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Water pollution trends in Ciliwung River based on water quality parameters

D Ratnaningsih[1], E L Nasution[1], N T Wardhani[1], O D Pitalokasari[1], and R Fauzi[1]

Center for Research and Development of Quality and Environmental Laboratory
Gd. 210, Komplek PUSPIPTEK, Serpong, Banten, Indonesia

Email: dewirinie@yahoo.com

Abstract
Ciliwung River is one of the rivers crossing West Java and special capital region of (DKI) Jakarta provinces which plays an important role in fulfilling the needs of human activities and living things surrounding it. Designated as a national priority for management, the Ciliwung River that runs from Mount Pangrango (upper stream) to Jakarta Bay (lower stream) has received pollution from results of human activities such as household activities, agriculture, plantations, animal husbandry, industry, and recreation areas. In addition, the decreased green cover in the upstream area also adds more pressure on the quantity of water in the Ciliwung River. The purpose of this study was to determine the trend of water pollution in the Ciliwung River in the period of 2011-2014 based on physical, chemical and biological parameters. Samples were taken from 22 points starting from upstream to downstream area. From 15 water quality parameters, there were only three parameters, namely total dissolved solid (TDS), pH and nitrate (NO_3-N) which still meet water quality criteria class II based on Government Regulation number 82/2001, in all observation periods and sampling sites. Other parameters invariably meet or beyond the water quality criteria. Pollution trend increased towards the downstream of Ciliwung River, however annual comparisons across the year of observations did not show significant differences. High pollution in the downstream area was caused by accumulated pollutants coming from waste disposal of densely populated area and diverse activities in the downstream. Fecal coliform bacteria and total coliform contributed the highest pollution in the Ciliwung River compared to other pollutants. Both those two parameters greatly exceed the water quality criteria at all sampling sites, except in the Ciliwung river spring. Controlling those two parameters may improve Ciliwung water quality.

1. Introduction
Increasing population and industrialization development commonly give rise to river water pollution. Changes in water quality are significantly affected by anthropogenic activities, and this condition eventually will influence the aquatic ecosystem. The dense population area with various activities often reduces the availability of clean river water. Various wastes originated from human activities such as household activities, agriculture, plantation, livestock, and industries could pollute the river water [1],[2]. In the hydrological cycle, the water might carries a various materials passed by, including nutrients and harmful pollutants. Besides the function of river water as a means of transportation, the river water also contributes to spread to and accumulate pollution from surrounding

area [1],[3]. River water is one of the natural resources that need to be conserved because it is a habitat for many aquatic biotas and source to meet the various needs of humans and living things [1],[3]. Human activities around the rivers will greatly affect water quality changes. It decreases water quality which results in biodiversity loss [4]–[6]. At present, the quantity and quality of good river water are becoming scarce. Poor water quality will have an impact on the health of living creatures that live nearby and affect the sustainability of the ecosystem, and in turn affect both productivity and biodiversity of a given ecosystem [7],[8].

Ciliwung River is a provincial cross-border river that flows from the Pangrango Mountain and ends up in Jakarta Bay by passing Bogor Regency, Bogor City, and Depok City in West Java Province. Designated as the national priority for water quality management, the Ciliwung River received pressure from the waste of various human activities such as household, livestock, farming and industries especially in the middle and downstream areas.

The decreased green covers in the upstream area also add more pressure on the water debit of the Ciliwung River. Most of the upstream segment of Ciliwung River has been shifted from secondary forest into agricultural area which has been subsequently developed into tourism area, including pavement of infrastructure, trade and service areas [9],[10]. Land cover in the middle segment of Ciliwung River has also been converted from plantations or agriculture to settlements or other land uses [10]–[13]. The downstream, which is located in the capital city of Jakarta is dominated by settlements and densely populated area [11]. The aim of this paper is to evaluate the characteristic trend of water pollution that occurred on the Ciliwung River in the period of 2011 to 2014. Description of river characteristics can be used as input for the water resources management plan [6].

2. Methodology

2.1. Sampling

Water quality sampling was carried out in the Ciliwung watershed in the provinces of West Java and DKI Jakarta. 320 water samples had been collected by Center for Research and Development of Quality and Environmental Laboratory (P3KLL) team from 2011 to 2014. The sample points were scattered in 22 locations, starting from upstream in Pangrango Mountains to the downstream in DKI Jakarta. Sampling methods was referred to the Indonesian National Standard (SNI) 6989.57:2008. Geographical location of Ciliwung River from upstream to downstream is $6^{o}42'47.34''$- $6^{o}08'01.41''$ N and $106^{o}58'16.79''$ - $106^{o}49'53.05''$ E, with the elevation range from 1206 to 3 meters above sea level (figure 1).

