results of our studies on the monitoring and assessment of the water quality of Laguna de Bay. It focuses on certain parameters which are considered critical in assessing the present state and trends in water quality relative to its multiple uses and in formulating mitigating measures needed to rehabilitate and save it from an untimely death.

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Methodology

Sampling

Sampling sites were selected in strategic areas in the West and East Bays (Figure 1). Collection of samples was done monthly starting March, 1986. Water samples were collected at two depth levels, surface (30 cm below the surface) and bottom (30 cm above the sediment layer).

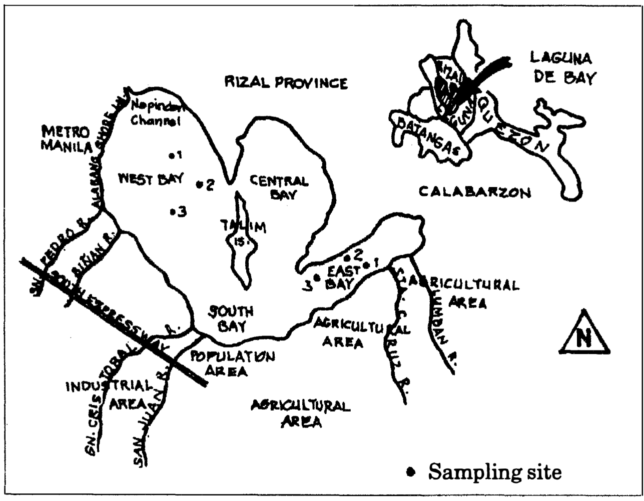

Figure 1. Map of Laguna Lake and its tributary rivers showing the sampling sites.

Samples were collected using an improvised water sampler. Samples for the analysis of chloride, hardness and alkalinity were placed in ice immediately after collection while samples for nutrient and chemical oxygen demand (COD) analyses were fixed with 2-ml conc. sulfuric acid per liter.

For dissolved oxygen (DO) measurements, samples were collected in 300-ml BOD bottles using an improvised water sampler. Two ml of manganous sulfate solution and two ml of alkaline azide solution were added immediately after collection.

Temperature, pH, transparency and conductivity were measured *in situ*.

Analytical Methods

The following parameters were analyzed using the indicated methods/instruments:

Parameters	Instruments/Methods Used
Transparency	Secchi disc
pH	Portable pH meter (Schott Gerate CG 727)
Conductance	YSI conductance meter Model 32M DO meter, YSI model 54 ABB (with integrated thermometer attachment)
Temperature	
Dissolved Oxygen	Modified azide method (EPA, 1983).
Ammonia-N	Modified salicylate-hypochlorite method (Fukomoto and Chang, 1983)
Nitrate-N	Brucine colorimetric method (APHA, 1989)
Total Kjeldahl N	Standard Kjeldahl digestion and distillation method with some modification. The liberated ammonia is taken up in acid and determined colorimetrically by the modified salicylate-hypochlorite method.
Phosphorus fractions (ortho-P and total P)	Modified ascorbic acid method (EPA, 1983)
Total hardness	EDTA titrimetric method (APHA, 1989)
Alkalinity	Titrimetric method (APHA, 1989)

Results and Discussion

Temperature

For "Class C" waters, the temperature criterion is that no changes greater than 3°C beyond the average ambient temperature for each month (EMB, 1990).

Variations in water temperature in Laguna de Bay indicated tropical setting with low and high periods. Generally, low levels (< 30°C) were noted from November to March and higher levels (> 30°C) from April to September. The temperature of West Bay was slightly higher than that of the East Bay (Figure 2). The highest temperatures were measured in the month of June, 1990 for both West and East bays with values equal to 32.7°C and 32.4°C, respectively. Both bays showed a decreasing trend in temperature but the changes were not significant enough to cause detrimental effects to the lake organisms.

For the period 1986-1992, temperature ranged from 22.0°C to 32.7°C which is about the same range reported by LLDA for the period 1973-1977. However, a narrower range in temperature (28 - 32°C) was reported by Centeno et. al. from 1978-1988.

