Environmental Technology & Innovation 5 (2016) 67–82

Contents lists available at ScienceDirect

Environmental Technology & Innovation

journal homepage: www.elsevier.com/locate/eti

Evaluation of water quality for the Nakdong River watershed using multivariate analysis

Kang Young Jung [a], Kyung-Lak Lee [a], Toe Hyo Im [a], In Jung Lee [a], Shin Kim [a], Kun-Yeun Han [b], Jung Min Ahn [a,*]

[a] *Nakdong River Environment Research Center, 24, Pyeongri-1gil, Dasan-myeon, Goryeong-gun, Gyeongsangbuk-do 717-873, Republic of Korea*

[b] *Department of Civil Engineering, Kyungpook National University, Republic of Korea*

HIGHLIGHTS

- The water quality characteristics were evaluated by conducting multivariate statistical analysis.
- The first factors were shown to be nutrient salts (TN, TP) and organic pollutants (TOC, COD).
- The priorities of required water quality were determined according to the water quality pollution level.

ARTICLE INFO

Article history:
Received 8 May 2015
Received in revised form 30 November 2015
Accepted 16 December 2015
Available online 21 December 2015

Keywords:
The Nakdong River
Factor analysis
Cluster analysis
Principal component analysis
Water quality
Water quality pollution level

ABSTRACT

Water quality observation data were collected from 20 representative monitoring sites located in the main stream of the Nakdong River and its major tributaries between 2008 and 2012. Based upon these data, the water quality distribution and characteristics of each river were evaluated by conducting multivariate statistical analysis for 12 pollution indicators using SPSS-17.0. Monitoring site T8 passing through the city of Daegu and monitoring site M5 located downstream of the Nakdong River exhibited high-concentration tendencies. The monitoring sites located near the city and midstream and downstream of the Nakdong River exhibited high pollution levels in the investigation. To analyze the spatial and temporal variations in the water quality at 20 major monitoring sites in the Nakdong River watershed, principal component and factor analyses were conducted by separating the average water quality data based upon (a) monitoring site, and (b) season. As a result, three factors were obtained for (a), and (b), respectively. In the Nakdong River watershed, the first factor was shown to be nutrient salts (total nitrogen and total phosphorus) and organic pollutants (total organic carbon and chemical oxygen demand), and as a result of cluster analysis, two statistically significant groups were classified. The results of multivariate statistical analysis indicated that the monitoring sites with high levels of pollution were mostly those sites going through the heart of the city or the sites affected by residential sewage directly, as well as the sites located midstream and downstream of the Nakdong River. The water quality pollution level was calculated based upon the above study results, and the priorities for water quality improvement items required in future watershed management were determined in order to facilitate efficient water quality management.

* Corresponding author. Tel.: +82 54 950 9780; fax: +82 54 950 9775.
E-mail addresses: happy3313@korea.kr (K.Y. Jung), micow1022@korea.kr (K. Lee), imtoehyo@korea.kr (T.H. Im), ijlee5344@korea.kr (I.J. Lee), sinima@korea.kr (S. Kim), kshanj@knu.ac.kr (K.-Y. Han), jahn@korea.kr (J.M. Ahn).

http://dx.doi.org/10.1016/j.eti.2015.12.001
2352-1864/

1. Introduction

A river is a system comprising both the main course and the tributaries, carrying the one-way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources (Shrestha and Kazama, 2007). Since rivers are the most important inland water resources for human consumption, it is imperative to have reliable information on characteristics and trends of water quality for effective water management. The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs (Bricker and Jones, 1995).

There are also several types of pollution indicators derived from these influences. However, up to now studies have only examined the pollution levels of plain watersheds based upon subjective pollution evaluations and mathematical water quality analyses regarding various pieces of information. There are many pollution sources affecting water quality, and there is a methodology that can provide basic data to accurately support this view. However, this methodology has not been utilized, and in most cases, the analysis and generalization were influenced by the subjectivity and experience of the researchers. Therefore, the effective, long-term management of rivers requires a fundamental understanding of watershed characteristics through multivariate analysis for the water quality monitoring data. Due to spatial and temporal variations in water quality, a monitoring program, providing a representative and reliable estimation of the quality of surface waters, is necessary (Dixon and Chiswell, 1996).

