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Nutrient budget for Saguling Reservoir, West Java, Indonesia

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Abstract

A preliminary nutrient budget for Saguling Reservoir is reported as a first attempt to quantify the behaviour of nutrients entering this reservoir. This work is part of a larger Indonesia–Australia collaborative research and training project, involving Padjadjaran University and Monash University, established to study nutrient dynamics in Saguling Reservoir.

Saguling Reservoir, the first of a chain of three large reservoirs (Saguling, Cirata and Jatilahur), built on the Citarum River in central Java, was completed in 1985. It has already become highly polluted, particularly with domestic and industrial effluent (organic matter, nutrients, heavy metals) from the urban areas of Bandung (population 2 million). The reservoir experiences major water quality problems, including excessive growths of floating plants, toxic cyanobacterial blooms and regular fish-kills.

The work reported in this paper shows that Saguling receives a very large nutrient load from the city of Bandung and because of this, is highly eutrophic. It is unlikely that the water quality of Saguling will improve until a substantial part of Bandung is sewered and adequate discharge controls are placed on the many industries in the region upstream of the reservoir.

1. Introduction

Inadequate supplies of good quality water will be one of the major constraints to future growth in Indonesia according to the World Bank [1]. The Indonesian Government has responded to this challenge with a number of initiatives, one of the most important being the national clean rivers program (PROKASIH). The current program (PROKASIH 2005) will seek to focus on whole catchments in an attempt to control pollution loads to rivers, improve land use practices in upstream areas, and recover the physical function of rivers, particularly in urban areas [2].

The focus of this study is the Citarum River basin in Java, a very important catchment that has been the subject of a number of studies [3]. The Citarum River is 350 km long and flows north-westward to the Java Sea through central Java from its source in the area surrounding Wayang Mountain (Fig. 1). The Citarum catchment has a total population of around 7 million and supports traditional agriculture and forestry activities in addition to urban and industrial activities associated with the city of Bandung (population 2 million). Below Bandung, the river is well regulated through a chain of three large reservoirs (Saguling, Cirata and Jatilahur). These reservoirs provide hydropower, irrigation water, domestic water to Jakarta (Jatilahur) and aquaculture opportunities (Saguling, Cirata).

Saguling Reservoir (Latitude 107°25′E, Longitude 6°55′S, elevation 651 m) is the upper most reservoir. It is located some 30 km west of Bandung and about 100 km south-east of Jakarta (Fig. 1). Cirata, the second dam in the series is about 45 km from Saguling, and Jatiluhur, the third, about 50 km downstream of Cirata.

Saguling Reservoir was completed in 1985 and has already become highly polluted, particularly with

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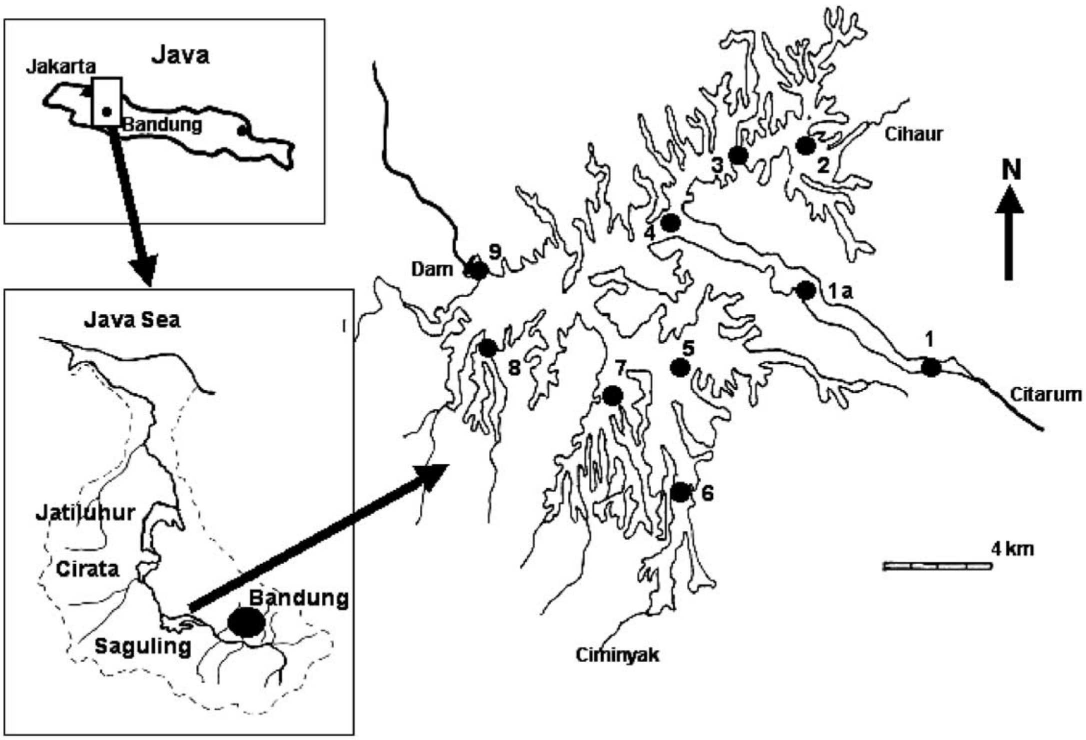