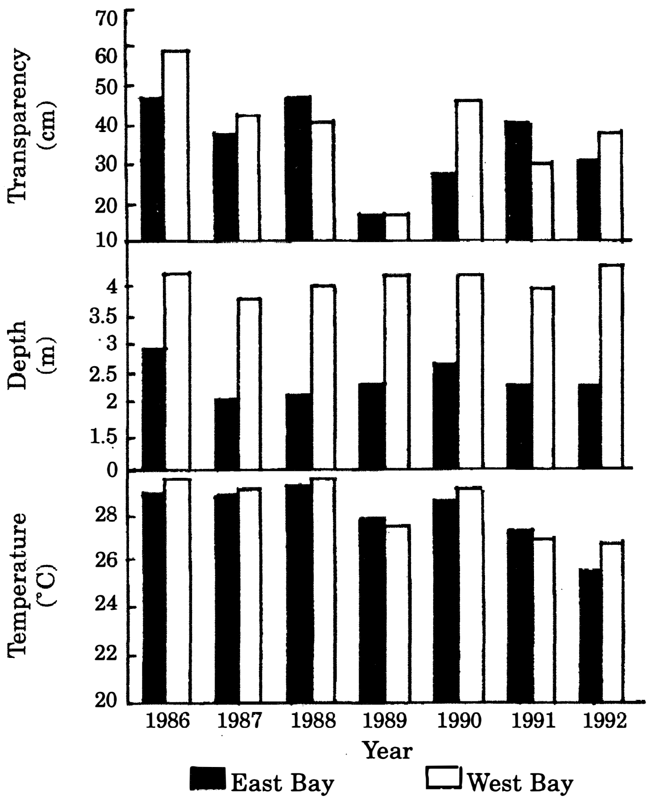

Figure 2. Annual mean temperature, depth and transparency.

Depth

Although depth is not a water quality parameter, its measurement is significant in monitoring the rate of siltation and turbidity.

Apparent depth measurement showed that West bay is almost twice as deep as the East bay (Fig. 2). Water levels follow the season, low during the summer months, and high during rainy months (Table 1).

Variations of annual mean depth values through time are not significant in both bays. However, East bay water reached the lowest value of 1.2 m in May 1991 while West bay of 3.1 m in April, 1990 and 1991 (Table 1).

The shallow nature of the lake makes the lake sediments prone to mixing and stirring-up by wind and wave action affecting the lake's turbidity and clarity.

Transparency

The turbidity may be caused by a wide variety of suspended materials, which range in size from colloidal to coarse dispersions, depending upon the degree of turbulence. In lakes, or other waters existing under relatively quiescent conditions, most of the turbidity will be due to colloidal and extremely fine dispersions. Extreme turbidity or very low transparency can result in the almost cessation of photosynthesis in aquatic environments.

Based on Secchi disc readings, the transparency or clarity of the lake water has been steadily deteriorating through the years. Our own data collected from 1986 to date generally showed a downward trend in transparency readings from an average of 59 cm and 46 cm in 1986 to 31 cm and 38 cm in 1992 for the West and East Bays, respectively, (Fig. 2). Readings as low as 10 cm or lower have been recorded, particularly during the first six months of 1989 where Secchi disc readings of 5 cm were recorded. This may be due to the stirring of the sediment caused by prevailing strong winds. Due to the shallowness of the lake, the possibility of mechanical stirring of the sediment by boats and barges could also be contributing factors.

The lowest annual mean transparency values of 18 cm for East bay and 17 cm for West bay were observed in 1989.

Based on LLDA data for 1973-1977 which gave transparency range of 8-77 cm, it appears that the lake has a history of low transparency. It may be noted however, that prior to 1977, the main reason for low transparency readings was due to high algal population while the low transparency readings during the last six years are done to high suspension of clay and organic matter.

Conductivity (Salinity)

Conductivity is a measure of total concentration of all dissolved ions in water. Conductivity values indicate relative degrees of salinity especially in fresh water. As a rule, salinity is not normally an important factor in fish culture, although some species of fresh water fish are sensitive to sudden changes in salinity (Boyd, 1982).

Variations in conductivity indicated a significant difference between bays (Figure 3). Conductivity readings were found to be generally higher in the West bay than the East bay waters with average annual means of 1.214 mS/cm and 0.379 mS/cm, respectively. This may be due to the variability in the wastewaters being dumped into the lake which come largely from highly urbanized communities and various industrial establishments surrounding the West bay. Higher conductivity readings observed might also be due to the intrusion of salt water from the Pasig river into the West bay during summer. This is supported by the higher chloride levels observed in West bay waters as shown in Fig. 3. Maximum conductivity value of 3.491 mS/cm was observed in the West bay in Aug. 1992. Both bays showed an upward trend in conductivity through time.

Chlorides

Chlorides occur in all natural waters in widely varying concentration. The chloride content normally increases as the mineral content increases. Concentrations above 250 mg/L give a salty taste to water, which is objectionable. The high levels of chloride may be the result of effluents containing industrial wastes, brine and sewage and other organic wastes.

Table 1. Annual mean and range of various water quality parameters of East and West Bays.

