Nitrate and phosphate from rivers as mitigation of eutrophication in Benoa bay, Bali-Indonesia

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Abstract. Benoa Bay is estuary of six rivers in Bali. In addition to carrying water, river flows also carry nutrients (nitrate and phosphate) derived from activities along the watershed. High nutrient concentrations have potential for eutrophication that leads to the Harm Alga Booms. The aims of this study were to determine the concentration, load, and trophic level of nutrients (nitrate and phosphate) in river which ends at Benoa Bay. Measurement of nutrients in water used brucine method for nitrates and ascorbic acid method for phosphate. The results were then compared with ministerial decree of the environment No 51 in 2004 for marine biota. The result show concentration of nitrate and phosphate is fluctuated along years. Nitrate concentration fluctuated form undetected to 16.950 mg/l, meanwhile phosphate concentration from undetected to 3.275 mg/l. The highest concentration of nitrate and phosphate found in dry season and the lowest concentration found in wet season. Nitrate and phosphate load to benoa bay also fluctuated in each season and river. The highest nitrate load found in Mati River during second transition season (4.387 tons/day) and also in Buaji River during dry season (4.366 tons/day). The highest phosphate load to Benoa Bay also comes from Mati River in dry season (6.980 tons/day). The Eutrophic condition for nitrate generally found in Second Transition Season, meanwhile for phosphate generally found in all river and season. The concentration of nitrate and phosphate found in all rivers and season which ends at Benoa Bay generally exceeded the quality standard base on Ministerial decree of environment No 51 in 2004 for marine biota. These conditions are potential for trigger eutrophication process in Benoa Bay.

1. Introduction
Eutrophication is a process of nutrients enrichment in aquatic environment caused by the human activities [1]. The danger effect of eutrophication is Harm alga blooms (HABs) which led to the creation of anoxic and toxic conditions in the aquatic environmental [2]. Eutrophication dominantly occurs in a closed or semi closed area (such as bay) that has high nutrient inputs and lack of water circulation [3, 4].

Benoa Bay is a semi-enclosed bay in Bali Island which has a very important function in terms of ecological and economical. Ecologically, the Benoa Bay is surrounding by mangrove (Taman Hutan Raya Ngurah Rai) which is the largest mangrove forest ecosystem in Bali. Economically, Benoa Bay is used as a port, cultivation area, catching area and for tourism activities. The condition of Benoa Bay
waters is very fluctuated and strongly influenced by the activities in land or sea. The results from model show that Benoa Bay during flood got water from the Indian Ocean, while during ebb, water dominantly come from the land, especially through the river [5]. Nutrient concentration is increasing in the river estuary in Benoa Bay [6].

The river is an area that consistently drains water from upstream to downstream areas, both during the rainy and dry seasons. In addition to carrying water, the river also carry pollutants that originating from activities along watershed [7]. Population activities either directly or indirectly along the watershed such as household waste disposal, agriculture, and industrial activities will greatly affect the pollution level in river water [7, 8, 9, 10]. The downstream of river are generally embouchure in the sea, so the pollution in the river area will be transfer to the sea also [11].

Benoa Bay is estuary of six major rivers: Bualu, Sama, Mati, Badung, Buaji and Loloan Rivers (Tukad in Balinese language). The pollution conditions in these six rivers will greatly affect the condition of waters in Benoa Bay. Previous research obtained the nitrate and phosphate in Mati River estuary generally exceed quality standards based on Ministerial decree of environment No 51 in 2004 for tourism, marine biota and port especially either at during ebb and flood [12]. This indicates that the concentration of pollutants, especially nutrients that enter the Benoa Bay is quite high.

Monitoring of nutrient input into the Benoa Bay is needed to prevent nutrient enrichment that high potential for HABs. Surely this HABs event will greatly disrupt all the activity at Benoa Bay. If a preventive action is taken, the possibility for the occurrence of this disaster can be minimized. The aims of this study were to determine the concentration, load, and tropic level of nitrate and phosphate in the river which ends at Benoa Bay.