The application of different multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA), factor analysis (FA) and discriminant analysis (DA), helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems, allows the identification of possible factors/sources that influence watershed, and offers a valuable tool for reliable management of water resources as well as rapid solution to pollution problems (Vega et al., 1998; Lee et al., 2001; Adams et al., 2001; Wunderlin et al., 2001; Reghunath et al., 2002; Simeonova et al., 2003; Simeonov et al., 2004). Multivariate statistical techniques has been applied to characterize and evaluate surface and freshwater quality, and it is useful in verifying temporal and spatial variations caused by natural and anthropogenic factors linked to seasonality (Helena et al., 2000; Singh et al., 2004). Abahams (1972) conducted a factor analysis to identify the characteristics of drainage watersheds, and Karim and Taha (2003) used principal component analysis to identify the commonality between the spatial and temporal factors influencing the water quality in New Jersey's Passaic River. To understand the nutrition state of lakes, Bernard et al. (2004) used principal component analysis for the evaluation and management of relevant water quality items. Fang et al. (2010) used a statistical method for spatial fluctuation characteristics of water pollution in Qiantang River, and Homa et al. (2010) conducted a study on spatial and temporal variability by using a pattern recognition method.

The water quality of the river is determined by interactions of pollution loads from the tributary flowing in, hydrological characteristics, sediment and metabolism in the water, and seasonal factors adjusted spatially and temporally. Therefore, to identify the characteristics of the Nakdong River watersheds, this study analyzed the spatial water quality distribution characteristics using the position and the changing characteristics of water quality according to time by season.

In this way, this study aims to analyze the major factors recently affecting the water quality spatially and temporally in the watersheds of the Nakdong River, and to provide data for more scientific and rational water quality management in response to the increases in the causes of environmental pollution and the water demand due to the effects of developments performed based on more complex and broader surrounding environments.

2. Materials and methods

2.1. Study area

The Nakdong River watershed is located between the longitude 127° 29′19″ and 129°18′00″, and the latitude 34°59′41″ and 37°12′52″. The Nakdong River faces the watersheds of Han River to the north and Geum River and Seomjin River to the west, the watersheds of the East Sea coast are formed by the Taebaek Mountains in the east, and it faces the southern sea area of the Nakdong River in the south (Jung, 2009).

The administrative districts include areas from three metropolitan cities and five provinces, including Busan Metropolitan City, Daegu Metropolitan City, Ulsan Metropolitan City, Gyeongsang Nam and Buk Provinces, Jeolla Nam and Buk Provinces, and Gangwon Province. The Nakdong River watershed is the second largest watershed in South Korea. The watershed's area is 23,817.3 km^2 (which is about 1/4 of the area of South Korea), the length of the channels is 521.5 km, the circumference of the watershed is 1097.13 km, the average width is 46.03 km, the average elevation is 291.2 m, and the average slope is 32.26%. The watershed consists of a total of 803 streams, including the watershed of West Nakdong River (758 Nakdong River watershed and 18 West Nakdong River watershed), and the total length of the river is 7422.02 km.

The major streams of the Nakdong River's watershed include thirteen national rivers (Nakdong River, Naeseong Creek, Gam Creek, Geumho River, Hwang River, Nam River, Deokcheon River, Miryang River, Yangsan Creek, West Nakdong River, Pyeonggang Creek, and Maekdo River), ten regional class 1 rivers (Nakdong River, Banbyeon Creek, Byeonseng Creek, Naeseong Creek, We Creek, Shin Creek, Hwea Creek, Geochangwi Creek, Nam River, and Hamyangwi Creek), and 31 regional