Fig. 1. Location map showing Saguling Reservoir, relative to Bandung, Jakarta and the other two reservoirs in this system (Cirata, Jatilahur). Modified from Soemarwoto et al. [15]. The water quality monitoring sites and sediment sampling sites are also shown.

domestic and industrial effluent (organic matter, nutrients, heavy metals) enter mostly from the northern catchment and the Citarum River [3,4]. Saguling essentially acts as a trap for pollutants discharged to the Citarum River in and around the urban area of Bandung. Although Saguling was built primarily for electricity generation, the displacement of approximately 40 000 people from their agricultural land led to the reservoir being used for floating fish farms which also contribute nutrient pollution.

From almost the beginning, Saguling has experienced major water quality problems. These include excessive growths of floating plants (e.g. water hyacinth, *Eichhornia crassipes*) particularly in the many shallow arms of the reservoir, toxic cyanobacteria blooms (e.g. *Microcystis* sp.), and regular fish-kills. The fish-kills probably result from a combination of low dissolved oxygen, high ammonia concentrations and high concentrations of toxic chemicals (e.g. pesticides).

In 1996, with funding from both the Indonesian and Australian Governments, a collaborative research and training project, involving the Institute of Ecology at Padjadjaran University and the Water Studies Centre at Monash University, was established to study nutrient dynamics in Saguling Reservoir.

In this paper, we report first the general limnology of Saguling Reservoir and then a nutrient budget for the reservoir as a first attempt to quantify the behaviour of nutrients entering the reservoir.

2. Experimental details

2.1. Study area

2.1.1. Saguling reservoir

Saguling is the first in a series of three dams along the Citarum River which flows north-westward to the Java Sea through central Java (Fig. 1). The major city of Bandung is located approximately 45 km upstream of the reservoir.

The climate in the Citarum basin is tropical and is characterised by distinct wet and dry seasons. The rainy season (November to April), results from the westerly monsoon, and the dry season (May to October) results from the prevailing easterly monsoon. Mean annual rainfall is 2322 mm, with almost 80% falling between November and April. The mean monthly inflow to Saguling Reservoir shown in Fig. 2, clearly illustrates the wet and dry seasons.

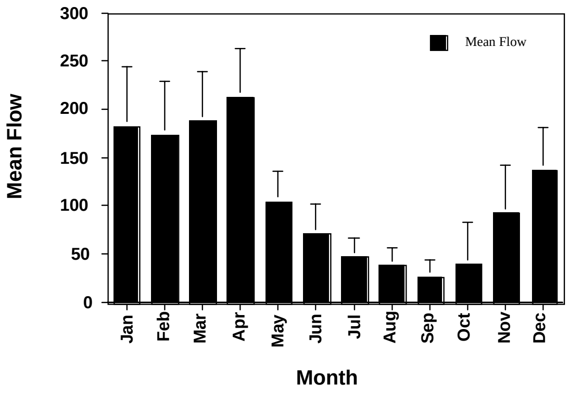

Fig. 2. Graph of the mean monthly flows (m^3/s) into Saguling Reservoir (records are for the period 1989 to 1995).

