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Determination of target water quality indicators and values on total maximum daily loads management system in Korea

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ABSTRACT

To improve the water quality of the four major rivers in Korea, Ministry of Environment of Korea (MOE) has introduced the Total Maximum Daily Loads (TMDLs) management system since 2002 and BOD was selected as one of the target materials during the first period (2004–2010). For an effective watershed management, it is necessary to have one or more quantitative measures that can be used to evaluate the relationship between pollutant sources and their impacts on water quality. Such measurable quantities are termed water quality indicators. Once an indicator is selected, target values for that indicator must be established to distinguish between the impaired and unimpaired state of the water-body. Various factors such as available data, application, management conditions and cost will be considered for the selection of an appropriate watershed management indicator. This paper introduces various factors required for choosing target water quality indicators and establishes reasonable target values during the second TMDLs period (2010–2015).

Keywords: BOD; TMDLs; TP; Water quality indicators; Watershed management policy

1. Introduction

Although the government of Korea has put effort to improve the water quality with various policies and measures since 1960s, water quality has failed to reach the level of satisfaction. That's because those policies and measures have been focused only on existing point sources of conventional pollutants deteriorating water quality including BOD. In 1998, the Ministry of Environment of Korea (MOE) established Comprehensive Water Quality Management Measures for the four major rivers, which are the Han River, the Nakdong River, the Guem River and the Youngsang/sumjin River. The Act on Watershed Management and Community Support was enacted to facilitate the implementation of the measures for the each river from 1999 to 2002. Total Maximum Daily Loads (TMDLs) management system of Korea started with these Acts and a basic target of this policy was to improve water quality [1,2].

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According to the TMDLs system of Korea, the target indicators are supposed to be selected by minister of MOE with agreement of local government. BOD_5 was decided for the first period (2004–2010). Kim [3] reported BOD had some weaknesses for use as the environmental pollution indicator although it had been one of the major target indicators for water quality control from the beginning stage of water quality management in Korea; (1) oxygen depletion is not an environmental problem any more in Korea, (2) BOD can not be an indicator of total organic matter in water, (3) BOD as an indicator of tap water quality is that recalcitrant organic matter produces 2–3 times more carcinogen than biodegradable organic matter (see Table 2 and Fig. 1), (4) Because Korea has secured enough point source control facilities already, BOD will drop even without TMDLs management system, and (5) labile organic matter removal in the watershed is not effective even for labile organic matter control in case of stagnant water condition. Therefore, MOE also proposed introduction of various target indicators with establishing the Water Environment Management Master Plan, which presents direction of governments policies for the next 10 years (2006–2015). It aims to not only promote ecologically healthy water environment in order to ensure high water quality, but also proceed present policies focused conventional pollutants such as BOD [4].

To improve water quality, it is necessary to have one or more quantitative measures that can be used to evaluate the relationship between pollutant sources and their impacts on water quality. And water quality indicators are expressed another term as measurable quantities. Once an indicator is selected, target values for that indicator must be established to distinguish between the impaired and unimpaired state of the water-body. As for boundaries between cities and provinces, they will be established by minister of MOE [5].

This paper introduces which factors have been considered during the process of selecting target water quality indicators and values in the three major rivers (Nakdong, Guem, Youngsang/Sumjin) of Korea which are mandatory water-body on TMDLs management system by each river's Act (2002).

2. Methods and results

2.1. Procedure for the determination of target water quality indicators

The target indicator is BOD for the first period (2004–2010) and BOD_5 and TP for the second TMDLs period (2010–2015). The indicators controlled by TMDLs have been decided through consultation of minister of MOE and Watershed Management Committee after investigation on their applicability and efficiency by research team [6–8].

USEPA [9] reported a process of selection of target indicators (Stressor Identification, SI). Although the SI process is scientifically rigorous, it is flexible enough to support various water management requirements. However, some potential applications of the SI process include the followings; (1) characterizing the quality of the nation's water, (2) identifying water-bodies and wetlands that exceed water quality, and (3) regulatory and non-regulatory pollution management programs. SI process consists of the following four major steps; (1) listing candidate causes, (2) analyzing evidence, (3) characterizing cause, and (4) iteration options.

