Monitoring quality of water sources in Madura: physicochemical and biological

V Vidayanti 1*, C Retnaningdyah 1, E Arisoesilaningsih 1

1 Biology Department, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, 65145, Indonesia
viky.vidayanti@ub.ac.id

Abstract. This study aims to (1) investigate the water sources quality based on physicochemical and biological parameters and (2) compare the water sources quality among locations of the study. The water sample takes from four locations water sources in Madura: Bangkalan area, Jokotole (JT), and Sumber Pocong (SP); Pamekasan, Samiran Reservoir (SR); and Sumenep, Nyapar (NY). Three sampling stations per location with three replications (station) are selected for sample collection. Some physicochemical parameters are measured, and phytoplankton samples are collected vertically and identified using keys from some references. The physicochemical parameters show that three locations are suitable for natural water sources based on the DO and salinity level: SP, SR, and NY. JT has the richest taxa than the other locations, but the highest number of plankton belongs to SP. The Importance Value Index (IVI) of plankton shows no dominance of plankton species in every water supply source location and is supported by the Simpson dominance index result. The evenness index shows a high evenness level of the species in every site. Based on the results of Shannon Wiener diversity index of plankton, the level of toxicity in the four research locations is in the light to moderate level.

1. Introduction
Madura is a lowland area which is consisted of Mediterranean soil (70%), alluvial soil (15%), and regosol soil (10%) [1]. This Mediterranean is formed from limestone that has a low capacity to hold water. Therefore, water scarcity is always happened in Madura, especially in the dry season [2]. Madura has so many water sources such as rivers, reservoirs, and lakes. Unfortunately, some of them have no information about the quality of their raw water. Because of this lack of information, the water sources are not fully utilized by the people. This issue is fundamental for managing freshwater resources to meet the people's needs.

Water quality is not only described in terms of physical and chemical characteristics but also biological. The responses of an organism or the communities can be monitored in various ways to indicate effects on the ecosystem. The abundance and co-existence of individual species at particular locations can mean altered habitat. Plankton is one of the standard biological indicators of freshwater habitat quality. That micro-size organism has a good ability to respond to habitat alteration since they are highly diverse and have a short life cycle. The plankton community is an early warning system for describing a healthy environmental level [3–5]. Research shows that the plankton communities of Bayuquan Port, Liaodong Bay dynamic changes within six years of observation, caused the eutrophication process from anthropogenic activities in this area. A study in Nasarawa reservoir also describes that the plankton communities reflect high organic pollution over there [6]. However, biotic
and diversity indices to determine water quality in Indonesia are rarely used because the water quality standards developed in Indonesia are only based on physico-chemical parameters. This study aims to (1) investigate the water sources quality based on physicochemical and biological parameters and (2) compare the water sources quality among locations of study.

Figure 1. Madura map shows four study area (c): Sumber Pocong (a), Jokotole (b), Samiran (d), and Nyapar.
2. Methods

2.1 Location of study
The water sample takes from four locations of water sources in Madura that are commonly used by the people (Figure 1). There are two places in the Bangkalan area, Jokotole (JT) (7°5'42.86"S; 112°42'20.23"E) and Sumber Pocong (SP) (7°3'35.22"S; 112°47'52.81"E). A location is from Pamekasan, Samiran Reservoir (SR) (7° 8'54.72"S; 113°26'33.50"E), and the last one site is located in Sumenep, Nyapar (NY) (6°54'8.23"S; 113°48'58.74"E).

2.2 Water sampling and phytoplankton analysis
Three sampling stations per location with three stations (three-replications) are selected for the purpose of sample collection. Some physicochemical parameters are measured using an instrument (Table 1). Phytoplankton samples are collected vertically with a plankton net of 100 nm mesh size beneath the water sources’ surface. About three liters of water is filtered, and it is preserved with formalin 4% and saturated CuSO4 solution then stored for the next examination. Species identification uses keys from some references (Bernard, 1908; Bold & Wynne, 1978; Prescot, 1978; Ward & Whipple, 1959). Numerical estimations of the phytoplankton are done using the method described by Effendie (1979).

| No. | Parameter          | Unit | Instrument/Method         |
|-----|-------------------|------|---------------------------|
| 1.  | Temperature       | °C   | Digital Thermometer       |
| 2.  | pH                | -    | pH meter                  |
| 3.  | Conductivity      | mS/cm| Conductivity Meter        |
| 4.  | Dissolved Oxygen  | mg/L | DO meter                  |
| 5.  | Turbidity         | NTU  | Turbidimeter              |
| 6.  | Salinity          | %    | Salinity Meter            |

2.3 Data analysis
Data of physicochemical parameters are compiled in Ms. Excel then it is calculated to get the average. This result is compared to water quality standards of government regulations No. 82 2001 about Water Quality Management and Water Pollution Control. Diversity index (H), species evenness (E), and Simpson index (D) are used to determine the phytoplankton species composition and abundance [7–11].