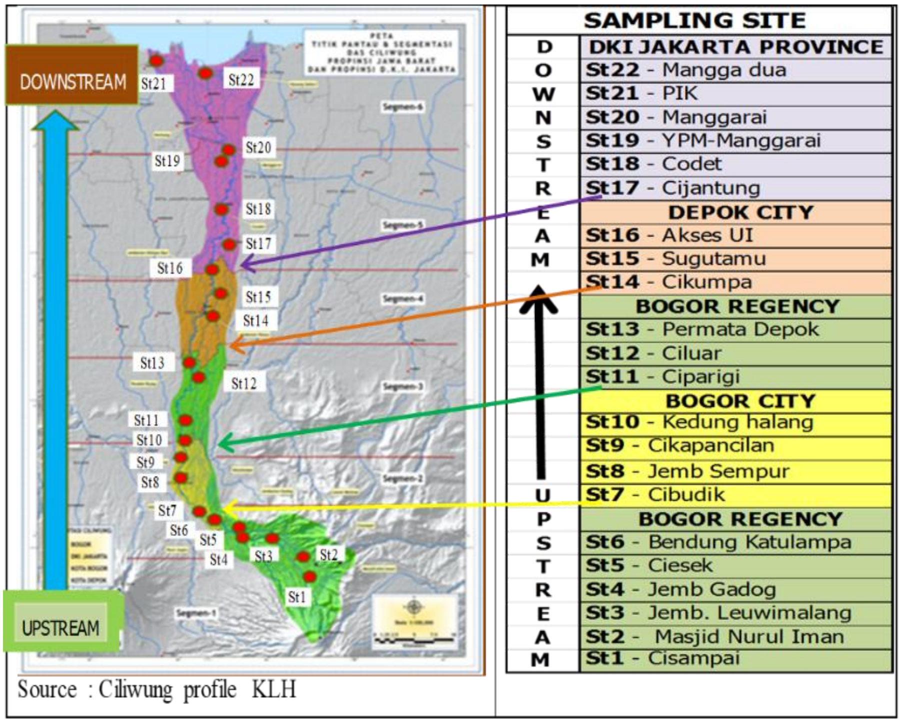

Figure 1. Sampling sites of Ciliwung River

2.2. Laboratory Analysis

Water quality testing had been carried out on 15 water quality parameters using standard methods or validated methods (table 1). The test was conducted at Center for Research and Development of Quality and Environmental Laboratory.

Table 1. Methods for water physical, chemical and biological characteristic analysis

No	Parameters	Unit	Test Method
1	pH	-	SNI 06-6989.11-2004
2	Dissolved Oxygen (DO)	mg/L	JIS K 0102 – 2008
3	Total Dissolved Solid (TDS)	mg/L	IK1/A/P3KLL/ Conductometry
4	Temperature	°C	SNI 06-6989.23-2005
5	Chemical Oxygen Demand (COD)	mg/L	SNI 6989.2:2009
6	Biological Oxygen Demand (BOD)	mg/L	JIS K 0102-2008
7	Nitrite (NO_2-N)	mg/L	SNI 06-6989.9-2004
8	Nitrate (NO_3-N)	mg/L	SNI 6989.79:2011
9	Ammonia (NH_3-N)	mg/L	SNI 06-6989.30-2005
10	Total phosphate (T-P)	mg/L	JIS K 0102-46.3.1-2008
11	Oil and Grease	mg/L	SNI 6989.10.2011
12	Phenol	mg/L	SNI 06-6989.21-2004
13	Detergent, Metylen Blue Active Surfaces (MBAS)	mg/L	SNI 06-6989.51-2005
14	Fecal Coliform	MPN/100 ml	APHA 9221 B, E, and F
15	Total Coliform	MPN/100 ml	APHA 9221 B, E, and F

2.3. Data Analysis
Analysis of variance (ANOVA) was used to compare the results among times (years) and locations at a confidence level of 95% or an error level of 5% (0.05). This study used data from 22 locations, collected annualy during four years. Data obtained was compared to a reference standard for class II water quality criteria (WQC), namely water for the purpose of water recreation facilities / infrastructure, cultivation of freshwater fish, livestock and irrigation. These criteria are stated in the appendix of Government Regulation number 82/2001 concerning the Management of Water Quality and Water Pollution Control [14].

3. Results and Discussion
3.1. Temperature, pH and TDS
Temperatures of Ciliwung River that were recorded at daytime, increased from upstream to downstream. The lowest temperature in the upstream was 19°C and the highest temperature in the downstream was 34 °C. These temperature changes can occur directly and indirectly. Changes in water temperature might be caused by changes in land use system, backflow of agricultural irrigation, flow modification, water transfer between basins, changes in vegetation to riparian, global warming, and closure factors in riparian [15],[16]. There was no significant changes in terms of water temperature of Ciliwung river from 2011 to 2014. Low temperature in the upstream region persists due to high elevation. The average temperature in the upstream section was 23.7°C, in the middle section was 27.1°C and in the downstream section was 28.8 °C.

The water pH of the Ciliwung River from upstream to downstream in 2011-2014 ranged from 6.0 - 8.6. The pH of the river water was still normal and in accordance with the standards of Government Regulation number 82/2001 for class II WQC of 6-9 [14].