The capacity of Saguling Reservoir is $982 \times 10^6\,m^3$ with a mean water residence time of around 84 days. The reservoir has a maximum depth of 99 m and a maximum area of 56 km^2 [5]. Most (75%) of the flow into Saguling comes from the Citarum River, with 23% also coming from smaller tributary rivers and 2% from other areas surrounding the reservoir [6].

2.1.2. Citarum River

As noted above, the Citarum River contributes the major inflow to Saguling and also the major pollution loads. The total area of the Citarum basin is about 6000 km^2, with a little over one third of this (ca. 2285 km^2) draining into Saguling Reservoir. The human population in the Citarum basin is around 7 million, with some 2 million of these living in the major city Bandung. The Citarum River upstream of Saguling Reservoir is heavily polluted by industrial wastewater (there are around 2500 industries in the basin), and domestic sewage [7]. About 50% of the domestic sewage is discharged directly into the Citarum River, with about 15% being pretreated in septic tanks. Bandung has a wastewater treatment plant, but it has a capacity for 400 000 people far short of the actual population [7].

2.1.3. Other tributaries

Most of the 23% of water which enters Saguling from tributaries other than the Citarum, comes from the southern tributaries (e.g. Ciminyak, Fig. 1). These southern catchments are less developed, and are dominated by traditional agriculture and forestry land uses. Of the northern catchment inputs, the largest volume (and the most polluted) input comes via the Cihaur (Fig. 1), which drains the urbanised northern parts of Bandung.

2.1.4. Catchment

It is estimated that the remaining catchment contributes only 2% of the water input to Saguling [6]. For this reason, it is unlikely that this general catchment run-off would contribute much to the total nutrient loads.

2.2. Data for Saguling Reservoir

A number of water quality monitoring programs have been undertaken since Saguling Reservoir was first filled in 1985. These are summarised below.

2.2.1. Early work

In the period 1986 to 1989, Soemarwoto et al. [6] monitored the water quality (including Total Phosphorus (Total-P) concentrations, but not Total Nitrogen (Total-N)) in Saguling Reservoir to determine its suitability for floating net cage aquaculture.

2.2.2. National limnological study

Saguling Reservoir was also sampled twice during the dry season (March, August) of 1992 as part of the Indonesian national study of *Major Lakes and Reservoirs in Indonesia, a Limnological Study*, a joint Indonesian–Finnish research project [5]. A total of 38 major lakes and reservoirs were included in this study.

2.2.3. Padjadjaran University

The Institute of Ecology at Padjadjaran University monitored water quality on a quarterly basis at 10 sites over the period 1990–1995. The nutrient data collected over this five year period are summarised in Table 1. Nutrients monitored included NH_4-N, NO_3+NO_2-N (refered to as NO_x-N) and filterable reactive phosphorus (FRP), but not Total-P or Total-N. Although there are a number of gaps in this data set, it by far the most comprehensive, and for this reason has been used for the budget calculations.

2.2.4. This study

To provide information on the diurnal changes occurring in Saguling, in situ monitoring of temperature, conductivity, pH and dissolved oxygen (DO) was undertaken at five sites over a 24 h period in January/February 1997 using an Horiba probe. The results are presented in Table 2 (sites are indicated in Fig. 1).

Surface water samples were also taken at the same time using a Van Dorn bottle, and analysed for Total-P, FRP, Total-N, NH_4-N and NO_x-N. Analytical methods used are those listed in the Water Studies Centre Methods Manual (WSC, 2001) [8] which are largely based on the standard methods for water analysis (APHA, 1995) [9]. Nutrient results are presented in Table 3.

Sediments samples were collected at five sites (1a, 4, 5, 6, 9, Fig. 1) in October, 1996 using an Eckman Grab.

Table 1
Summary of the nutrient concentrations in Saguling reservoir for period 1990–1995 (see Fig. 1 for site locations)

Site	FRP				NH_4-N				NO_3+NO_2-N				DIN	
	Mean	Median	*n*	SD	Mean	Median	*n*	SD	Mean	Median	*n*	SD	Mean	Median
1	266	261	10	219	164	122	9	77	684	256	10	685	848	378
4	160	168	11	110	251	210	9	174	908	507	11	1000	1160	717
9	109	113	11	82	269	145	10	268	538	455	11	434	807	600
2	222	234	11	162	431	495	10	202	1010	510	11	966	1440	1010
3	214	288	11	144	191	147	10	82	569	593	11	465	760	740
5	80	69	10	53	223	141	10	182	479	281	11	530	702	422
6	158	113	11	184	179	148	10	129	494	234	11	536	673	382
7	115	104	10	80	205	187	10	174	530	282	11	620	735	469
8	127	129	11	91	228	146	10	156	450	384	11	333	678	530
Reservoir (3, 4, 5, 7, 8, 9)	142	145			213	163			572	380			785	543