Parameters		1986	1987	1988	1989	1990	1991	1992
Temperature (°C)	EB	28.9 (26.0Mar-30.6May)	28.7 (24.6Jan-31.0May)	29.3 (26.3Apr-31.5Jul)	27.8 (24.5Dec-30.0May)	28.7 (25.0Mar-32.4Jun)	27.3 (23.8Dec-29.4May)	25.6 22.0Jan-28.0Oct)
	WB	29.6 (28.4Mar-30.9Jun)	29.0 (25.4Feb-30.6May)	29.6 (27.8Jan-31.4May,Jun)	27.6 (24.9Jan-30.5Jun)	29.0 (26.4Feb-32.7Jun)	27.0 (24.6Dec-29.5May)	26.8 (23.4Jan-29.0Oct)
Depth (m)	EB	2.9 (1.5Apr-4.2Oct,Nov)	2.0 (1.4May-2.8Jan)	2.1 (1.5May-2.5Jan)	2.3 (1.7May-3.2Sept)	2.6 (1.3May-5.0Mar)	2.3 (1.2May-3.5Sept)	2.3 (1.5Mar-3.6Nov)
	WB	4.2 (2.9Apr-5.3Jul)	3.8 (3.2May-4.2Sept)	4.0 (3.5Apr-4.4Aug)	4.2 (3.7Apr-5.0Aug)	4.2 (3.1Apr-5.5Aug)	4.0 (3.1Apr,May-5.0Sept)	4.4 (3.6Jun-5.7Nov)
Transparency (cm)	EB	46 (15Mar-78Sept)	38 (20Jan,Jul-120Oct)	47 (20Apr-87Sept,Oct)	18 (5Feb,Mar,Nov,Dec-37Jul)	27 (5Mar-67Jun)	41 (20Jun-67Oct)	31 (10Jan-53May)
	WB	59 (10Mar,Apr-140Sept)	42 (20Feb-70Jul)	40 (10Jan,Apr,May-72Aug)	17 (5Jan,Mar-40Jul,Sept,Oct)	46 (5Mar-93Jun)	30 (15Apr,Dec-47Jul)	38 (10Jan,Feb,Mar-60Nov)
Conductivity (mS/cm)	EB	0.280 (0.055Nov-0.580May)	0.223 (0.080Nov-0.390May)	0.232 (0.086Feb-0.387Aug)	0.219 (0.088Jun-0.246Feb)	0.423 (0.160Nov-1.375Sept)	0.545 (0.097Dec-1.094May)	0.732 (0.128Nov-1.362Sept)
	WB	1.138 (0.618Mar-1.715Jul)	0.540 (0.355Feb-0.708May)	0.598 (0.390Jan-0.816Sept)	0.386 (0.268Nov-0.668Mar)	1.872 (0.334Mar-3.606Jun)	1.861 (1.084Nov-5.212Jun)	2.104 (0.977Feb-3.491Aug)
Chloride (mg/L Cl^-)	EB	48 (11Nov-134Jun)	57 (12Nov-108Jul)	35 (8Jan-105Aug)	20 (6Jul-37Mar)	42 (19Aug-111Nov)	155 (36Jul-255Aug)	167 (26Nov-361Aug)
	WB	94 (42Apr-144May)	108 (42Nov-146Jul)	109 (80May-156Sept)	45 (31Aug-71Feb)	126 (16Jun-501Oct)	373 (114Jan-1329Jun)	486 (217Feb-883Aug)
pH	EB	8.0 (7.2Aug-9.0Jul)	7.7 (7.1Apr-8.2Sept)	7.9 (7.2Jun-8.6Mar)	7.8 (7.2Oct-8.2Apr)	8.0 (7.2Oct-8.6Sept)	7.9 (6.5Dec-8.8Feb)	7.8 (6.7Nov-8.8Jun)
	WB	8.8 (8.2Apr-9.4Sept)	8.1 (7.7Feb-8.3Nov)	8.4 (7.8Mar-8.8Aug)	8.2 (7.2Oct-8.6Jul)	8.8 (8.1Apr-9.6Jun)	8.2 (7.2Dec-8.7Mar)	8.4 (7.4Nov-9.4Jun)
Alkalinity (mg/L $CaCO_3$)	EB	61 (29Aug-100Mar)	59 (42Jan-74Oct)	42 (24May-82Oct)	42 (32Oct-50Aug)	33 (17Nov-87May)	42 (18Jan-58Nov)	45 (20Nov-67Mar)
	WB	94 (68Sept-110May)	66 (61Feb-76Jun)	78 (34Jun-152Mar)	48 (44Oct-61May)	56 (51Oct-105Apr)	51 (36Jul-70Dec)	56 (39Nov-85Mar)
Hardness (mg/L $CaCO_3$)	EB	46 (24May-80Sept)	64 (48Nov-90Feb)	74 (38Feb-154Nov)	58 (14Oct-103Feb)	57 (12Jun-145Sept)	65 (34Dec-99May)	65 (4Nov-127Aug)
	WB	116 (62Apr-146Jul)	86 (74Nov-105Mar)	98 (66Jan-138Jun)	88 (29Nov-141Mar)	160 (42Mar-357Jul)	160 (106Nov-438Jun)	189 (79Feb-336Jun)
Dissolved Oxygen	EB	7.3 (5.2Jul-10.2May)	7.1 (6.2Jul-8.4Jan)	7.0 (5.8Jun-8.0Aug,Sept)	7.2 (6.2Aug-8.3Feb)	7.5 (6.0Jul-9.3Sept)	6.5 (4.6May-7.8Mar)	7.2 (6.2Aug-8.3Jul)
	WB	7.5 (6.5Jul-9.6Jun)	7.6 (6.8Jul-9.0Aug)	7.4 (6.8May-8.0Mar)	7.4 (6.8Nov-8.0Dec)	8.1 (6.2Jul-8.8Nov)	7.0 (4.6May-8.3Mar,Nov)	8.0 (6.7Feb-9.1Jun)

