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Elevated phosphate, ammonia and total suspended solids near sewage outlets and reclamation sites in coastal waters of Makassar, Indonesia

Elevated phosphate, ammonia and total suspended solids near sewage outlets and reclamation sites in coastal waters of Makassar, Indonesia

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Abstract. Makassar is a large city in Southeast Asia with a strategic role to play in supporting the development of Indonesia. Its position as a centre for local and regional development has led to a sharp increase in the human population and a concomitant need for supporting facilities. With limited land in coastal areas, reclamation is one option being implemented. The increases in population and reclamation have both had negative effects on the condition of coastal waters. This study aimed to compare the levels of phosphate, ammonia and TSS in the waters near selected drainage outlets of Makassar City before and after land reclamation. The results showed increasingly high levels of phosphate at two sites (Jongaya and Paotere Canals). Increased ammonia, nitrogen and TSS were only found at the outlet of the Jongaya Canal. Four of the outlets (Jeneberang River, Benteng Canal and Tallo River) had relatively low nutrient concentrations. The results indicate that domestic waste is a major source of phosphate and ammonia pollution in the Jongaya and Paotere Canals. In the Jongaya Canal, all parameters (phosphate, ammonia, nitrogen, and TSS) were higher after the reclamation than beforehand

1. Introduction

Makassar City is a large city in the low latitude tropics with a strategic role in supporting the development of Indonesia. As a major centre of development, both at the local level and in the context of Eastern Indonesia, Makassar has seen a sharp rise in population over recent decades. From 2005 - 2016, the population of Makassar city population increased by 80%. This fast growth has resulted in an increase in the demand for facilities and infrastructure such as housing, restaurants, hotels and other developments, all of which contribute to an increasing load of wastewater containing organic materials and nutrients most of which is discharged into coastal waters. Such an increase is likely to lead to increased algal biomass and decreased dissolved oxygen [1]. Several studies have been conducted on nutrient concentrations in the coastal waters of Makassar City. It has been found that nutrient contamination has reached high levels, leading to eutrophication and creating conditions likely to stimulate the development of harmful algal blooms (HABs) in marine waters [2,3,4].

In an effort to provide adequate land in the coastal areas of Makassar City, the government has supported the expansion of reclamation. Coastal reclamation is the activity of dumping material into in coastal waters to create additional land above sea level. A major coastal reclamation project in Makassar was initiated in 2015; part of the land thus made available is to be developed as a business centre called the "central point of Indonesia" (CPI).

Coastal reclamation not only completely covers the natural marine habitat of all biological communities, affecting the structure and biodiversity of biological communities, but also changes hydrological process, affecting the sediment dynamics and seabed relief of adjacent sea areas [5,6]. Reclamation may lead to changes in currents, sources of coastal erosion and sources of nutrients that degrade water quality [7]. Coastal reclamation can thus obstruct or disrupt water flow and circulation, which can result in increased seawater nutrient concentrations, especially phosphate and ammonia [8].

Increased phosphate and ammonia create undesirable eutrophication and can be used as an indication of marine pollution status [9]. Anthropogenic sources of both nutrients in marine waters may be derived from the land, including residential and industrial sources; climate change can also contribute to the disruption of biophysical and chemical balances in the sea [10]. Anthropogenic nutrient enrichment has been proposed as a major contributing factor to the increase in harmful algal blooms (HABs) in coastal waters [2,11]. Studies have described rivers and canals as potential sources of pollution entering the coastal waters around cities, and have shown high levels of ammonia and phosphate pollution entering coastal waters from rivers [12.13].

The reclamation in Makassar has resulted in a drastic decrease in current velocity to 7.52% of former speeds along part of the coastline [14]. Furthermore, additional pollution loads could adversely affect public health and coastal tourism in Makassar. Therefore, the present study was undertaken with the purpose of monitoring changes in the concentrations of phosphate, ammonia and TSS on nearby of sewage coastal waters of Makassar before and after reclamation.