TDS parameters in all sampling locations were still in accordance with class II WQC of 1000 mg/L, except for one sample location in Mangga Dua, which is downstream of the Ciliwung River, reaching TDS at 1,708 mg/ L. The highest value of TDS at this point could be influenced by the sea water tide that reaches those sampling locations. In most cases, TDS values tended to be the same from 2011 to 2014, and likewise, locations did not show a significant difference ($P < 0.05$).

Table 2. Analysis of variants results of water quality parameters in Ciliwung River

No.	Parameters	p-values	
		Locations	Years
1	Temperature	***0.000	0.374
2	Total Dissolved Solid (TDS)	0.102	0.925
3	Biological Oxygen Demand (BOD)	***0.001	0.223
4	Chemical Oxygen Demand (COD)	***0.000	0.460
5	Dissolved Oxygen (DO)	***0.000	0.396
6	Nitrite (NO2-N)	***0.003	0.590
7	Ammonia (NH3-N)	***0.000	0.607
8	Total phosphate (T-P)	**0.022	0.275
9	Detergent, Metylen Blue Active Surfaces (MBAS)	**0.028	0.737
10	Oil and Grease	0.679	0.955
11	Phenol	0.092	0.782
12	Fecal Coliform	**0.047	0.176
13	Total Coliform	***0.000	0.565

Note: *** statistically significant at 1%, **statistically significant at 5%

3.2. BOD, COD, DO

BOD describes the content of organic matter, namely the amount of oxygen used by aerobic microorganisms to oxidize organic matter. The majority of BOD in the Ciliwung watershed did not comply with WQC class II Government Regulation number 82/2001 at 3 mg/ L (figure 2). BOD in the Ciliwung watershed from upstream to downstream ranged from 2 ~ 144 mg/ L in 2011; in 2012 were between 2 ~ 838 mg/ L; in 2013 between 2 ~ 138 mg/ L and in 2014 between 2 ~ 188 mg/ L. There were no significant differences between years of sampling (P < 0.05). However, BOD concentrations were influenced by the sampling position along the river. The highest BOD concentration was obtained in the downstream of Ciliwung River. Downstream of the Ciliwung River in DKI Jakarta is in fact, a densely populated area, where a lot of domestic wastes containing organic material might enter into the water body.

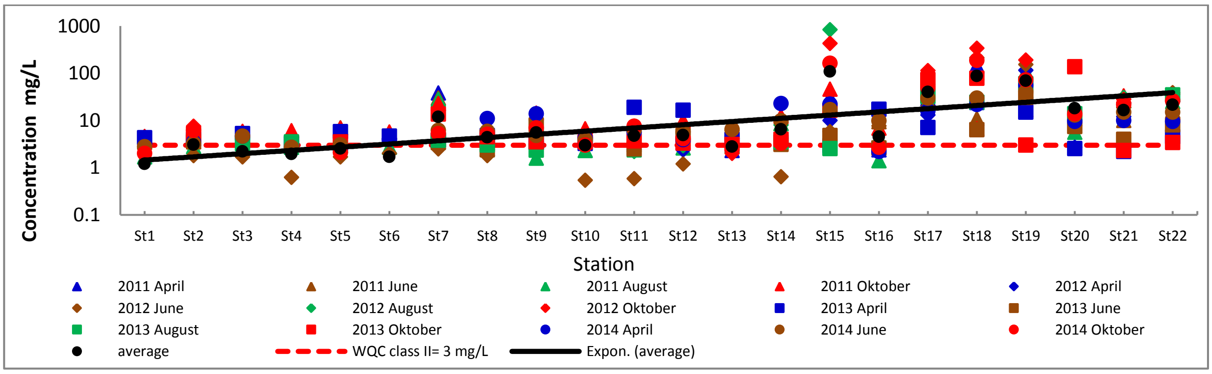

Figure 2. BOD concentration from upstream to downstream of the Ciliwung River.

COD describes the total amount of oxygen needed to oxidize organic matter chemically. COD in the Ciliwung watershed in 2011 were detected in the range of 1~330 mg/L: in 2012 between 1~1535 mg/L; in 2013 between 1~166 mg/L; and in 2014 between 2.4~523 mg/L. Statistical analysis showed significant differences between sampling locations from upstream to downstream, while there are no significant differences across the year of sampling (P<0.05) (figure 3). The highest COD concentration was obtained in the downstream area. The downstream area was a densely populated area that contributed high pollution and accumulated pollution from upstream and middle segment of Ciliwung River.