Table 1 *continued*

COD ($Mg/L\ O_2$)	EB	13.9 (4.2Nov-29.0Jun)	12.4 (3.4Feb-26.5Aug)	24.6 (4.8Oct-22.2Aug)	14.4 (3.8Aug-25.8Dec)	12.3 (3.5Dec-21.1Jan)	10.6 (3.5Dec-21.5Jun)	16.5 (6.4Jan-34.7Aug)
	WB	22.9 (9.5Sept-32.7Mar)	18.2 (2.6Feb-29.0May)	16.9 (10.3Aug-25.2May)	14.3 (4.9Jun-28.4May)	18.6 (8.3Dec-33.7Aug)	19.8 (6.2Apr-61.1Jul)	34.7 (7.4Jan-65.6Oct)
Phosphorus fractions								
a. Ortho-Phosphate (mg/L P)	EB	0.072 (0.009Jun-0.116Nov)	0.064 (0.024Mar-0.098Jul)	0.088 (0.070Aug-0.130Jul)	0.192 (0.084May-0.309Nov)	0.235 (0.050Jul-0.760Mar)	0.079 (0.016Jan-0.131Aug)	0.092 (0.011Dec-0.181Mar)
	WB	0.136 (0.026Jun-0.270Apr)	0.046 (0.018Aug-0.070Nov)	0.178 (0.081Sept-0.148Jul)	0.246 (0.178Nov-0.374Oct)	0.260 (0.036Oct-0.820Mar)	0.092 (0.023Jun-0.233Dec)	0.122 (0.006Dec-0.391Mar)
b. Total Phosphorus (mg/L P)	EB	0.157 (0.106Sept-0.264Mar)	0.102 (0.071Jun-0.143May)	0.173 (0.130Sept-0.251Nov)	0.323 (0.163Jun-0.590Dec)	0.465 (0.129Sept-1.720Mar)	0.160 (0.039Jan-0.282May)	0.173 (0.049Dec-0.425Mar)
	WB	0.279 (0.095Jun-0.578Mar)	0.116 (0.040Jul-0.196Oct)	0.234 (0.116Aug-0.380Mar)	0.496 (0.262Jul-0.513Apr)	0.495 (0.080Sept-1.860Mar)	0.245 (0.136Jan-0.449May)	0.196 (0.048Oct-0.665Mar)
Nitrogen fractions								
a. Total Kjeldahl Nitrogen (mg/L N)	EB	0.81 (0.34Oct-1.62Jun)	0.64 (0.23Nov-0.98Oct)	0.44 (0.20Sept-0.69May)	1.03 (0.47Apr-2.51Dec)	1.03 (0.42Dec-2.43Jun)	0.84 (0.42Dec-1.50Apr)	1.00 (0.51Jul-1.52Aug)
	WB	1.41 (0.70May-2.19Jun)	0.77 (0.46Jan-1.13Oct)	0.72 (0.41Jun-1.21Mar)	0.83 (0.18Aug-1.45Dec)	1.04 (0.32Jul-2.70Jun)	1.44 (0.53Feb-4.19Jul)	1.26 (0.72Sept-1.75Feb)
b. Ammonia-Nitrogen (mg/L N)	EB	0.190 (0.086Mar-0.329Jun)	0.086 (0.042Aug-0.178Jun)	0.076 (0.018Aug-170Nov)	0.146 (0.014Jun-0.248May)	0.542 (0.205-1.340Jul)	0.362 (nilFeb,Nov-1.295Apr)	0.365 (nilJan,Apr-1.334Nov)
	WB	0.173 (0.032Mar-0.246May)	0.082 (0.030Jul-0.121Aug)	0.092 (0.034Mar-0.228Aug)	0.130 (0.042Mar-0.273Oct)	0.489 (0.128Sept-0.952Oct)	0.420 (nilFeb-1.088Apr)	0.343 (nilJan,Apr-0.905Nov)
c. Nitrate-Nitrogen (mg/L N)	EB	0.135 (0.112Sept-0.156Nov)	0.129 (0.084Jun-0.222Nov)	0.106 (0.045Sept-0.205Nov)	0.192 (0.048Jun-0.366Mar)	0.179 (0.016Jul-0.492Oct)	0.199 (0.048Feb-0.604Aug)	0.205 (0.075Apr-0.415Feb)
	WB	0.138 (0.077Sept-0.209Mar)	0.117 (0.052Jul-0.188Oct)	0.087 (0.035Jun-0.151Jan)	0.239 (0.028Jun-0.566Oct)	0.224 (0.014Jul-0.615Feb)	0.190 (0.022Mar-0.578Dec)	0.611 (0.060Apr-1.502Jan)