2. Methods
This research was conducted for 1 year with 4 times sampling that cover all season. Samples were collect once in every season: wet season on January 2017, first transition season I on April 2017, dry season on July 2016, and second transition season on October 2016. The sampling location was conducted in Bualu, Sama, Mati, Badung, Buaji and Loloan River (figure 1). Water Discharge from Badung River was measure in outlet of Badung Dam.

![Figure 1. Map of research location, the red dot are sampling site for each river](image)
Hydrological investigation was conducted before collecting water samples in each river. Salinity measurement using conductivity, temperature and depth (CTD) instrument is first step in hydrological investigation to ensure the water samples are all from the river. Accuracy of Castway CTD is 0.01 for salinity. If the water sample has 0 psu salinity, then measured the river water discharge using flow meter for current \( (v) \) in m/s and area measurement using ruler for width (m) and depth (m) of the river. To have uniform form for water discharge, the measurement was dividing in several areas and flows in one river. The water discharge \( (Q) \) calculated using [13]:

\[
Q = v \times \text{depth} \times \text{width}
\]

After this step, we were collecting 600 ml water sample and stored in the cool box for later brought to the laboratory. We keep the temperature in cool box around 4°C using ice. The sample in the laboratory was filtered first using Whatman filter paper no 42, then the nutrient concentration was measured using Spectrophotometer. Nitrate was measure using brucine method and phosphate using ascorbic acid method [14]. The load of nutrient \( (F) \) from all rivers which ends at Benoa Bay was calculated using [15]:

\[
F = C \times Q \times 10^6 \times 86400
\]

where \( C \) is nutrient concentration (Nitrate or Phosphate) (mg/l), \( Q \) is water discharge (m³/s), 10⁶ is conversion factor from mg/l to ton/m³, and 86400 is conversion factor from second to day).

Tropic level status of river which ends at Benoa Bay was determining using table 1 [16, 17]. Total N and P were only calculated from nitrate and phosphate only. These approaches were done with the consideration that phosphate and nitrate are the main nutrients that cause eutrophication [18]. Nitrate and phosphate concentration were also compared to the Ministerial decree of the environment No 51 in 2004 for marine biota standard. Potential eutrophication based on Ministerial decree of the environment No 51 in 2004 obtained when the nitrate and phosphate concentration has exceeded the standard of marine quality for marine biota.

| Tabel 1. Trophic level in river [16, 17] |
|----------------------------------------|
| Total N (mg/L) | Oligotrophic | Mesotrophic | Eutrophic |
| <0.700        | 0.700 – 1.500 | >1.500      |
| Total P (mg/L) | <0.025        | 0.025 - 0.075 | >0.075 |

3. Result and Discussion

3.1. Water Discharge

The water discharge form all rivers during the research are fluctuated in each river and season (figure 2). The lowest discharge found in Bualu River (0 m³/s) in all season because Bualu River is a temporal river that only flows during the rainy season. During research, the water in Bualu River never flowed and the water samples were only taken from the stagnant water. The highest water discharge was found in Mati River (10.3 - 46.2 m³/s) and Badung River (4.6 to 2.5 m³/s). The high discharge in both river allegedly because these river is the longest river with the largest catchment area. Mati River is 12 km length and Badung River is 17 km length [18]. Although Badung River are longer than Mati River, the discharge form Badung River are smaller than Mati River, it is because the downstream of Badung River dammed by the Regional Water Company (PDAM) as a water source. The water discharge from Buaji and Loloan River is smaller than Mati and Badung River, this is allegedly because both rivers have short watershed. Buaji River is 4 km long and Loloan River is 5.2 km long [19].