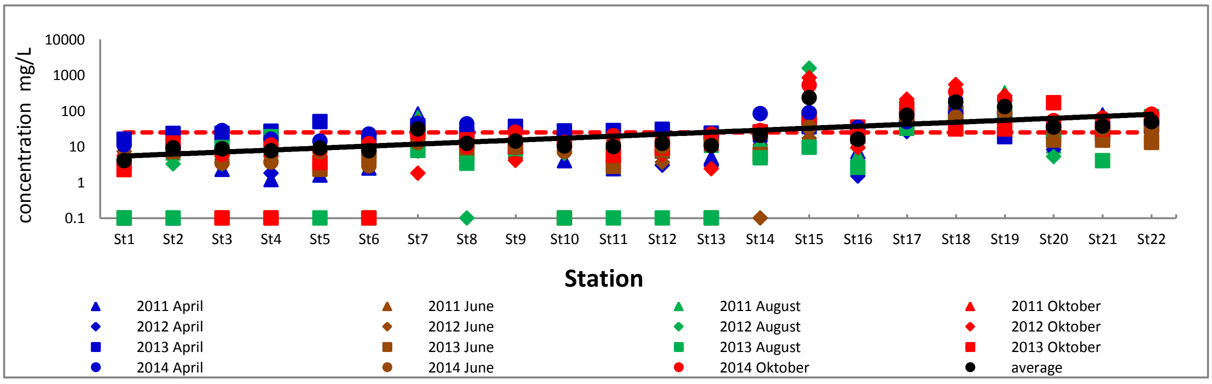

Figure 3. COD concentration from upstream to downstream of the Ciliwung River.

Dissolved Oxygen (DO) is very influential on aquatic life and biochemical processes. DO is necessary for aquatic biota to survive [16]–[18]. DO in waters vary and it is influenced by temperature, salinity, water turbulence, atmospheric pressure, and the presence of organic waste entering the river [19],[20]. The monitoring results indicated that DO in the downstream of Ciliwung River had decreased exceeding the standard based on the Class II WQC of 4 mg/L. Decreasing DO also occurred and even reached oxygen-unavailable conditions. Drastic decreasing DO could cause sudden death in fish. The DO from upstream to downstream of the Ciliwung river in 2011 ranged from 8.4 ~ 0.1 mg/L; in 2012 between 8.1 ~ 0.1 mg/L; in 2013 between 8.1 ~ 0.1 mg/L and in 2014 between 7.9 ~ 0.1 mg/L. The results showed significant differences between sampling locations and relatively similar concentrations each year of sampling ($P < 0.05$). The good condition of DO was only found in the upstream of Ciliwung River located in Bogor Regency (figure 4).

Low DO in the downstream indicated high pollution of organic waste. DO was needed for decomposition of organic matter. Domestic wastes containing low DO, high BOD, high COD, and high nutrients caused the river contains tremendous amount of pollutants[1].

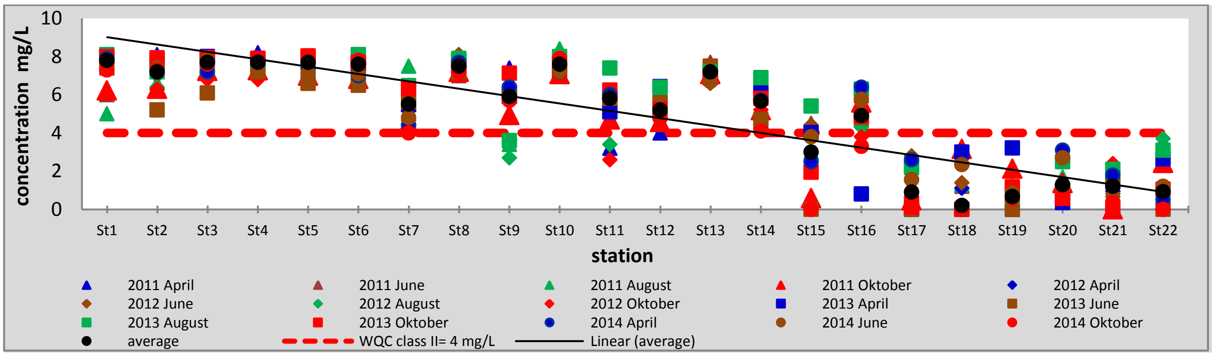

Figure 4. DO concentration from upstream to downstream of the Ciliwung River.

3.3. NO_3-N, NO_2-N, NH_3-N, TP.

High nitrates (NO_3-N) causes eutrophication of waters and encourage algae blooming [21],[22]. The existence of nitrogen in the water occurred due to fertilizer residue run off from an agricultural area and also waste disposal from industrial activities [18],[23],[24]. The level of NO_3-N in the Ciliwung watershed in 2011 were detected in the range of 0.01 ~ 2.28 mg/L; in 2012 between 0.01 ~ 6.40 mg/L; in 2013 between 0.01 ~ 2.60 mg/L; and 2014 between 0.02 ~ 4.11 mg/L. In term of nitrate concentration, all of these locations are still fulfilled the standard in accordance with WQC Class II PP 82/2001 at 10 mg/L.