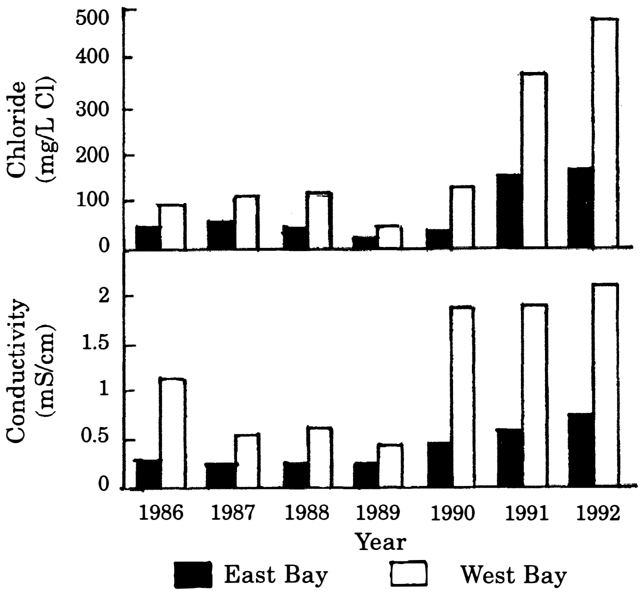

Figure 3. Annual mean conductivity and chloride.

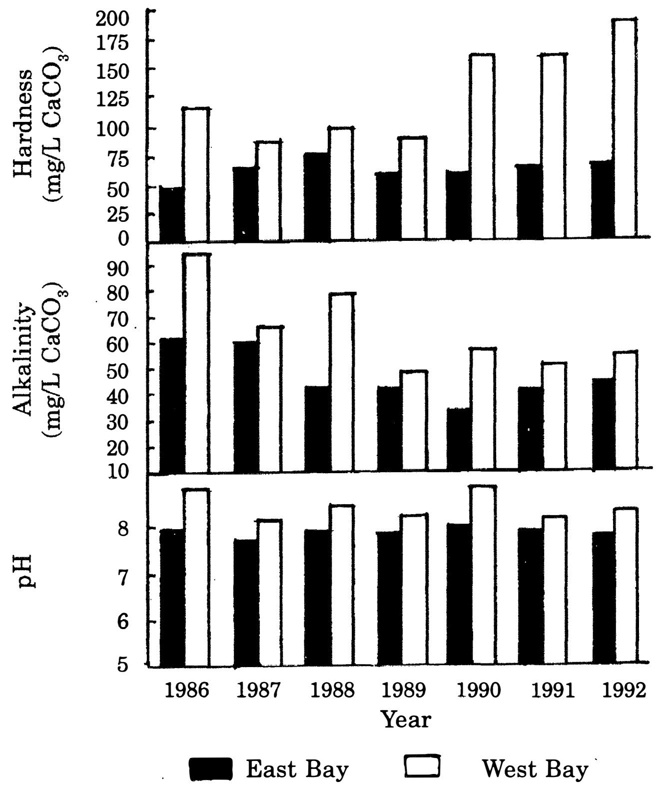

Figure 4. Annual mean pH, alkalinity and hardness.

Higher levels were generally observed from May to August (Table 1). Previous observations indicate that towards the end of the dry season, the lake is at its lowest level and at this time saltwater inflow from any river occurs resulting in the reduction of turbidity or increase in transparency. Data collected during our study however, did not conform with this observation.

Chloride levels of West bay waters were significantly higher than those of the East bay waters. The values are nearly tripled (Fig. 3). This difference may be due to the proximity of the West Bay to Pasig River where saltwater intrusion or to the greater amount of industrial effluents that are discharged into this part of lake.

pH

In general, the pH range of the lake tends towards the alkaline than the acidic side. The pH of West Bay was higher than that of the East Bay (Figure 4). The highest pH annual mean value was 8.8 in West bay and 8.0 in East bay both determined in years 1986 and 1990. (Table 1).