TMDLs management system in Korea considers various factors for the selection of an appropriate indicator such as available data, application, management conditions, cost-benefit efficiency, etc. Fig. 1 shows how applicable water quality indicators are selected.

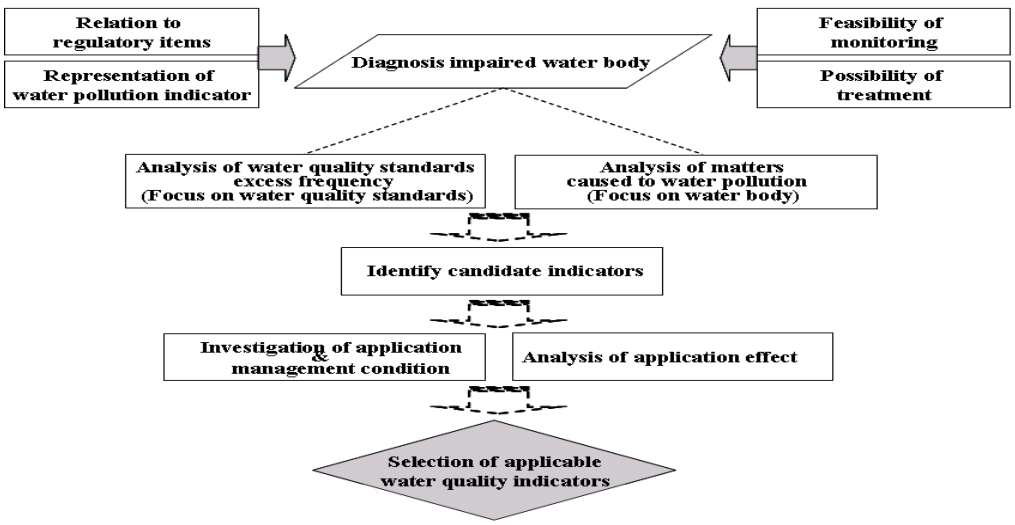

Fig. 1. Flow diagram for selection of the applicable water quality indicators.

2.2. The principle for establishment of indicators

Several candidate target indicators were derived with four factors as shown Fig. 1. In regulatory items steps, 8 items on human environment and 9 items on human health protection can be considered for the candidate target indicators (Table 1) and these indicators were contracted with organic matters, SS, nitrogen compounds, phosphorus compounds, heavy metals, pathogens and Chl-a as considering the next step (representation of water pollution indicators in three mandatory water-body on TMDLs management system).

It is important to consider feasibility of water quality indicator monitoring, because water quality and flow should directly be measured in situ to estimate achieving the target values of each boundary point in watershed. Automatic analyzer for Organic matters (BOD, COD, TOC), Chl-a, TN and TP were commonly used in situ and these indicators are effectively treated in treatment facilities with various technology.

2.3. Diagnosis impaired water body

2.3.1. Analysis on frequency of failing to meet water quality standard

The measured data by MOE during the 1994–2003 were used for analysis on frequency of failing to meet water quality standard (total 162 stations). As shown in Table 2, seven items exceeded water quality standard greatly and, especially, BOD and TP did frequently.

Table 1
Water quality standards

Constituent	Items
Human environment	
River	pH, BOD, SS, DO, Total coliform
Lake	pH, COD, SS, DO, Total coliform, TP, TN
Human health protection	
Total water body	Cd, As, CN, Hg, Org-P, Pb, Cr(VI), PCB, ABS

2.3.2. Analysis on limiting factor for algae growth

Various water quality policies and measures have contributed to improving river water quality but have still showed algae bloom (eutrophication) on lake and stagnant water body due to high concentration of nitrogen and phosphorus.