Nitrite (NO_2-N) concentration in natural water is usually very small because they are unstable in the presence of oxygen. NO_2-N in the Ciliwung River fluctuated in 2011 in the range of 0.007 ~ 0.39 mg / L; in 2012 between 0.007 ~ 0.44mg/L; in 2013 between 0.007 ~ 0.37mg/L and in 2014 between 0.007 ~ 0.47 mg/L. NO_2-N concentrations in the upstream area still meet WQC class II Government Regulation number 82/2001 at 0.06 mg/L, except for station 2 where the riverbanks have been fully occupied by residential housing. High concentration of NO_2-N was mostly detected in the middle to downstream areas (figure 5). There was no significant diference in the trend of NO_2-N concentrations from 2011 to 2014. However, nitrite concentrations among sampling locations were significantly different ($p < 0.05$).

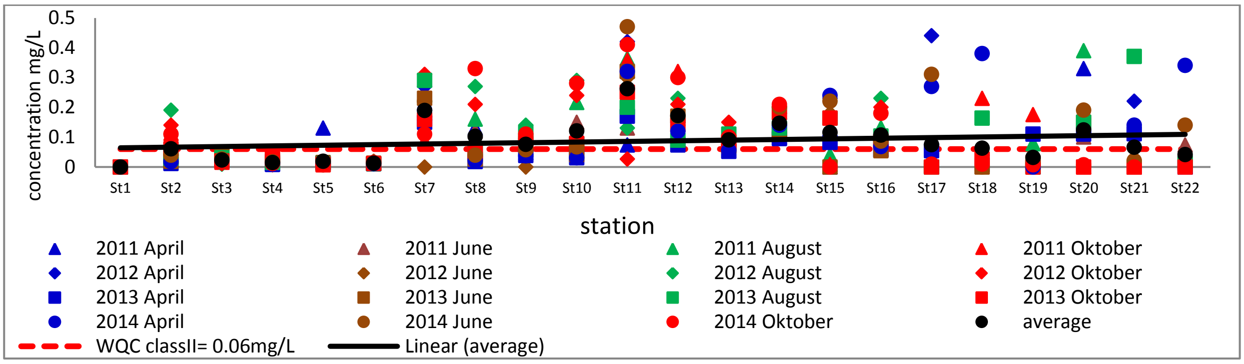

Figure 5. NO_2-N concentration from upstream to downstream of the Ciliwung River.

Ammonia (NH_3-N) can be gaseous and form a complex with several metal ions. NH_3-N were detected in the Ciliwung in 2011 ranging between 0.05 -24 mg/L; in 2012 between 0.05-41mg/L; in 2013 between 0.05 - 17.8mg/L; in 2014 from 0.05-21 mg/L. High concentration of NH_3-N was detected in the downstream. The trend of NH_3-N concentrations increased significantly from upstream to downstream and there were no significant differences by year of observations ($p < 0.05$) (figure 6). The increased NH_3-N in the downstream can be due to the accumulative effect of the river flow passed through high populated area [25].

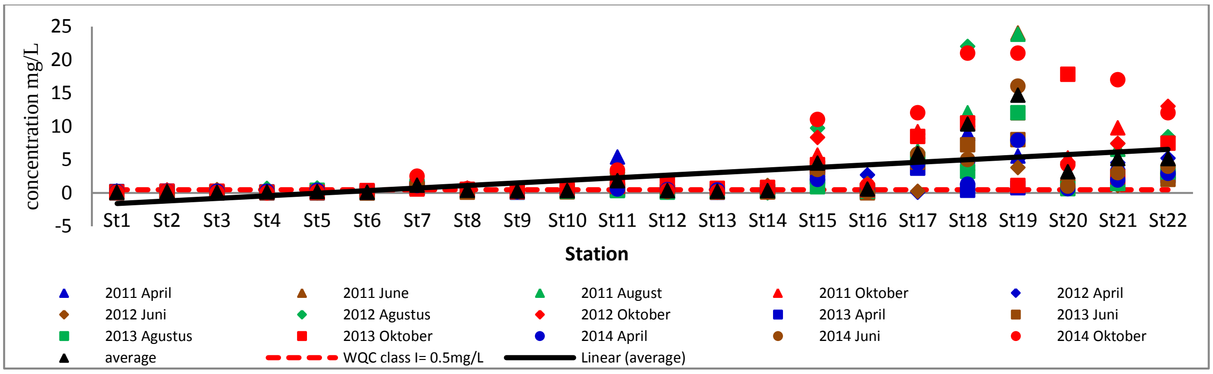

Figure 6. NH_3-N concentration from upstream to downstream of the Ciliwung River.

The presence of high phosphate and nitrogen will trigger an explosion of algae growth in the waters [21],[26],[27]. The allowable maximum level of phosphate in river waters has been reported at 0.1 mg/L [28]. The phosphate concentration of 0.025 mg/L can accelerate the eutrophication process in rivers [29]. Total phosphate (T-P) detected in the Ciliwung river water in 2011 was in the range of 0.024 - 3.9 mg/L; in 2012 between 0.009 - 2.5 mg/L; in 2013 between 0.01 - 2.4 mg/L and in 2014 between 0.017 - 3.1 mg/L. High concentration of total Phosphate (TP) were detected in downstream area, which exceeded the WQC class II Government Regulation number 82/2001 of 0.2 mg/L (figure 7). There were no significant differences in T-P concentrations between 2011 and 2014. However, the T-P concentration tendency increased significantly from upstream to dowstream ($P < 0.05$). T-P in the waters may be affected by utilization of fertilizers in agriculture and detergents in household washing activities [24].