The permissible range of pH for "Class C" waters is 6.5 to 8.5 but pH values ranging from 7 to 8 are best for support and rearing of fish life. The slight variations of pH observed in both bays are not significant and within the tolerable values except in year 1986 and 1990 for West bay. Higher values of 9.0 (July 1986) and 9. 6 (June, 1990) were observed in East and West bays, respectively. High pH levels is a cause of concern because of its influence on the concentration of un-ionized ammonia in water.

The trend in pH value has not exhibited any significant change within the last 19 years. Except for some occasions when pH reached a value of 9.0 and above, annual mean pH range remained within the acceptable range of 6.5-8.5.

Alkalinity

The alkalinity of waters as expressed in mg/L $CaCO_3$ is due principally to salts of weak acids and strong bases, and such substances act as buffers to resist drastic changes in pH. Natural waters with total alkalinity of 40 mg/L or more are considered more productive than waters of lower alkalinity (Moyle, 1945, Mairs, 1956 as cited in Boyd, 1982).

Total alkalinity of West bay waters (Fig. 4) were generally higher than those of East bay waters. The highest annual mean values of 94 and 61 mg/L $CaCO_3$ were observed in West and East bays, respectively, in the year 1986. Alkalinity values lower than 40 mg/L were observed in both bays in some particular months of the year; East bay Aug. 1986, May, 1988, Oct. 1989, Nov. 1990, Jan. 1991 and Nov. 1992 and West bay Jun. 1988, Jul. 1991 and Nov. 1992. It may be observed further that there is a decreasing trend in alkalinity values from 1986 to 1989 for West bay. The decreasing trend is consistent with values observed by LLDA which reported alkalinity range of 46-177 mg/L from 1973-1977 which is higher than the range obtained from 1986-1992. It appears that there is a continuing decrease in alkalinity of the lake waters up to 1989, when it leveled off thereafter, and started to increase since 1991.

Hardness

Waters with total hardness ranges of 0-75, 75-150, 150- 300, and 300 up mg/L (expressed as $CaCO_3$) are classified as soft, moderately hard, hard and very hard, respectively. (Sawyer and McCarty, 1978). Water for fish culture must have total hardness of at least 20 mg/L.

Results of an analysis show no value below 20 mg/L for total hardness in the waters of either bay (Fig. 4). Total hardness values in West bay waters were higher than those of East bay waters. The highest annual mean value of 189 mg/L was observed in West bay in 1992. The East bay waters can be classified as soft waters while those of West bay as moderately hard and hard waters. West bay waters showed an increasing trend in hardness starting 1987.

The highest hardness of 438 mg/L as $CaCO_3$ is comparable to the highest value reported by LLDA from 1973-1977.

Dissolved Oxygen (DO)

The dissolved oxygen is the major parameter used in water assimilative capacity and is a primary parameter for the suitability of water for fish production. For "Class C" water, the minimum DO standard is at 5 mg/L (EMB,1990). The annual averages of daytime DO values revealed that there were slight differences in DO between West bay and East bay waters. (Figure 5). The average annual means is 7.5 for West bay and 7.1 for East bay. It was noted however, that a DO of 4.6 mg/L was observed in both bays in May 1990.

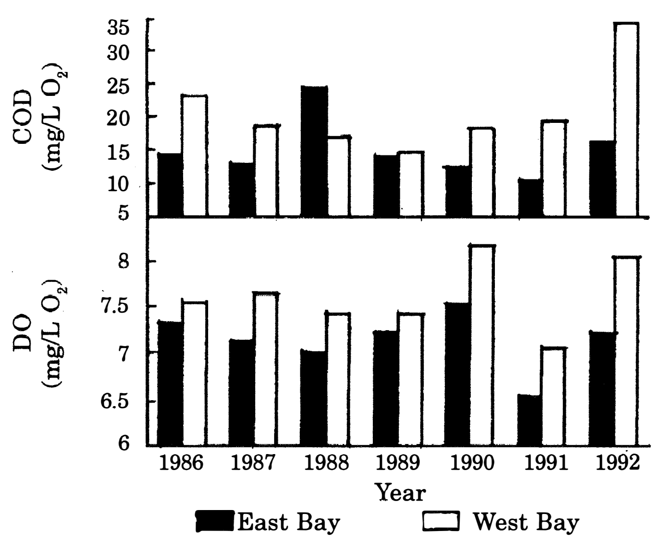

Figure 5. Annual mean DO and COD.

Although in general the observed DO values seem to indicate values within the quality standards for "Class C" waters, some caution should be made. It must be noted that the measurements were made during the day and the values do not reflect diurnal variation when DO is depleted during the night time particularly in the early morning. Besides the fact that the lake is very shallow with agitation, DO is expected to be high due to sheer atmospheric oxygen pressure.