High concentration of algae deteriorates quality of drinking water, therefore, control of N and P in stagnant water is important. In this paper, TP is the limiting factor between TN and TP analyzed using the Forsberg method and estimated in three river system. As shown in Figs. 2–4, TP was limiting factor in all river systems.

2.4. Identify candidate water quality indicators

Based on the analysis of frequency of exceeding water quality standard and matters caused water pollution, organic matters (BOD, COD, TOC), total coliform, nutrient (TN and TP) and SS can be considered candidate of water quality indicators in three river watershed (Table 3).

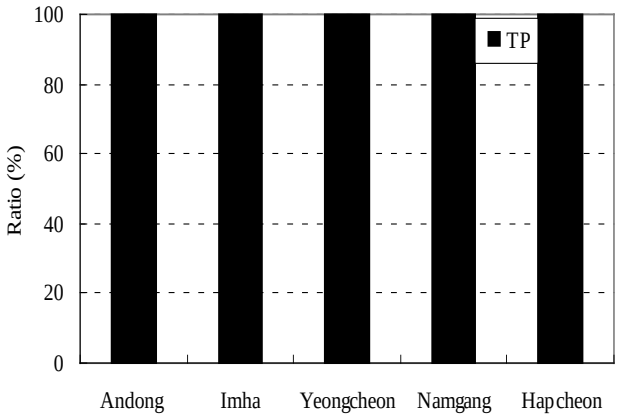

Fig. 2. Algae limiting factor of lakes in the Nakdong River watershed.

Table 2
Water quality items violating water quality standards frequently for each watershed (unit: %)

Items	Nakdong River		Geum River		Yeongsan River	
	Streams	Lakes	Streams	Lakes	Streams	Lakes
BOD	30–52		60–73		40–99	
COD		95–100		71.3–100		96–100
SS	10–25	66–100	2–45	45.3–95.7	1–99	88–99
TP		50–100		49.8–88.7		65–97
Total coliform	15–80	5–100	52–67	1.5–37.1	3–85	3–64
TN		100		0.4–24.6		95–100
DO		8–62	4–26	0.6–28		3–42

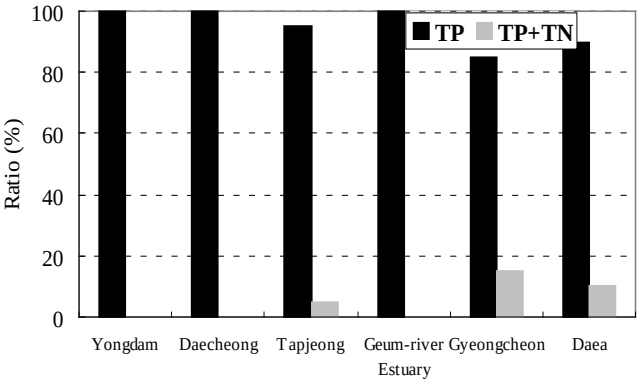

Fig. 3. Algae limiting factor of lakes in the Guem River.

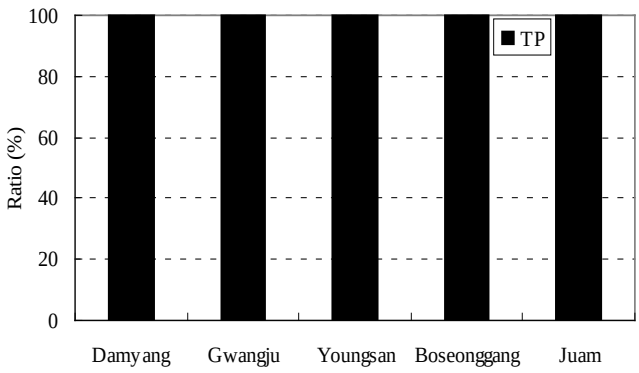

Fig. 4. Algae limiting factor of lakes in the Yeongsan River.