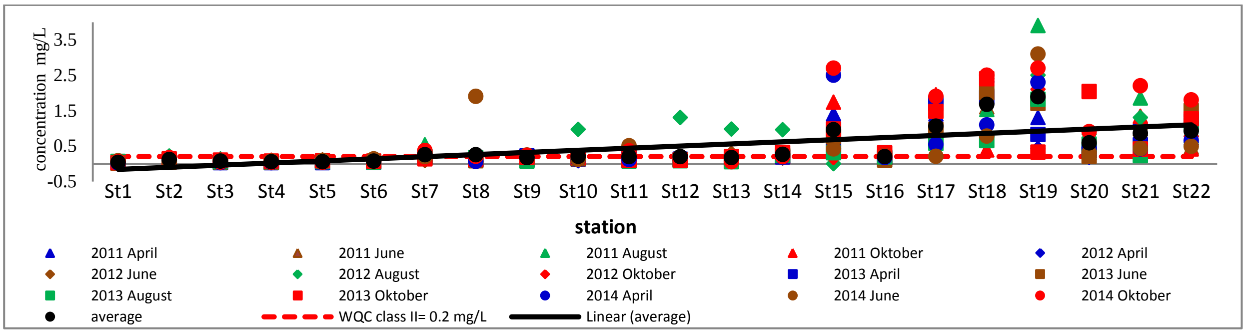

Figure 7. T-P concentration from upstream to downstream of the Ciliwung River.

3.4. MBAS, Oil and Grease, and Phenol

MBAS (Methylene Blue Active Substances) or detergent pollution was originated from utilization of soap disposed to surface water by industries or households. MBAS often contains nutrients such as nitrogen and phosphate which can induce algae blooming. MBAS was detected in 2011 with a range of 6-2500 ug/L; in 2012 between 6-150000 ug/L; in 2013 between 6 - 6548 ug / L; in 2014 between <6 - 3500 ug / L. In Jakarta area, in most cases, MBAS was detected above the WQC class II Government Regulation number 82/2001 of 200 ug/L. During observation in 2011-2014, there were no significant differences in terms of MBAS. However, MBAS concentration was significantly affected by sampling location. The MBAS concentration tend to increase with downstream position ($P < 0.05$) (figure 8).

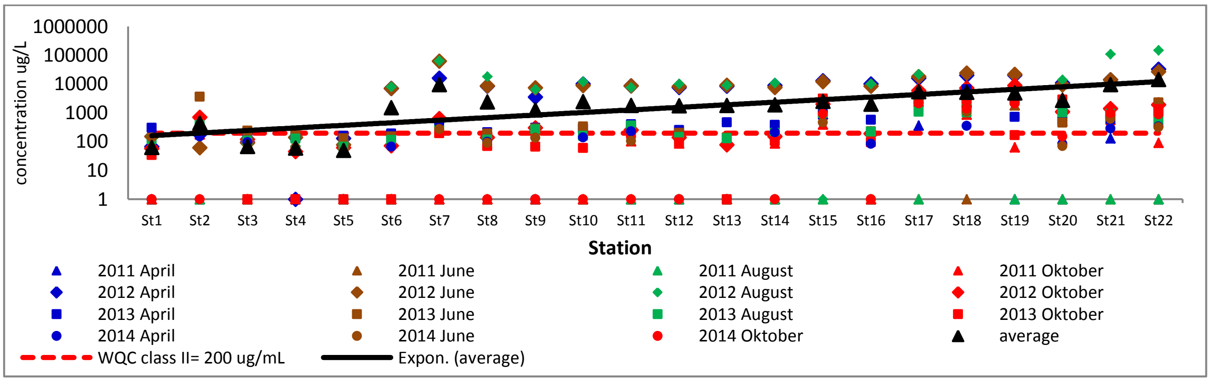

Figure 8. MBAS concentration from upstream to downstream of the Ciliwung River.

Oil and grease in the Ciliwung River water were detected during the observation from 2011 to 2014. Some of the locations were clean from oil and grease pollution, while others, especially in the downstream exceeded WQC Class II of Government regulation number 82/2001 at 1000 mg/L. The concentration of oil and grease in 2011 was in the range of 2,000 – 12,000 ug/L.; in 2012 between 2000 -18,000 ug / L; in 2013 between 2,000 -21,300 ug/L; in 2014 between 2000 – 14,000 ug/L. The results indicated that there were no significant differences among locations and years of sampling in regard of oil and grease concentration ($P < 0.05$) (figure 9).