Table 2
Results of in situ monitoring at five sites in Saguling Reservoir in January/February 1997 (for location of sites see Fig. 1)[a]

Location	Temp (°C)	EC (μS/cm)	TSS (mg/L)	Secchi (cm)	pH	DO (mg/L)
Citarum (site 1)						
Mean	23.9	266	141	38	6.3	0.9
SD	0.3	7	9	4	0.1	0.2
Cihaur (site 2)						
Mean	23.2	367	279	11	8.2	6.0
SD	1.3	99	33	6	0.6	1.1
Ciminyak (site 6)						
Mean	23.6	136	41	Nd	8.1	8.4
SD	1.7	6	2	Nd	0.3	0.6
Cilanang (site 8)						
Mean	23.9	126	92	27	8.4	7.3
SD	1.6	5	10	2	0.2	0.4
Dam (site 9)						
Mean	23.7	202	24	Nd	6.9	3.0
SD	0.4	4	4	Nd	0.7	0.7

[a] In all cases, samples taken 1500, 1800, 2100, 2400, 0300, 0600, 0900, 1200h; $n = 8$.
Nd—not determined

These samples were returned to Australia and analysed for Total-P and Total-N in the Water Studies Centre laboratory. Appropriate quality control techniques were employed as outlined in WSC [8]. These procedures included use of a standard reference sediment (SRM2704, National Institute for Standards & Technology, Gaithersburg, USA).

The results of the sediment analyses are presented in Table 4.

2.3. Nutrient budget

The nutrient budget for Saguling is given in Table 5. All flow data were obtained from the electricity company, Pembangkitan Tenaga Listrik (PLN) which manages Saguling Reservoir.

2.3.1. Inputs

Tributary inflows: The inflow from Citarum (site 1) was obtained from the mean inflows for the years 1989–1995 (PLN, pers. com.). These inflows ranged from 81.6 to 136 m^3/s, with a mean of $102 \pm 18\,m^3/s$. Over this period, PLN estimate the following contributions to the total inflow: Citarum—75.2%, tributaries—22.5%, catchment—2.3%. The mean FRP and dissolved inorganic nitrogen (DIN = NH_4-N + NO_x-N) concentrations used in the calculations are shown in Table 5.

Table 3
Nutrient concentrations in water samples collected at five sites in Saguling Reservoir January/February 1997 (for location of sites see Fig. 1)[a]

Location	FRP (μg/L)	Total-P (μg/L)	NO_3-N (μg/L)	NO_2-N (μg/L)	NH_4-N (μg/L)	DIN (μg/L)	Total-N (μg/L)
Citarum (site 1)							
Mean	43	114	503	73	228	803	883
Sd	31	38	601	74	121	764	683
Cihaur (site 2)							
Mean	90	211	2360	513	646	3520	3460
Sd	57	59	539	229	148	749	689
Ciminyak (site 6)							
Mean	2	41	595	47	163	805	881
Sd	0	8	164	16	45	223	218
Cilanang (site 8)							
Mean	2	66	974	66	267	1310	1350
Sd	0	19	96	19	26	130	136
Dam (site 9)							
Mean	39	84	2310	558	632	3500	3290
Sd	25	13	558	393	153	876	556

[a] In all cases, samples taken 1500, 1800, 2100, 2400, 0300, 0600, 0900, 1200h; $n = 8$.

Table 4
Nutrient concentrations (TP and TN) in sediment samples collected from five sites in Saguling Reservoir (for location of sites see Fig. 1)

Site	Total-P (μgP/g)	Total-N (μgN/g)	Total-N/Total-P (mol/mol)
1a	2200	3600	3.6
4	1300	2600	4.4
6	1200	2900	5.4
5	460	930	4.5
9	940	1900	4.5

These were obtained from the data in specific inputs—see Table 1.