2. Materials and Methods

2.1. Study site

The study was carried out at five Makassar City sewerage outlets discharging into the coastal waters of the city (Figure1). The five sampling stations had different characteristics. Station 1 (N 05° 5’ 39” E 119° 26’ 43”) was sited at the mouth of the Tallo River which flows through lands used for agriculture, human settlement and aquaculture. Station 2 (N 05° 6’ 29” E 119° 25’ 48”) was at the outlet of the Paotere Canal, an urban wastewater disposal channel with high population density in its catchment area. Station 3 (N 05° 8’ 13” E 119° 24’ 8”) was at the outlet of the Benteng Canal, an urban wastewater disposal channel flowing though a catchment area with relatively low population density and a large number of offices. Station 4 (N 05°8’ 49” E 119°24’ 17”) was at the outlet of the Jongaya Canal, an urban wastewater disposal channel with high population density in its catchment area. Finally, Station 5 (05° 11’ 33” E 119° 22’ 50”) was at the mouth of the Jeneberang River, a stream running through agricultural land and human settlements.

2.2. Data collection

Seawater samples were collected from the five stations (Figure 1). All sampling stations had an average depth of 1m at low tide. Seawater samples were collected using a 5L Van Dornwater sampler and then transferred to 1-L acid washed polyethylene bottles. The bottles were stored in a coolbox and transported to the laboratory for further analysis.

In the laboratory, the water samples were filtered using a 0.45µm Millipore membrane filter prior to the analysis of phosphate and ammonia nitrogen. Phosphate and ammonia were determined following the method described in [15]. The total suspended solid (TSS) in each sample was determined following the method prescribed in [16].

2.3. Data Analysis

Phosphate, ammonia and TSS data before reclamation were obtained from secondary data collected in 2005 [4]. Data before and after reclamation were compared descriptively (graphically) to determine the trends of concentration change.

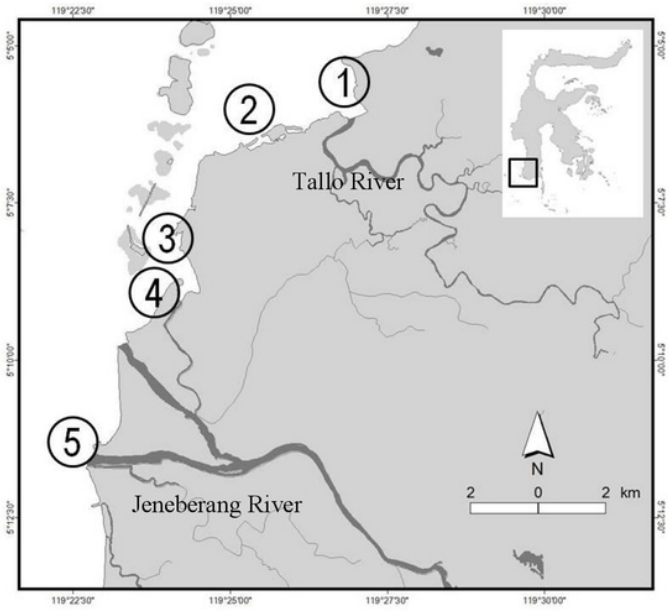
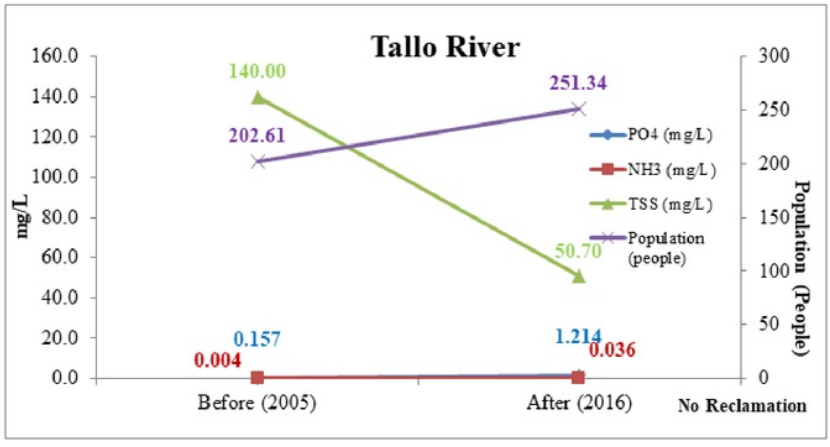
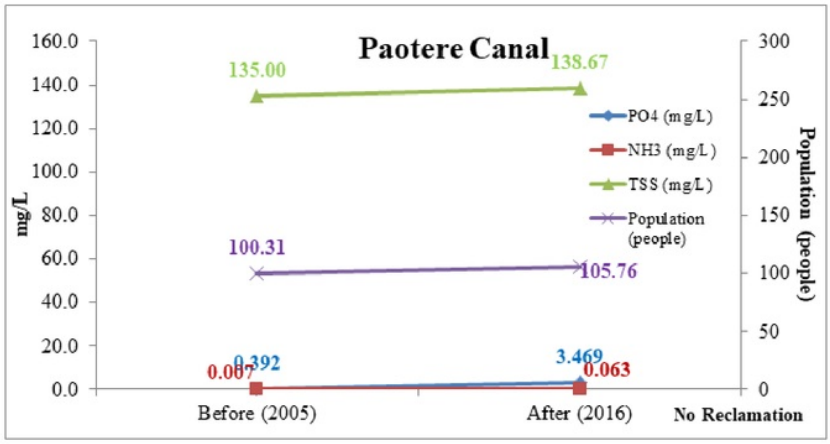