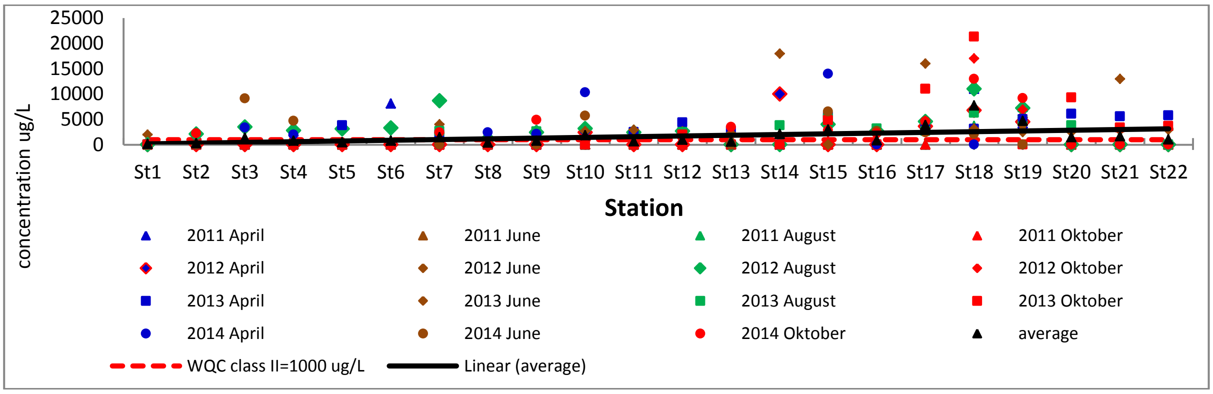

Figure 9. Oil and grease from upstream to downstream of the Ciliwung River.

Phenol concentrations detected in the river water in 2011 was in the range of 6- 76 ug / L; in 2012 between 6 - 240 ug / L; 2013 between 6 - 110 ug / L; 2014 between 6 - 41 ug / L. There was no significant difference in phenol concentration found each year and at each location of samplings (figure 10).

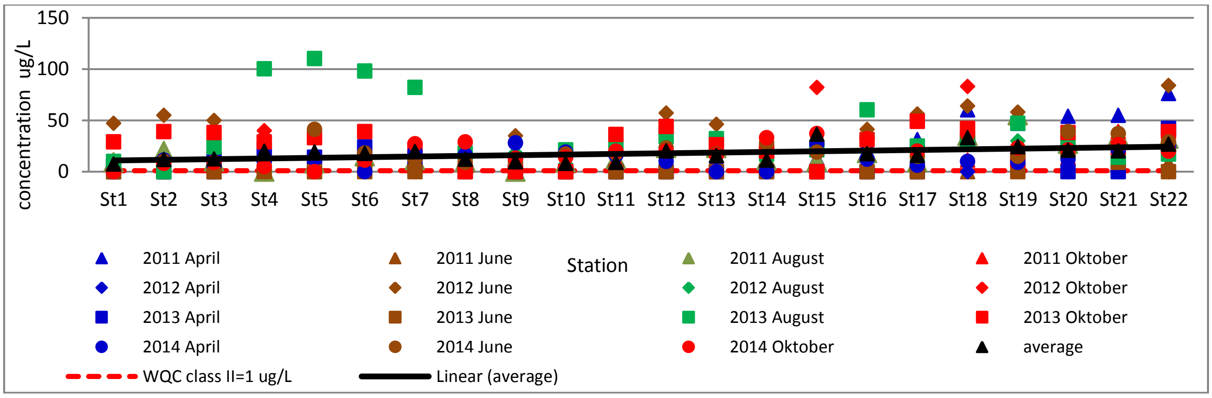

Figure 10. Phenol concentration from upstream to downstream of the Ciliwung River.

3.5. Fecal Coliform and Total Coliform

Coliform is a bacterial group commonly found in the environment [30]. Coliform is not harmful to humans, but it is used as an indicator of the presence of pathogenic organisms such as bacteria, viruses and parasites. These bacteria in water can come from intestinal tracks of human and warm-blooded animals or mammals such as pets, livestock and wildlife [31]. Fecal coli and total coliform bacteria have contaminated the Ciliwung River in high numbers. The number of fecal coliforms from upstream to downstream per 100 mL in 2011 was between 0 - 172,000,000; in 2012 between 100-15,700,000 ; in 2013 between 100 - 1,360,000,000 and in 2014 between 0 - 122,000,000. Fecal coliform has exceeded WQC Class II Government Regulation number 82/2001 of 1,000/100 mL except for Ciliwung water sources, considered as spring water, that still satisfies WQC class II standard. Fecal coliform pollution showed an increasing trend towards the downstream, however there was no significant differences among years of sampling (figure 11).