Fish farms: Bamboo cage culture of fish (common carp *Cyprinus carpio*) has been practiced in Indonesia for centuries. Floating net cage culture in West Java accelerated rapidly after the construction of Cirata and Saguling Reservoirs. In more recent years, the hybrid red tilapia *Oreochromis* sp. has also been farmed. The Indonesian Fisheries Department estimate that Saguling Reservoir has about 4425 fish cages, each using 10.8 tonne of feed per year, or a total of ca. 48 000 tonne/yr. Lehmusluoto and Machbub [5] report that annual fish production is 160 tonne (400 nets each producing 400 kg/yr), although more recent estimates are higher than this (ca. 6000 tonne/yr, Indonesian Fisheries Department, pers. com.).

The greatest density of fish cages in Saguling is located in Bongas Bay (see Fig. 1). Over recent years, major fish kills have occurred, mainly in the months of January and February. The reason for these fish kills is not known.

Internal sediment release: Saguling Reservoir inundated vast quantities of organic matter and rich organic soils when it filled, although unfortunately we have no information of the nutrient concentrations of these soils. Sediment samples taken in October 1997 from five sites contained 450–2 200 μg P/g (dry wt) and 930–3 600 μg N/g (dry wt) (Table 4).

2.3.2. Outputs

Outflow: The annual outflow of P and N was calculated using the data in Table 4. The annual volume was provided by the Saguling Reservoir operator Pembangkitan Tenaga Listrik (PLN) and mean FRP and DIN concentrations were estimated from the data collected at site 9 close to the dam wall (see Table 1).

Fish harvesting: We have assumed that 5735 tonne of fish are harvested each year [10], and that this contains 215 tonne of P and 660 tonne of N (N/P ratio is ca. 7 mol/mol).

2.3.3. Amount in reservoir

The loads of P and N in the water column were estimated using a total volume of $982 \times 10^6\,m^3$ and mean concentrations of FRP (140 μg/L) and DIN (790 μg/L) obtained from the mean concentrations at sites 3, 4, 5, 6,

Table 5
Preliminary nutrient budget for Saguling Reservoir

Inflow/outflow	System	Flow (ML/yr)	FRP (μg/L)	DIN (μg/L)	P (tonne/yr)	P%	N (tonne/y)	N%	Comments
Inflow	Citarum	3 204 000	270	850	865	57	2720	44	Site 1 used
	North tributaries	153 400	220	1440	34	2	221	4	Site 2 used
	South tributaries	805 300	160	670	129	8	540	9	Site 6 used
	Catchment	98 000	160	310	16	1	30	0	
	Fish farms				478	31	2630	43	
	In situ release					0		0	
	Totals	**4 260 700**			**1520**		**6140**		
Outflow	Reservoir	2 636 000	109	807	287	57	2130	76	Site 9 used
	Fish harvesting				215	43	657	24	
	Totals				**502**		**2780**		
Load in reservoir water column ($V = 982 \times 10^6\,m^3$)			140	790	**137**		**776**		Sites 3,4,5,6 7,8,9 used
Residual = Inflow—load in Reservoir water column—Outflow					**881**		**2580**		

7, 8 and 9 (these sites were taken as representative of the main Saguling waterbody).

3. Results and discussion

3.1. General limnology of Saguling

Saguling is the first reservoir in the Saguling–Cirata–Jatiluhur chain of reservoirs. Approximately 75% of the inflow occurs via the Citarum River, and is highly polluted from domestic and industrial wastewater from the city of Bandung (population 2 million).

Like most tropical reservoirs, Saguling is highly influenced by the wet–dry season climate [11–13]. The major amount of inflow (ca. 80%) to the reservoir occurs during the wet season (November to April). Water temperature is high and reasonably constant during the year, ranging from ca. 20°C to 30°C. The temperature difference between surface and bottom waters is generally small (0.2–3°C), but this is still sufficient to permit stratification to occur [13,14].

The deeper areas of the reservoir appear to be constantly stratified with a very sharp thermocline (and oxycline) at a depth of 5–10 m depending upon season [5]. In January 1997, the thermocline was at around 5 m, and below this the oxygen concentration was very low (0.2–3.2 mg/L). In fact, at this time the inflow from Citarum was also very low in dissolved oxygen with values of 0.6–1.2 mg/L recorded in the surface waters (Table 2). During 1995, hydrogen sulfide concentrations in bottom waters ranged from 0 to 1.3 mg/L depending upon location and time of the year (Univ. Padjadjaran, unpublished data).

