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Research paper

Trends of eutrophication and effects of measures in feitsui reservoir during 1987 – 2018

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Abstract

Purpose: Reservoir watershed is one of the most important sources of domestic water of people. The quality of water is crtical for the users.
Approach: Using trends of environmental water quality information during 1987 – 2018. We approached the Carlson trophic state index (CTSI) and evaluated the effects of measures on water quality of Feitsui reservoir compared to the controlled Shihmen reservoir.
Results: The CTSI (46.4) was peak in 2001 and decreased to 36.8 in 2018. Water quality was improved after the establish of Best Management Practices (BMPs) after 2003. The CTSIs in Feitsui reservoir were lower than that in Shihmen reservoir generally.
Conclusions: Non-point source pollution could cause a higher CTSI. The eutrofication shold be prevented by use of total phosphorus.

Keywords: *CTSI; BMPs; Eutrophication; Total Phosphorus.*

1. Introduction

Eutrophication is when a body of water becomes overly enriched with minerals and nutrients which induce excessive growth of algae (Chislock et al. 2013). This process may result in oxygen depletion of the water body (Schindler & Vllentyne 2004). Eutrophication is often induced by the discharge of sewage, fertilizers, or phosphate-containing detergents into an aquatic system. The ecological impacts were decreased biodiversity, new species invasion, and toxicity (Shumway S E 1990, Lawton & Codd 1991, Martin & Cooke 1994).
CTSI is a water quality index invented by Carlson (Carlson1977). CTSI is calculated by 3 variables considered secchi depth, chlorophyll a, and total phosphorus. If the value of CTSI is greater than 50, it means the water quality in the water body is eutrophic. If the value of CTSI is smaller than 40, the water quality is oligotrophic. Between 40 and 50, it is mesotrophic.
The Feitsui reservoir has supplied domestic water to the 650 million people of the Taipei metropolis and its immediate vicinity since 1987. In order to prevent eutrophication from occurring, the government had regulated the pollution from point source and nonpoint source. However, the pollution regulation from point sources contributed 21% of effects only (Lin & Hsieh 2003). The pollution regulation from nonpoint source need to be evaluated importantly.

2. Methods

Using environmental water quality information during 1987 – 2018 from Environmental Protection Administration Taiwan. This study investigated the changes of CTSIs and evaluated the measures that prevented from the eutrofication. Differences between various groups were evaluated using Student t-test, Mann – Whitney U test, and x^2- test. The level of significance was set at 0.05.

3. Results

The CTSI (46.4) was peak in 2001, and declined to 36.8 in Feitsui reservoir in 2018, The CTSI (53.5) was peak in 2012, and declined to 45.0 in Shihmen reservoir in 2018. The trends of CTSIs expressed the sign of scissors opened after 1999 between in Feitsui reservoir, and Shihmen reservoir. The Water quality was improved in Feitsui reservoir after 2005 (Fig 1).

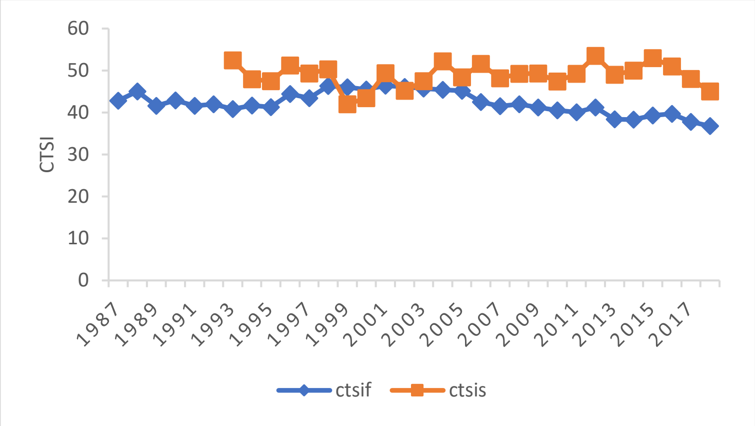

Fig. 1: Trends of CTSI in Feitsui Reservoir, And in Shihmen Reservoir.