Seasonally, the highest river floods were found during the wet season (average 16.2 ± 17.93 m³/s) and the lowest water discharge during the first transition season (3.82 ± 4.51 m³/s) (figure 3). The pattern of water discharge in rivers is strongly associated with the amount of precipitation, the higher precipitation the higher water discharge [20]. The precipitation pattern in Bali region is affected by the monsoon system, with the highest rainy (wet) season on December to February related to north-west monsoon characterized by moist warm air blow and the lowest precipitation in dry season on June to
July related to south-east monsoon characterized by dry wind blow [21, 22, 23]. The lowest water discharge generally found in dry season, but in this research the lowest water discharge distorted and found in first transition season. The distorted assumes do to the El Nino even in 2015-2016 that occurred earlier in the central Pacific [24]. El Nino southern oscillation (ENSO) even in Pacific Ocean also close related to the rainfall in Indonesia region [25] and driving rainfall anomalies [26].

![Figure 2. Water discharge in all rivers during wet season (dash line), first transition season (solid line), dry season (dash dot line), and second transition season (dot line).](image)

3.2. Nitrate and Phosphate Concentration
Nitrate and phosphate concentration was measure in all rivers was fluctuated along year. Nitrate concentration fluctuated form undetected to 16.950 mg/l, meanwhile phosphate concentration from undetected to 3.275 mg/l (figure 4). The highest concentration of nitrate found in Buaji River in dry season (figure 4 left panel) and phosphate in Loloan River during second transition season (figure 4 right panel). The lowest nitrate (undetected) concentration found in Buaji and Loloan River in first transition season, meanwhile undetected phosphate concentration found in Bualu, Buaji and Loloan Rivers in second transition season. The fluctuation of nitrate and phosphate in Buaji River need further research and monitoring because in dry season we found the highest concentration but in the other season nitrate and phosphate concentration was undetected. During dry season measurement, the water form Buaji River is black and gave strong odor, but in other season the water was clean and less smelling. Fluctuated concentration of nitrate and phosphate in Buaji and Loloan Rivers, it’s supposed there is no fix source of domestic waste in both rivers. Domestic waste affects the concentration of nutrients in waters [27].

![Figure 3. Average water discharge form all season](image)
The highest concentration of nitrate in Buaji River in dry season supposed of low discharge water (3.0 m³/s) and accumulation of nitrate from first transition season. Low discharge causes low dilution of material along river [28]. Otherwise the concentration of nitrate and phosphate are lower and relative constant in Badung and Mati Rivers which have high discharge water (figure 2). Similar result also found in Mississippi River as high river discharge has low nutrient concentration [29]. Relative constant of nitrate and phosphate concentration in both river presume because the upstream of these river is agricultural area [30] and through Denpasar City. The main source of water pollution recognize from agriculture [9, 10] that come from residues of fertilizer [31]. In organic fertilizer contain nitrogen and phosphate that use in agricultural system reach water body through leaching, flow and drainage [32].

![Figure 4](image1.png)

**Figure 4.** Nitrate (left) and phosphate (right) concentration in all rivers during wet season (dash line), first transition season (solid line), dry season (dash dot line), and second transition season (dot line).

The highest average concentration of nitrate (4.45 mg/l) and phosphate (1.26 mg/l) was found in dry season and the lowest nitrate (0.60 mg/l) dan phosphat (0.68 mg/l) was found in wet season (figure 5). The lowest concentration in wet season and first transition season assume due to high dilution by water in the river. Similar result also found in Lena River that dilution process during flood season decrease dissolved salt concentration [28]. The examples of opposite result in Yangtze River, the highest concentration found in wet season that link with dissolution of fertilizer and mother rock through runoff [33]. The average concentration of nitrate (2.00 ± 1.91 mg/l) is higher than phosphate (0.85 ± 0.30 mg/l) in all river and season. The high concentration of nitrate is thought due to characterize of nitrate in some type of soil is easier leached than other contaminant [34].