Shannon Index \( (H) = -\Sigma (pi \ln pi) \)

Evenness \( (E) = \frac{H}{(\log S / \log 2)} \)

Simpson Index \( (D) = -\Sigma \left(\frac{ni}{N}\right)^2 \)

Where
\( pi = \) the proportion of the \( n \)th species in the sample
\( H = \) the Shannon-wiener index of diversity
\( S = \) number of species or species richness
\( ni = \) the total number of organisms of a particular species
\( N = \) the total number of organisms of all species
Figure 2. Physicochemical parameters in three stations from four locations: Sumber Pocong (SP), Jokotole (JK), Samiran (SR), and Nyapar (NY). (Different subset above the bar shows statistically significant difference (P < 0.05)).
3. Results and Discussion

3.1 Physicochemical parameters
The temperature of every water source is quite similar, which is about 27 to 29°C. The pH level is also normal to the slightly alkaline range for pH in surface water systems about 6.5 to 8 (alkaline) (Figure 2a). The other physicochemical parameters are shown in the Figure 2. The conductivity is ranged from 0.5 – 2,002 mS/cm and Jokotole station is the highest one (2,002 mS/cm) (Figure 2b). The conductivity is a measure of the concentration of ions that carry electrical current. It can also be used to estimate the salinity since those two parameters have a positive correlation. Jokotole station is located near the seashore area that is why this station has the highest salinity (Figure 2c). Fresh, brackish, and sea-water possess viable minerals that differ in concentration and availability. The ions of brackish water in the Nandoni Reservoir are higher and more abundant than freshwater, such as the chloride, sulphate, hydrogen carbonate, sodium, magnesium, and calcium [12]. Other shows that the salinity value has a positive correlation with conductivity and dissolved solids, so that the higher the salinity, the higher the conductivity and dissolved solids [13, 14].

The DO concentration is ranged from 2.7 – 4.5 mg/L and Jokotole station has the lowest concentration because of its water type (Figure 2d). The DO levels still meet the water quality standards based on Indonesia Government Regulation No. 82/2001 Class II and III [15]. The water from Sumber Pocong, Samiran, and Nyapar can be used for raw water, but the Jokotole’s water is only for farming and water irrigation. DO has a relationship with temperature and salinity. Freshwater can hold more dissolved oxygen than seawater because it has less space for oxygen molecules due to the sodium and chloride ions. The DO concentration in a water ecosystem depends on its biota, water plants, oxygen exchange in the water column, water temperature, wind, and solar radiation [16].

The turbidity level from four stations is ranged from 0.9 – 13 NTU. Jokotole in 1st station is the highest one (13 NTU) then is followed by Samiran in 2nd and 3rd station (5.7 NTU) (Figure 2e). Its location can cause a high concentration of turbidity in Jokotole. The estuary is an intermediate zone, a mixing area between river (freshwater) and sea [17]. The river mouth has muddy characteristics, and pollution increases along the river, so there is a lot of sedimentation, increasing turbidity. The water of Samiran Reservoir is from various streams, so the sediment level is getting higher. Sediment carried by river water collects in reservoirs causing high turbidity values. Those sediments may contain clay, silt, very tiny inorganic and organic matter, algae, dissolved colored organic compounds, plankton, and other microscopic organisms that cause water to be turbid. A high turbidity level can prevent sunlight penetration to the water and reduce the productivity of producers in the water and affect the food chain [18, 19].