Chemical Oxygen Demand (COD)

COD value indicates the concentration of materials oxidizable by chemical reaction. The COD test is also helpful in indicating toxic conditions and the presence of biologically resistant organic substances.

COD annual means for West Bay waters were several units higher than those of East bay waters (Fig. 5). Annual mean values ranged from 10.6 to 24.6 mg/L and from 16.9 to 34.7 for East bay and West bay waters, respectively (Table 1). Generally, both bays showed an increasing trend of COD through time.

Phosphorous fractions (Ortho-PO_4, total-P)

Phosphorus determinations are extremely important in the potential biological productivity of surface waters, and in many areas limits are being established on amounts of phosphorous that may be discharged to receiving bodies of water, particularly lakes and reservoirs. A general index of maximum desirable concentration in lakes and reservoirs for total phosphorous is 0.025 mg/L (EPA, 1976)

West bay waters exhibited relatively higher orthophosphate than those of East bay waters (Figure 6). The average annual means of orthophosphate in East bay and West bay were 0.117 and 0.154 mg/L, respectively.

Higher concentrations of total phosphorus were also observed in West bay than those of East bay with annual average of the means of 0.294 and 0.222 mg/L, respectively (Fig. 6).

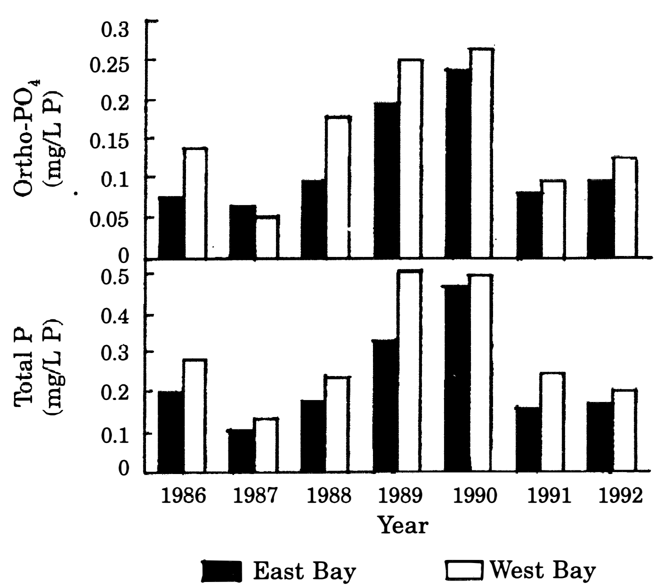

Figure 6. Annual mean phosphorus fractions (total -P- and ortho-PO_4).

LLDA data from 1973-1977 showed phosphate concentrations ranging from 0-0.13 mg P/ml; while our studies showed a range of 0.024 to 0.820 mg/L (Table 1). There was a continued increase in dissolved phosphate up to a peak in 1990 and a decrease thereafter. A similar trend was exhibited by total phosphate.

Nitrogen fractions (Total Kjeldahl-N, NH_3-N, NO_3-N)

Nitrogen and phosphorus compounds play an important part in biological growth. The presence of these nutrients in their oxidized states such as nitrates and phosphates, is responsible for accelerating the alterations in the quality of lake waters, through eutrophication. Thus, the levels of nutrients in effluents discharged to waters are cause for concern.

Generally, the total Kjeldahl nitrogen (TKN) of West Bay is higher than those of East bay except in 1989 (Figure 7). In this year, the TKN of East and West bays were 1.03 and 0.83 mg/L, respectively. The TKN of the East and West bays were lower in years 1987 and 1988 as compared to the other years.