![Figure 5](image2.png)

**Figure 5.** Average concentration of nitrate (black) and phosphate (grey) in all seasons
3.3. Nitrate and Phosphate Load
Nitrate and phosphate load along year is fluctuated in each season and river (figure 6). The lowest nitrate and phosphate load (0 tons/day) found in Bualu River in all season, it’s because zero water discharge from this river. The highest nitrate load found in Mati River during second transition season (4.387 tons/day) and also in Buaji River during dry season (4.366 tons/day). The highest phosphate load to Benoa Bay also comes from Mati River in dry season (6.980 tons/day). Badung and Mati River need more special attention because it gives a great load throughout the season.

The average load of nitrate and phosphate in all season is fluctuated along year (figure 7). The lowest nitrate (0.82 tons/day) and phosphate (1.76 tons/day) loads found in first transition season, meanwhile the highest of nitrate (7.38 tons/day) and phosphate (9.77 tons/day) loads found in dry season. Opposite result found in Jakarta bay, the nutrient load is higher two times in rainy season than dry season because of high water discharge from river [35]. The nutrient load fluctuation to Benoa Bay not only affected by the concentration of nutrient, but also by water discharge from each river.

3.4. Eutrophication Status
Euthropication status for nitrate and phosphate is fluctuated in all river and season (table 2). Nitrate concentrations during the wet season almost all in oligotrophic status, opposite result in second transition season show almost all of the rivers in eutrophic condition. In dry season, eutrophic status found in Buaji dan Bualu River, while the other river in oligotrophic condition. Bualu River almost eutrophic throughout the season except in wet season, but there is no load to Benoa Bay. Eutrophic status in Second Transition Season in both Badung and Mati River need more attention because this
river has constant water discharge along year. Trophic level status based on Total N in all rivers and season can be increased considering that the data in this research calculated only from nitrate only without nitrite, ammonia and organic bound nitrogen data. The status level of phosphate indicates that phosphate is in eutrophic condition almost in all rivers and season. Oligotrophic status of phosphate only found in second transitional season. High phosphate concentrations in Badung and Mati River are thought derived from agricultural waste in the upstream [36].

The concentration of nitrate and phosphate found in all rivers and season which ends at Benoa Bay generally exceeded the quality standard base on Ministerial decree of environment No 51 in 2004 for marine biota. The Indonesian environment ministry only allows maximum concentration of nitrate is 0.008 mg/l and phosphate is 0.015 mg/l for marine biota. The nitrate and phosphate concentration from all rivers are potential for trigger eutrophication process in Benoa Bay.

**Table 2.** Nitrate and phosphate trophic level status base on Total N and P during Wet Season (WS), First Transitional Season (FTS), Dry Season (DS) and Second Transitional Season (STS)

|          | Nitrate |          |          |          | Phosphate |          |          |          |
|----------|---------|----------|----------|----------|-----------|----------|----------|----------|
|          | WS      | FTS      | DS       | STS      | WS        | FTS      | DS       | STS      |
| Badung River | *       | *        | *        | ***      | ***       | ***      | ***      | *        |
| Mati River  | *       | **       | *        | ***      | ***       | ***      | ***      | ***      |
| Sama River  | *       | **       | *        | *        | ***       | ***      | ***      | ***      |
| Bualu River | *       | ***      | ***      | ***      | ***       | ***      | ***      | *        |
| Buaji River | *       | *        | ***      | *        | ***       | ***      | ***      | *        |
| Loloan River| **      | *        | ***      | ***      | ***       | ***      | ***      | *        |

Oligotrophic (*), Mesotrophic (**), Eutrophic (***)

4. **Conclusion**

The concentration of nitrate and phosphate is fluctuated along years. Nitrate concentration fluctuated form undetected to 16.950 mg/l, meanwhile phosphate concentration from undetected to 3.275 mg/l. The highest concentration of nitrate and phosphate found in dry season and the lowest concentration found in wet season. Nitrate and phosphate load to Benoa Bay along year also fluctuated in each season and river. The highest nitrate load found in Mati River during second transition season (4.387 tons/day) and also in Buaji River during dry season (4.366 tons/day). The highest phosphate load to Benoa Bay also comes from Mati River in dry season (6.980 tons/day). The concentration is strongly affected by concentration and water discharge. The Eutrophic condition for nitrate generally found in Second Transition Season, meanwhile for phosphate generally found in all river and season. The concentration of nitrate and phosphate found in all rivers and season which ends at Benoa Bay generally exceeded the quality standard base on Ministerial decree of environment No 51 in 2004 for marine biota. These conditions are potential for trigger eutrophication process in Benoa Bay.