3.2 Phytoplankton
A total of 29 taxa, represented by 32995 individuals, are collected in the four stations (Figure 3a). Taxa richness of the plankton varied among stations. Jokotole has the highest richness (21 taxa), especially in the 3rd station; Sumber Pocong is in the 2nd place (18 taxa); then Samiran and Nyapar are less diverse with only 14 and 17 taxa. Based on the Shannon Wiener Index, the diversity scale in four stations is intermediate and high. All of the stations in the Jokotole have high diversity (H’> 3). The high-level diversity is also shown by Sumber Pocong 3rd station, Samiran 3rd station and Nyapar 1st substation, and then the other stations are at the intermediate level. The evenness of four stations has relatively evenly distributed (0.71 – 0.97). The diversity index and evenness result are also supported by the INP that shows no dominant species in every location.
Figure 3. Physicochemical parameters in three stations from four locations: Sumber Pocong (SP), Jokotole (JK), Samiran (SR), and Nyapar (NY). (Different subset above the bar shows statistically significant difference (P 0.05))
Jokotole is the only station located at the estuary, a transition zone from the river to the sea. This condition allows the types of taxa in this location to be more diverse than the other locations. Due to the mixing of two different water bodies, a gradient of physico-chemical factors is formed, and it dramatically affects to gradient phytoplankton community structure. The Vire River's mouth, which ends in the Vire Sea, shows that the wealthiest taxa are found in the estuary [20]. Meanwhile, Sumber Pocong has the highest density of individual plankton. Sumber Pocong is the most visited place by tourists than the other locations, and they do an anthropogenic activity such as swimming and taking a bath. Anthropogenic activities can increase organic matter in the water environment so that it will affect the structure of the plankton community. Meanwhile, Nyapar still has a minimum number of visitors, and other activities, so organic matter (OM) input is less than that of Sumber Pocong. OM and nitrogen are also phosphorous quantities in lagoons affected by anthropogenic activities such as agriculture and bathing, then they will then affect values in primary producers and consumers [21].

The results of the Importance Value Index (IVI) for plankton show that each location of the water supply source, there is no dominance of plankton species (Figure 4.3.b). This is also supported by the calculation of the Simpson dominance index which shows a value in the range of 0.11 - 0.27, which means that there is no domination in the four locations (Id < 0.5) (Figure 4.3.c). Besides, from the evenness index value (0.71 - 0.97), it is known that the evenness level of species at the four locations is high (E > 0.6). Based on the results of the Shannon Wiener diversity index from plankton, it was found that the level of toxic material contamination in the four study locations was classified as light to moderate contamination (Figure 4.4.b). Anthropogenic activities by local people likely cause the pollution that occurs. Sumber Pocong and Nyapar have two moderately polluted stations (H ' = 2 - 3). Diversity index can reflect the characteristics of plankton communities and the status of water nutrients, so it is widely used to determine water bodies’ level of pollution [22, 23]. Even though it is lightly to moderately polluted, this water source's status is oligotrophic with 300,000 ind/L of individual plankton. There may be an increase in status to meso and even eutrophication if more and more organic material is input from the surrounding community's activities, especially in Sumber Pocong. Based on the monitoring results, several types of plankton were also found which are indicators of waters that have been contaminated with organic matter, such as Navicula, Nitzschia, and Stephanodiscus [24, 25].

4. Conclusion
The physicochemical parameters show that three locations are suitable for natural water sources based on the DO and salinity level. JT has the richest taxa than the other locations, but the highest number of plankton belongs to SP. Every water supply source location shows no dominance of plankton species and is supported by the Simpson dominance index result. The evenness index shows a high evenness level of the species in every site. Furthermore, based on the results of Shannon Wiener diversity index of plankton, the level of toxicity in the four research locations is in the light to moderate level.

Acknowledgment
Authors thank to Brawijaya University DPP-SPP 2020 for research supporting fund.

References
[1] European Soil Data Centre (ESDAC) Java Soil Maps, https://esdac.jrc.ec.europa.eu/ (2020, accessed 12 March 2020)
[2] Subroto P H and Santosa A P B (Universitas PN ‘Veteran’, Y (Indonesia). FP. [The characteristic of mediterranean soil in Seribu Mountains, Gunungkidul (Indonesia)] Agrivet (Indonesian)
[3] Hemraj D A, Hossain Md A, Ye Q, Qin J Q and Leterme S C 2017 Plankton Bioindicators of Environmental Conditions in Coastal Lagoons Estuarine Coastal and Shelf Sci. 184 (2017) 102-114
[4] Gökçe D 2016 Algae as an Indicator of Water Quality, Algae - Organisms for Imminent Biotechnology (Rijeka: IntechOpen)
[5] Pourafrasyabi M and Ramezanpour Z (2020) Phytodetoxon as bio-indicator of water quality in Sefid Rud River, Iran (South of Caspian Sea), http://research.guilan.ac.ir/cjes (Accessed 12 March, 2020).

[6] Yusuf Z H 2020 Phytodetoxon as bioindicators of water quality in nasarawa reservoir, Katsina State Nigeria. Acta Limnol. Bras. 32 4.