The conductivity of water in Saguling is relatively low (160–400, mean ca. 200 μS/cm) with the highest values observed during the dry season.

pH was measured during the study period in Jan./Feb. 1997 and was found to be quite variable at the different locations (Table 2). For example, inflowing Citarum water (pH ca. 6.3) and water at the dam wall (ca. 6.9) were circa neutral or slightly acidic, while that at the other three sites had higher mean pH values (8.1–8.4). The higher pH values at sites 2, 6 and 8 may reflect high phytoplankton primary production at the time. Unfortunately, we do not have any chlorophyll-*a* values to test this hypothesis.

Bandung contributes high loads of organic matter and nutrients to the Citarum River and hence to the reservoir. For example, Djuangsih [4] reported dissolved organic carbon (DOC) concentrations of 25–31 mg/L in the Citarum and Cihaur Rivers in December 1996. Also at this time, the DOC concentration in Bongas Bay (site 6) was less (ca. 11 mg/L), but still elevated. Nutrient loads are discussed below.

3.2. Nutrient concentrations

3.2.1. Water column

As noted above, Bandung contributes a high nutrient load to the Citarum River and then to the reservoir.

Relatively high concentrations of DIN were consistently measured in Saguling over the period 1990–1995, with mean values ranging from 640 to 1400 μg N/L (Table 1). The DIN was made up of around 70% nitrate (and nitrite) and 30% ammonia. During the 1997 wet season study, the DIN concentrations were generally higher (800–3500 μg N/L, Table 3), although the proportions of nitrate (and nitrite) and ammonia were similar (80%, 20%). The consistently high ammonia concentrations (mean values—160–650 μg N/L, Table 3) are of concern as free ammonia is quite toxic to fish. For example, the Australian water quality guidelines recommend the ammonia concentrations should be less than 320 μg/L (as total ammonia at pH 8) to protect 99% of freshwater biota [15].

Very high concentrations of FRP were measured during the period 1990–1995. For example, mean values ranged from 80–266 μg P/L (Table 1). It is possible that these high concentrations are the result of analytical errors, since the more recent FRP data are considerably lower (mean concentrations 2–90 μg P/L; Table 3).

These high nutrient loads would be expected to result in high plant growth in Saguling. This appears to be the case, although the phytoplankton and macrophyte biomass have not been studied systematically. Lehmusluoto and Machbub [5] reported high chlorophyll-*a* concentrations in Saguling (0.82–5.0 mg/m^3). They also reported observing dense mats of *Eichhornia crassipes* in Bongas Bay (site 6) in March 1992, but very few plants in August. Djuangsih [4] reported phytoplankton counts for December 1996—highest counts were observed in Bongas Bay (site 6—dominated *Straurastrum* sp. (2340 cell/mL) and *Fragilaria* sp. (420 cell/mL) and Moroko (site 4; dominant—*Microcyctis* sp. (1,020), *Artrospira* sp. (730) and *Oscillatoria* (560)).

3.2.2. Sediments

Sediment samples were taken from five sites in Saguling Reservoir in October 1997 and analysed for total-P and total-N concentrations (Table 4). Total-P concentrations ranged from 460 to 2200 μg/g (dry wt), and total-N concentrations from 930 to 3600 μg/g (dry wt). The highest concentrations were observed at site 1a and site 4. These presumably reflect the deposition of polluted suspended material transported into the reservoir by the Citarum River. High sediment nutrient concentrations were also found at site 6, possibly due to the deposition of fish food added to the large number of fish cages in Bongas Bay.

The relatively low nutrient concentrations at site 9, near the dam wall suggest that most of the contaminated suspended matter input from the Citarum drops out of the water column close to where this river enters the reservoir. The lowest nutrient concentrations were in sediments taken at site 5.

3.3. Nutrient budget

The preliminary nutrient budget (Table 5) is focused on phosphorus and nitrogen because these are considered to be the main contributors to the excessive plant growth and cyanobacterial problems observed in Saguling.