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**References**

[1] Nixon S W 1995 Coastal marine eutrophication: A definition, social causes, and future concerns *Ophelia* 41 199–219

[2] Anderson D M, Glibert P M, Burkholder J M 2002 Harmful Algal Blooms and Eutrophication: Nutrient Sources, Composition, and Consequences *Estuaries* 25(4b) 704–726
[3] Yang X-e, Wu X, Hao H-l, He Z-I 2008 Mechanisms and assessment of water eutrophication J. Zhejiang Univ. Sci. B 9(3) 197-209

[4] Karydis M 2005 Eutrophication Assessment Of Coastal Waters Based On Indicators: A Literature Review Global NEST J. 7(2) 228-235

[5] Hendrawan I G, Asai K 2014 Numerical study on tidal currents and seawater exchange in the Benoa Bay, Bali, Indonesia Acta Oceanol. Sin. 33(3) 90-100

[6] Rahayu N W S T, Hendrawan I G, Suteja Y 2018 Distribusi Nitrat dan Fosfat secara Spasial dan Temporal saat Musim Barat di Permukaan Perairan Teluk Benoa, Bali J. Mar. Aquat. Sci. 4(1) 1-13

[7] Bhuiyan A B, Mokhtar M B, Toriman M E, Gasim M B, Ta G C, Elfitihi R, Razman M R 2013 The Environmental Risk And Water Pollution: A Review From The River Basins Around The World Am-Eurasian J. of Sust. Agr. 7(2) 126-136

[8] Bogen J 2009 The impact of environmental changes on the sediment loads of Norwegian rivers CATENA 79(3) 251-256

[9] Billen G, Garnier J, Lassaletta L 2013 Philos. T. R. Soc. B. 368 1–13

[10] Fowler D, et al. 2013 The nitrogen cascade from agricultural soils to the sea: modeling nitrogen transfers at regional watershed and global scales Philos. T. R. Soc. B. 368 20130164.

[11] Owa FD 2013 Water Pollution: Source, Effects, Control and Management Mediterr. J. Soc. Sci. 4(8) 65-68

[12] Suteja Y and Dirgayusa I G N P 2015 Analisis Beban Pencemar dan Kapasitas Asimilasi Muara Tukad Mati – Bali Proc. Seminar Nasional Sains dan Teknologi 29 – 30 Oct (Bali)

[13] Michaud J P and Wierenga M 2005 Estimating Discharge and Stream Flows. A Guide for Sand and Gravel Operators. Ecology Publication Number 05-10-070

[14] APHA 2005 Standard Method for the Examination of Water and Wastewater. 21st edition Eaton A D, Clesceri L C, Rice E W, Greenberg A E, editor. United State of America: American Public Health Association.

[15] Xiuli Y, Weidong Z, Huasheng H, Yan L, Weidong G, Xiao H 2012 Distribution, fluxes and decadal changes of nutrients in the Jiulong River Estuary, Southwest Taiwan Strait Oceanology 57(8) 2307 – 2318

[16] Dodds W K, Jones J R, Welch E B 1998 Suggested classification of stream trophic state: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus Water Res. 32 1455–1462

[17] Dodds W K, Smith V H 2016 Nitrogen, phosphorus, and eutrophication in streams Inland Waters 6 155-1164

[18] Khan F A, Ansari A A 2005 Eutrophication: An ecological vision The Botanical Rev. 71(4) 449–482

[19] Central Bureau of Statistics (BPS) Bali Province 2015 Bali In Figures 2015 Integrated Processing and Statistic Dissemination Divison (Bali) Statistic of Bali Province p 616

[20] Pandzic K, Cesarec K, Grgic B 1997 An Analysis of the Relationship Between Precipitation and Discharge Fields Over a Karstic River Basin Int. J. Climatol. 17 891-901

[21] Aldrian E and Djamil Y S 2008 Spatio-temporal climatic change of rainfall in East Java, Indonesia. International Journal of Climatology Int. J. Climatol. 28 435–448.