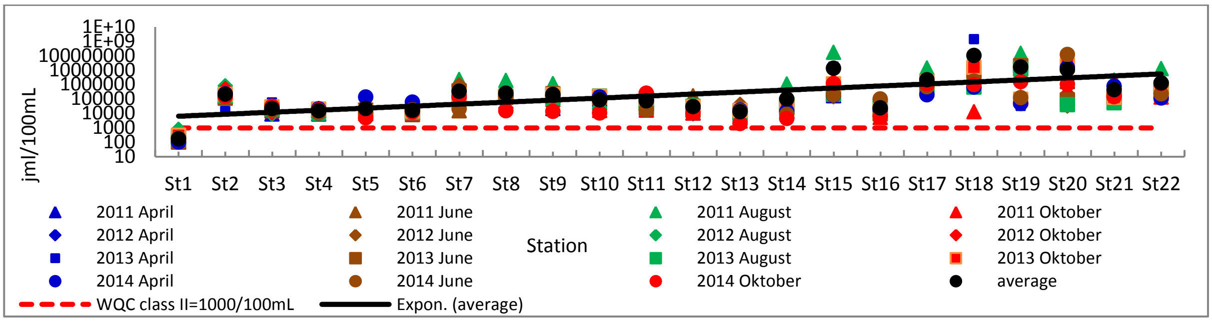

Figure 11. Fecal coliform number from upstream to downstream of the Ciliwung River.

In general, total coliform observed in this study were exceeded WQC class II at 5,000/100 mL. Total coliform in 2011 was detected in the range of 10 - 1,170,000,000/100 mL; in 2012 between 17,400 - 119,000,000/100 mL; in 2013 between 15,000 - 1,710,000,000/100 mL; in 2014 between 6,400 - 197,000,000/100 mL. The total coliform trend increased significantly towards the downstream ($P < 0.05$), however there was no significant difference in each year of sampling (figure 12).

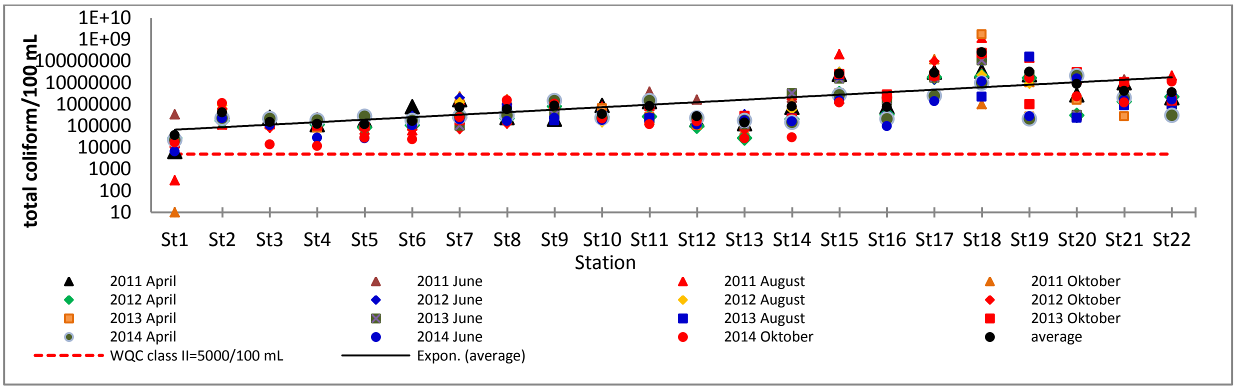

Figure 12. Total coliform number from upstream to downstream of the Ciliwung River.

High number of fecal coliform and total coliform in the Ciliwung River indicated high level of pollution from human and animal waste. Populated areas with high activity and livestock areas contribute high coliform pollution. The presence of coliform bacteria was originated from human and animal wastes, especially from washing, animal manure on farms, improper disposal of septic tanks, and disposal water from farms.

Based on 15 water quality parameters observed at 22 locations from 2011-2014, only three parameters, namely pH, TDS and NO_3-N that still satisfied the standard WQC class II Government Regulation number 82/2001. Other parameters invariably meet or beyond the water quality criteria. Pollution trend increased towards the downstream of Ciliwung River and in general, annual comparisons did not show significant differences. Fecal coliform and total coliform greatly influence water quality of the Ciliwung River and significantly polluted Ciliwung River. Controlling coliform pollution needs to be done in order to get better water quality and avoid the spreading of pathogens from coliform in Ciliwung River. Pollution control in the Ciliwung River needs to be prioritized due to the fact that water quality parameters decrease as pollution increase.

4. Conclusion

Water pollution in the Ciliwung River tended to be increasing towards downstream. However, different observation times from 2011 to 2014 did not show significant differences of the pollution trend for majority of the parameters. Based on the Government Regulation number 82/2001, three parameters, namely TDS, pH and NO3 were still meet water quality criteria class II standard, while other parameters invariably meet or beyond the water quality criteria. Fecal coliform and total coliform were dominant parameter polluted the Ciliwung River except in the spring of Ciliwung River. Water pollution control should be prioritized based on the fact where critical parameters gave high pollution contribution in Ciliwung River.

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