The various inputs and outputs considered in the budget are shown in Table 5. We stress that this budget has used data on the most bioavailable forms of phosphorus (FRP) and nitrogen (DIN). Two other possible inputs not considered because of insufficient data, were the loss of nutrients from plant harvesting, and nitrogen added via nitrogen fixation. Nutrient loss from plant harvesting is probably not significant since most is left to rot on the banks and the nutrients released would run back into the reservoir. Although nitrogen fixation has not been considered, we have also not considered nitrogen that will be lost via denitrification.

The results show that the greatest contribution of nitrogen and phosphorus entering the reservoir comes from the Citarum River, with the next most significant amount coming from fish feed. Water outflow and fish harvesting are responsible for removing around 30%–45% of the nutrients entering the reservoir. The residual amounts (ca. 60% FRP and ca. 40% DIN—Table 5) are most probably tied up in the sediments and macrophytes.

Unfortunately, our data are not adequate to estimate the relative contributions during the wet and dry seasons. However, given that ca. 80% of the water inflow occurs during the wet season, it is most probable that a high proportion of the inflow passes directly through the reservoir in wet season. Most of the input during the dry will be deposited or biologically consumed within the reservoir.

The mean concentrations of both FRP (ca. 140 μg P/L) and DIN (ca. 790 μg N/L) in the water column are large, suggesting that the phytoplankton biomass should also be large. Unfortunately, we have few chlorophyll-*a* measurements to assess this hypothesis, but those data which are available suggest the biomass can be relatively large (0.8–5.0 mg Chla/m^3 [5]). Although elevated, the few chlorophyll-*a* measures are perhaps not as large as expected given the very high FRP and DIN concentrations measured, which would suggest chlorophyll-*a* concentrations could reach as high as ca. 100 mg Chla/m^3.

The ratio of N:P has commonly been used to evaluate the nutrient status of a water body [16,17], although this measure has its problems [18]. It is generally assumed that when the molar N:P ratio is greater than 16:1 the waterbody is phosphorus deficient and when the ratio is less than 16:1 it is nitrogen deficient. The latter ratio is considered to favour the growth of nitrogen-fixing cyanobacteria. In Saguling, the molar N:P ratio averaged over wet and dry seasons was ca. 13:1, which suggests neither phosphorus nor nitrogen are likely to limit phytoplankton growth. We have insufficient data to be able to comment on the likely fluctuations in the N:P ratio during the wet and dry seasons.

We noted in an earlier section the possibility that the FRP concentrations measured during the period 1990–1995 are too high because of analytical problems. However, even if we assume the recent data are more representative of the FRP concentrations in this reservoir, there is still a large FRP load entering the reservoir (880 tonne/yr) and a large residual (410 tonne/yr); these are approximately one half the values calculated using the earlier data.

The errors in this preliminary budget are likely to be large for two main reasons. First, we have relatively few data available, and second there are few data for the wet season inflows when the majority of the nutrients would be transported. Both these deficiencies are being addressed in the on-going monitoring program being continued by Padjadjaran University.

A preliminary assessment of the trophic state of Saguling reservoir can be obtained using the modified Vollenweider loading diagram, which plots the areal P loading vs. the mean depth/hydraulic residence time. Saguling has a very short water residence time of ca. 84 days, which combined with the mean depth of 20 m, gives a high value for mean depth/residence time (87 m/yr) which is at the high end of this scale for lakes and reservoirs. Equally, whether we assume the low or high P load, the areal P loading to this reservoir is very high (18 g/m^2 yr or 30 g/m^2 yr). Combining these estimates identifies Saguling as highly eutrophic.

It is possible that despite the high nutrient concentrations, phytoplankton growth in this reservoir is limited by light availability. Unfortunately, there are few long-term data on light penetration in Saguling. However, data collected during the wet season of 1997 (Jan./Feb.) suggests the reservoir was very turbid in places (Table 2). For example, secchi depth ranged from 10–80 cm depending upon location, with the clearer water observed in the mid-reservoir locations. Additionally, total suspended solids concentrations ranged from 20–320 mg/L, with the lowest concentrations at the dam wall (site 9) and highest at site 2 in the Cihaur estuary.

In summary, this study has shown that Saguling Reservoir receives a very large nutrient load from the city of Bandung and because of this is highly eutrophic. It is unlikely that water quality of Saguling will improve until the greater part of Bandung is sewered and there are adequate discharge controls on the many industries in the region upstream of the reservoir.

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