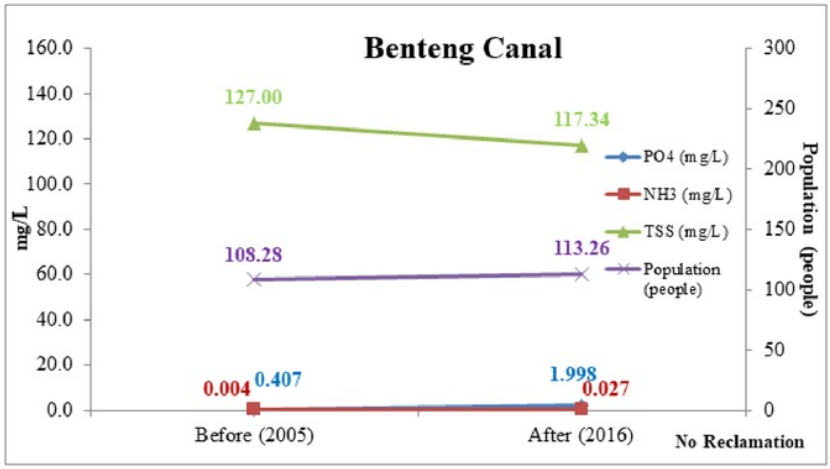
Figure 1. Study Site and Sampling Stations

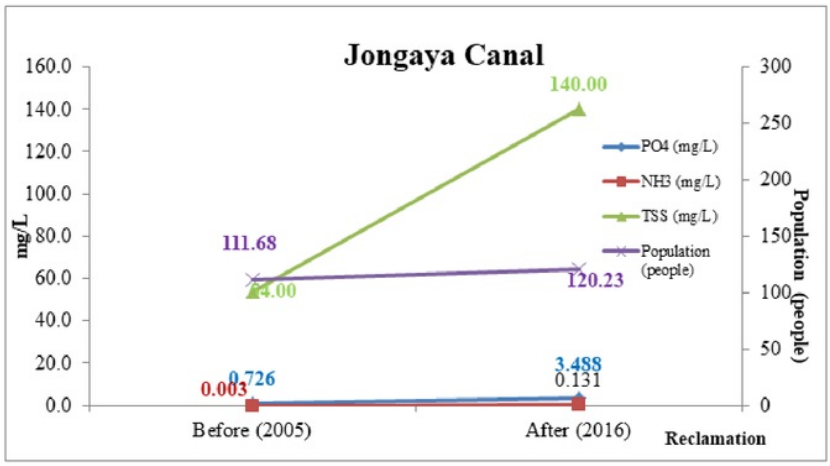
3. Results

The trends in the concentration of phosphate, ammonia, TSS at each station and the human population around each station are shown in Figure 2. The data show that phosphate (PO_4) concentration has increased nearly fourfold over the past ten years in the coastal waters of Makassar. The highest PO_4 concentrations were found in the Jongaya and Paotere Canals. The concentration of ammonia also increased significantly, with NH_4 concentrations in 2016 an order of magnitude larger than in 2005. The Jongaya Canal appears to be the highest source of NH_4 discharge (Fig. 2), with a sharp increase in phosphate and ammonia concentrations after coastal reclamation.