Table 3
Candidate water quality indicators for each watershed

	Nakdong River	Guem River	Youngsan River
Organic matter	BOD/COD or TOC	BOD/COD or TOC	BOD/COD or TOC
Nutrients	TP (algae limiting factor)	TP (algae limiting factor)	TP (algae limiting factor)
	TN	TN	TN
Others	Total coliform	Total coliform	Total coliform
	SS	SS	SS

2.5. Investigation of application and management conditions

Among the candidate, water quality indicators in Table 4, organic matters and nutrients can be considered preferentially because of current situation of technology level and data available for driving the TMDLs.

2.5.1. Organic matter

The target indicators are decided as BOD for the first period (2004–2010). Comparison of COD and TOC, BOD data is available in various fields. Those items have been basis of regulations. However, to address limitation of

Table 4
Comparison of advantage and disadvantage according to selection of COD, TOC as organic control items

Advantage	Disadvantage
COD	
• Has many data • Able to measure non-biodegradable organic matter (in case of CODcr) • Has enough legal and systematical foundation • Exists various treatment process • Promptly able to practice	• Needs to change CODMn to COD(CODcr) in emission standards and water environmental standards for lake (If CODMn value is used, it has limitation as an indicator of total organic matter because of low oxidation rate) • Needs to change water quality model • Needs to prepare water environmental standards for streams
TOC	
• More effectively measure non-biodegradable matter than BOD and COD • Possible to control pollution source and to manage wastewater treatment facilities • Possible to decide control target for lake management by exactly evaluating organic matter quantity • Can be able to improve water quality by monitoring and control non-biodegradable matter	• Insufficient of data for each emission routes • Does not have enough legal and systematical foundation • Needs to change water quality model module • Needs a preparatory period • Needs great expense • Needs to prepare water environmental standards and emission standards for wastewater treatment facilities

BOD as an environmental indicator, COD and TOC should be considered as the alternative target indicators. Advantage and disadvantage according to selection of COD and TOC as organic control items are shown in Table 4.

2.5.2. Nutrients

TN and TP should be restrained to control the algae growth. Even though there are a lot of technologies controlling the two nutrients, it is better to apply TP preferentially because TP is limiting factor and it cannot clarify the input source of TN.

2.6. Analysis of application effect

In case of control the BOD and TP, ecologically healthy water environment can be maintained with control of the algae growth and manage of the supply water. Fig. 5 shows that simulation results for TP reduction to algae production and BOD and predicted that algae and BOD concentration decreased.

2.7. Target water quality values

Target water quality values are the standards for establishing TMDLs management targets. They were established considering the use of stream (water supply, irrigation etc.), concentration of pollution source, level of local community development, administrative infrastructure investment, quality of water and integrity of water ecosystem etc. Fig. 6 shows basic concept for deciding the target values in achieved and exceed area on reference value for the establishment of target values.

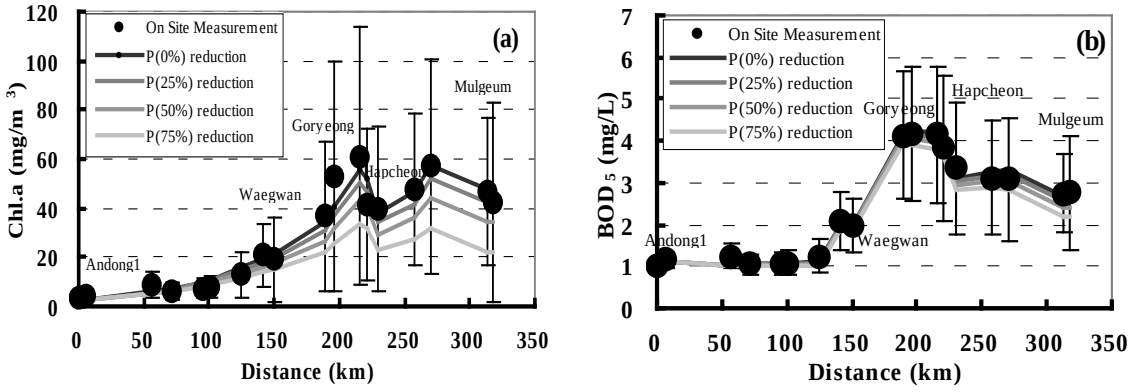

Fig. 5. Simulation results for TP reduction–algae production (a) and TP reduction– BOD (b) of the Nakdong River.