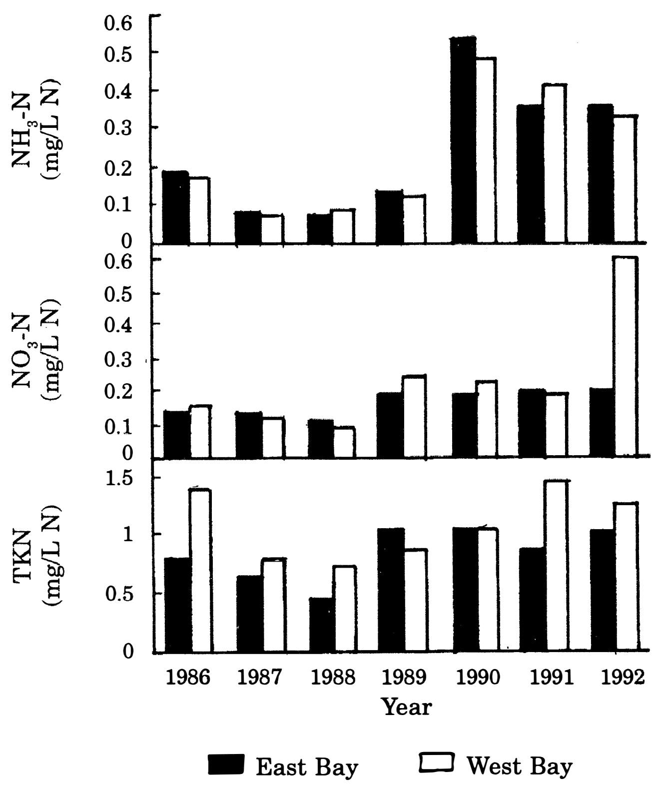

Figure 7. Annual mean nitrogen fractions (TKN, NO_3-N and NH_3-N).

Ammonia is a non-persistent, noncumulative toxic substance and fish cannot tolerate large quantities of this substance since it reduces the oxygen capacity of the blood, thus fish may suffocate. A level not to exceed 0.016 mg/L ammonia nitrogen is prescribed for the protection of fresh water aquatic life (US Environmental Studies Board, 1973).

The NH_3-N in East bay waters were slightly higher than those of the West bay waters except in 1990 (Fig. 7). The average of the annual means for East and West bays were 0.252 and 0.247 mg/L, respectively which are more than 15 times the limit considered safe by the US Environmental Studies Board.

The level of NH_3-N has alarmingly increased in the last three years with an average of annual means of 0.45 mg/L. This should be a cause for concern. In the event the pH rises to 9 or higher, there is a great possibility for fish kills due to ammonia toxicity.

Nitrate is the principal form of combined nitrogen commonly present in natural waters. As a micronutrient, it stimulates plant growth and when present in excessive amount may result in profuse algal growth. The subsequent algal die-off and decay produce secondary pollution. The critical level of nitrate prescribed for freshwater lakes is 0.30 mg/L or 0.067 NO_3-N.

There is an increasing trend in the nitrate levels of the lake (Fig. 7). The average of the annual means of nitrate-N (NO_3-N) concentration in the East bay and West bay waters were 0.163 and 0.229 mg/L, respectively. Nitrate levels were generally higher in the West bay than in the East bay waters (Fig. 7). The highest NO_3-N level was observed Jan. 1992 in the West bay.

Nitrate followed a seasonal pattern as a result of algal growth and decay. Some nitrate peaks are possibly the consequence of algal die-off or may come from surface run-off after heavy rains. It may also be possible that the nitrate peaks observed during periods of high turbidity may be mainly due to subsequent release of nitrogen from the interstitial water when the sediment layer (containing algal decay from preceding season) is stirred up and disturbed.

Based on the data found, indications of decreasing nitrate concentration with increasing algal concentrations were noted at the same time that orthophosphates also increased. Similar observations have been noted in a highly eutrophic lake, Lake Kasumigaura in Japan (Otsuki,et.al. 1987) and seemed to be characteristic of hypereutrophic lakes.

Summary and Conclusion

Results of water quality monitoring studies of Laguna de Bay, particularly from 1986 to 1992, show a worsening condition of the lake in terms of the values of important physico-chemical parameters. The values obtained for most of the parameters have exceeded the water quality standards prescribed based on its classification as "Class C" waters or as fishery resource. The major findings and conclusions are summarized below.

An increasing trend in the values of conductivity, chlorides, hardness, phosphorus, ammonia and other nitrogen fractions, and a decreasing trend in the values of alkalinity, pH, dissolved oxygen, and transparency, have been observed indicating a continuing deterioration of water quality due to the continued influx of water pollutants. Between East and West Bays, the latter showed poorer water quality indicating the greater impacts of water pollution in the area.

The worsening turbidity or decreasing transparency and depth of the lake reflect the effects of heavy siltation which include the destruction of bottom rooted plants. With all rooted plants gone and with poor water transparency, photosynthetic levels are limited and so are the levels of dissolved oxygen.

On the other hand, the high levels of nitrogen and phosphorus fractions make the lake highly eutrophic or susceptible to massive algal bloom, once the water clears during calm and sunny weather conditions. These algal blooms have been observed from time to time and in several cases have caused fish kill in the lake. The worsening eutrophication of the lake is indicated by the alarming levels of ammonia-N which reflect the worsening anaerobic condition in the bottom sediments which further threatens the dissolved oxygen levels. The NH_3-N, NO_3-N total-P levels of the lake were already exceeding the prescribed standards by 22 times, 6 times and 7 times, respectively, in 1992.

By and large, the results indicate the hypereutrophic nature of the lake as well as the increasing environmental stresses and impacts of water pollution on the water quality of the lake threatening its viability as a fishery resource. If the present trend in the deterioration of its water quality continues, it will not be long until the lake becomes dystrophic.

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