[22] As-syakur A R, Tanaka T, Prasetia R, Swardika I K, Kasa I W 2011 Comparison of TRMM multisatellite precipitation analysis (TMPA) products and daily-monthly gauge data over Bali Int. J. Remote Sens 32(24) 8969–8982

[23] Prasetia R, As-syakur A R, Osaka T 2013 Validation of TRMM Precipitation Radar satellite data over Indonesian region Theor Appl Climatol 112 575–587

[24] Jacox M G, Hazen E L, Zaba K D, Rudnick D L, Edwards C A, Moore A M, Bograd SJ 2016 Impacts of the 2015–2016 El Niño on the California Current System: Early assessment and comparison to past events Geophy Res.Lett 43(13) 7072–7080

[25] Aldrian E, and Susanto R D 2003 Identification of three dominant rainfall regions within
Indonesia and their relationship to sea surface temperature *Int. J. Climatol* **23** 1435–1452.

[26] Hendon H H 2003 Indonesian rainfall variability: impacts of ENSO and local air–sea interaction *J. Climate* **16** 1775–1790

[27] Ololade I A, Adegwunmi A, Ologundudu A, Adeleye A 2009 Effects of household wastes on surface and underground waters *Int. J. Phys. Sci.* **4(1)** 022-029

[28] Gordee V V and Sidorov L S 1993 Concentrations of major elements and their outflow into the Laptev Sea by the Lena River *Mar Chem* **43** 33-45

[29] Dinnel S P and Bratkovich A 1993 Water discharge, nitrate concentration and nitrate flux in the lower Mississippi River *J. Mar. Syst.* **4** 315-326

[30] As-syakur A R, Suarna I W, Adnyana I W S, Rusna I W, Ulksmiwati IAA, Diara IW 2010 Identifikasi Hubungan Fluktuasi Nilai SOI Terhadap Curah Hujan Bulanan Di Kawasan Batukaru-Bedugul, Bali *Jurnal Bumi Lesatri* **10(2)** 200-207

[31] Lawniczak A E, Zbierska J, Nowak B, Achtenberg K, Grześkowiak A, Kanas K 2016 Impact of agriculture and land use on nitrate contamination in groundwater and running waters in central-west Poland *Environ. Monit. Assess.* **188** 172

[32] Savci S 2012 An Agricultural Pollutant: Chemical Fertilizer *Int. J. Env. Sci. Dev.* **3(1)** 77-80

[33] Li M, Xu K, Watanebe M, Chen Z 2007 Long-term variations in dissolved silicate, nitrogen, and phosphorus flux from the Yangtze River into the East China Sea and impacts on estuarine ecosystem *Estuar. Coast. Shelf S.* **71** 3-12

[34] Devito K J, Fitzgerald D, Hill A R, Aravena R 2000 Nitrate Dynamics in Relation to Lithology and Hydrologic Flow Path in a River Riparian Zone *J. Environ. Qual.* **29** 1075-1084

[35] Nugrahadi M S, Yanagi T, Tejakusuma I G, Adi S, Darmawan R A 2010 Seasonal variations of nutrient budgets in Jakarta Bay, Indonesia *Mar. Res. Indones.* **35(1)** 9-20

[36] Wijana I M S, Dewi I G A K S P, As-Syakur A R 2012 Studi Dan Pemantauan Kualitas Air Di Daerah Aliran Sungai (DAS) Badung *Ecotrophic* **7(1)** 54-58.