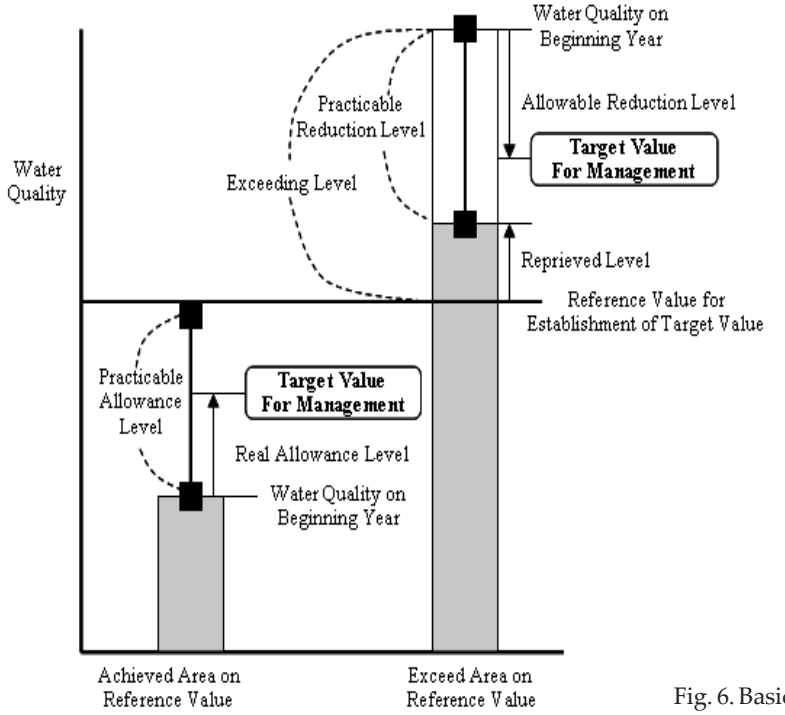

Fig. 6. Basic concept about decision of the target.

3. Conclusions and future

In TMDLs system of Korea, the target indicators selected by minister of MOE with agreement of local government, decided BOD for the first period (2004–2010) and BOD and TP for the second TMDLs period (2010–2015), in view of the applicability and representation of water quality.

BOD alone, as a target indicator, is not enough to represent complexity of water quality and characteristics of aquatic ecosystem. In the future, we need more comprehensive and target-specific indicators for an advanced water management. Biological method can be an alternative measure.

References

[1] Y.M. Jung, Work manual for watershed TMDLs management system (11-1480000-000712-01), Ministry of Environment, Korea, 2004.
[2] [Korean Ministry of Environment, Green Korea 2005, Korea, 2005.
[3] B.C. Kim, Suggestions of target parameters for water quality TMDL in Korea. International Symposium on the Watershed Waste Load Management Act for Water Quality Protection, Korean National Assembly, Seoul, Korea, 2007.
[4] B.K. Lee, Water environment management master plan outline (2006–2015). Korea Environ. Policy Bull., 4 (2006) 1–11.
[5] D.I. Jung, TMDL management system —promoting both development and conservation (11-1480523-000069-01). National Institute of Environment Research, Korea. 2006.
[6] NIER, Study on the selection of target water quality indicators on second TMDLs period in the Nakdong River watershed, 2005.
[7] NIER, Study on the selection of target water quality indicators on second TMDLs period in the Guem River watershed, 2005.
[8] NIER, Study on the selection of target water quality indicators on second TMDLs period in the Yeongsan/Sumjin River watershed, 2005.
[9] USEPA, Stressor Identification Guidance Document, 2.