[7] Brower J E, Zar J H and Ende C von 1998 Field and laboratory methods for general ecology 4th ed. (New York: WCB McGraw-Hill).

[8] Kelly M G 1998 Use of the trophic diatom index to monitor eutrophication in rivers Water Res. 32 236–242.

[9] Kelly M G and Whitton B A 1995 The Trophic Diatom Index: a new index for monitoring eutrophication in rivers J. Appl. Phycol. 7 433–444

[10] Korycinska M and Królak E 2006 The Use of Various Biotic Indices for Evaluation of Water Quality in the Lowland Rivers of Poland (Exemplified by the Liwiec River) | Semantic Scholar

[11] Odum E P 2004 Fundamentals of Ecology [Paperback] 5th ed. (Boston: Thomson Brooks)

[12] Nhuny L N, Maipti S, Mamba B B, Verlifide A R and Mhlanga S D 2018 Spectroscopic Determination of Water Salinity in Brackish Surface Water in Nandoni Dam, at Vhembe District, Limpopo Province, South Africa Water 10 990

[13] Baharuddin M F T, Masirin M, Hazreek A M, Azman M A A and Madun A 2017 Correlation between conductivity and total dissolved solid in various type of water: A review Related content Investigation of groundwater-seawater interactions: a review A Purwoarminta, N Moosdorf and R M Delinom-Resistivity-Chemistry Integrated Approaches for Investigating Groundwater Salinity of Water Supply and Agricultural Activity at Island Coastal Area Correlation between conductivity and total dissolved solid in various type of water: A review IOP Conf. Series: Earth and Environmental Science (Malaysia) pp 1–6

[14] Sylus K J and Ramesh H 2015 The Study of Sea Water Intrusion in Coastal Aquifer by Electrical Conductivity and Total Dissolved Solid Method in Gurpur and Netravathi River Basin Aquat. Procedia 4 57–64

[15] BPK PP No. 82 Tahun 2001 tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air [JDIH BPK RI], https://peraturan.bpk.go.id/Home/Details/53103/pp-no-82-tahun-2001 (Accessed 12 October 2020) (Indonesian)

[16] Banerjee A, Chakraborty M, Rakshit N, Bhowmick A K and Ray S 2019 Environmental factors as indicators of dissolved oxygen concentration and zooplankton abundance: Deep learning versus traditional regression approach. Ecol. Indic. 100 99–117.

[17] Onabule O A, Mitchell S B, Couceiro F 2020 The effects of freshwater flow and salinity on turbidity and dissolved oxygen in a shallow Macrotidal estuary: A case study of Portsmouth Harbour Ocean Coast Manag 191 105179

[18] Butler B A and Ford R G 2018 Bewertung der Beziehungen zwischen der Gesamtsumme gelöster Feststoffe und der gesamten Schwefelstoff-Fracht in einem bergbaueinflussten Wassereinzugsgebiet Mine Water Environ 37 18–30

[19] Omer N H 2020 Water Quality Parameters, Water Quality - Science, Assessments and Policy (Rijeka: IntechOpen)

[20] Bazin P, Jouenne F, Friedl T, Deton-Cabanillas A, Le Roy B and Véron B 2014 Phytoplankton Diversity and Community Composition along the Estuarine Gradient of a Temperate Macrotidal Ecosystem: Combined Morphological and Molecular Approaches PLoS One 9 e94110.

[21] Philips E J, Badylak S and Grosskopf T 2002 Factors affecting the abundance of phytoplankton in a restricted subtropical lagoon, the Indian River Lagoon, Florida, USA. Estuar Coast Shelf Sci 55 385–402

[22] Gao H, Zhang S, Zhao R and Zhu L 2018 Plankton community structure analysis and water quality bioassessment in JiuLong Lake IOP Conf. Ser. Earth Environ. Sci. 199 22031
[23] Protasov A, Barinova S, Novoselova T and Sylaieva A 2019 The Aquatic Organisms Diversity, Community Structure, and Environmental Conditions Diversity 11 190
[24] Wu N, Faber C, Ulrich U and Fohrer N 2018 Diatoms as an indicator for tile drainage flow in a German lowland catchment Environ. Sci. Eur. 30 4
[25] Földi A, Ács É, Grigorszky I, Ector L, WetzelC E, Várboró G, Kiss K T, Dobosy P, Trábert Z, Borsodi A K and Duleba M 2018 Unexpected consequences of bombing. Community level response of epiphytic diatoms to environmental stress in a saline bomb crater pond area PLoS ONE 13 (10) e0205343