Paotere Canal
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/L
300
250
200
150
100
50
0
Population (people)
135.00
138.67
100.31
105.76
0.007
0.392
3.469
0.063
PO4 (mg/L)
NH3 (mg/L)
TSS (mg/L)
Population (people)
Before (2005)
After (2016)
No Reclamation


Benteng Canal
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/L
300
250
200
150
100
50
0
Population (people)
127.00
117.34
108.28
113.26
0.004
0.407
1.998
0.027
PO4 (mg/L)
NH3 (mg/L)
TSS (mg/L)
Population (people)
Before (2005)
After (2016)
No Reclamation


Jongaya Canal
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/L
300
250
200
150
100
50
0
Population (people)
140.00
111.68
120.23
4.00
0.003
0.726
3.488
0.131
PO4 (mg/L)
NH3 (mg/L)
TSS (mg/L)
Population (people)
Before (2005)
After (2016)
Reclamation

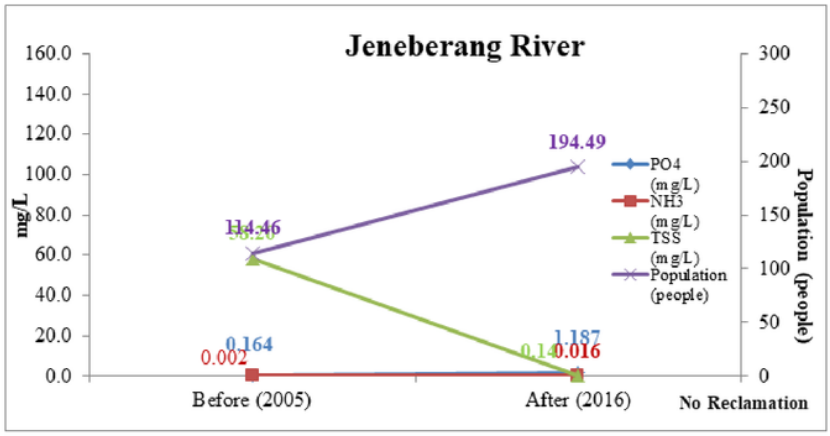


Figure 2. Trends in the concentrations of phosphate, ammonia and TSS as well as the nearby human population at the five sampling stations

4. Discussion

Over a period of 10 years, the phosphate concentration increased considerably at each of the outlets. The impact of reclamation activities in terms of phosphate values was apparent in the waters around the Jongaya Canal outlet, a heavily urbanised area close to the reclamation site, where the highest phosphate concentration (3.48 mg/L) was recorded. In contrast, the lowest concentration recorded was at the Jeneberang River station with a more rural catchment. Overall, the data indicate that areas with high human population densities are the major contributors of phosphate pollution in the coastal waters of Makassar. A similar pattern was reported from research in Barnegat Bay, New Jersey where phosphate was detected in the more urbanised Southern Bay (0.029 to 0.053 mg P/L) and was below the detection level of 0.021 mgP/L in the less urbanised Northern Bay [9]; however the levels phosphate in the coastal waters of Makassar are much higher.

One major source of phosphates entering the Jongaya Canal is the use of detergents in household washing and cleaning by the residents of this densely population area. Similarly in Bangladesh, India and Pakistan, high levels of nitrogen and phosphorus come from household waste [17]. In addition, the difference in phosphate concentrations is also to some extent caused by the coastal reclamation close to the outlet of this canal, which resulted in slow moving and unpredictable currents leading to the accumulation of pollutants, in particular phosphate.

Ammonia concentrations increased after reclamation. As for phosphates, the highest increase and the highest post-reclamation concentration of ammonia (0.13 mg/L) were also found in the Jongaya canal. Sources of ammonia in this canal include the decomposition of liquid wastes and organic matter from human settlements. Other studies have reported high concentrations of ammonia in coastal waters exposed to domestic sewage and other waste water discharges [18,19,20,21]. Sources of nitrogenous pollutants in coastal ecosystems may be derived from urban and industrial wastewater, run-off from land and septic tank leachate [22]. All these waste water sources are present, including residential waste and discharges from hotels on or near the Makassar coast.

The results of this study show that the phosphate concentration has exceeded the maximum limit of 0.015 mg/L in the standards set by Decree of the Ministry of the Environment Decree on seawater quality. The phosphate level at the Jongaya station was several orders of magnitude greater than this top limit. Although ammonia concentrations have increased, they are still below the 0.3 mg/L top limit set in this Decree. The concentration of phosphate and nitrogen in the form of ammonia is likely to trigger an increase in the density of phytoplankton in coastal waters of Makassar City, with potential adverse impacts on the health and wellbeing of Makassar city residents [22].

5. Conclusions

Reclamation activities have contributed to increased concentrations of phosphate, ammonia and TSS, especially in the waters of Jongaya Canal. The increase in concentration at each station is related to the increase in urban population growth. The phosphate concentration has exceeded the Indonesian government's seawater quality standard.

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