The CTSIs during 1987 – 2018 by year interval are seen table1. The CTSIs in Feitsui reservoir were lower than that in Shihmen generally. The average CTSI in

Feitsui reservoir was 43.9 during 1987 – 1991which increased to 45.3 during 2000 – 2006 (3.19 %). The average CTSI 45.3 declined to 38.1 during 2016 – 2018 (15.89 %). The declined rate was large than the increased rate ($p < 0.05$). The average CTSI in Shihmen reservoir was 48.7 during 1992 – 1999 which increased to 50.2 during 2009 – 2015 (3.08 %). The average CTSI 50.2 declined to 48.0 during 2016 – 2018 (4.38 %). The declined rate was similar to the increased rate ($p > 0.05$).

In Feitsui reservoir, the water body was mesotrophic during 1987 – 2008. It improved to oligotrophic water body after 2008. The water body was oligotrophic during 2016 – 2018 consistently. In Shihmen reservoir, the water body was mesotrophic or eutrophic during 1992 – 2018 by year interval (table 2).

Table 1: Estimated Means of CTSIS in Feitsui Reservoir, And Shihmen Reservoir (1987 – 2018)

Year	CTSI in Feitsui reservoir	CTSI in Shihmen reservoir
1987 – 1991	43.9	--
1992 – 1999	43.2	48.7
2000 – 2006	45.3	48.2
2007 – 2008	41.6	48.7
2009 – 2015	39.9	50.2
2016 – 2018	38.1	48.0

Table 2: Eutrofication Distribution in Feitsui Reservoir, And Shihmen Reservoir (1987 – 2018)

Year	CTSI in Feitsui reservoir			CTSI in Shihmen reservoir		
	<40	40-50	>50	<40	40-50	>50
1987 – 1991	0	7	0	-	-	-
1992 – 1999	0	8	0	0	4	3
2000 – 2006	0	6	0	0	4	2
2007 – 2008	0	2	0	0	2	0
2009 – 2015	3	4	0	0	4	3
2016 – 2018	3	0	0	0	2	1

4. Discussion

In the past 32 years (1987 – 2018), the CTSIs due to initiative measures dropped by 14.02 %, as well as the water body was improved to oligotrophic after 2012 in Feitsui reservoir. For the reasons, the government has set up hydraulic engineering to supply clean water from Feitsui reservoir to the more people lived in Taipei city area since 2013.

The governments and non-governmental organizations (NGO) established many measures to improve water quality of the Feitsui reservoir, despite a road engineering (Freeway No. 5) during 1991 to 2006 affecting the water quality. In the period, they built sewage pipes and treatment systems at the upper reaches of reservoir to regulate the nutrient loading after 1999. The average CTSI in Feitsui reservoir was 43.2 during 1992 – 1999 which increased to 45.3 during 2000 – 2006. The results Implies CTSI is a sensitive indicator that could be affected by any engineering. The scale of a road engineering is larger than a sewage engineering that reflected the high CTSIs logically. They also established the protection belts and best management practices (BMPS) on water quality for the Feitsui reservoir after 2003 (Lin & Hsieh 2003, Lin & Lee 2004, Lin et al. 2006).

To prevent the intrusion of contaminants from people, they regulated the 4000 cars limited to exit from Freeway No. 5 to the Pinglin distric (at the upper reaches of Feitsui reservoir) everyday after 2006. The Tse-Xin Organic Agriculture Foundation has trained and supported farmers to adopt organic agriculture in order to prevent runoff from fertilizers and pesticides since 2007 until now. The government offered 600 parcels of non- phosphorus sanitizer to the Pinglin citizens in order to prevent phosphorus discharges from households after 2016.

The average CTSI (41.6) during 2007 – 2008 expressed the effect of regulation for a range of cars reaching the watershed. Organic farming could minimize land degradation, the amount of soil runoff, and phosphorus- based fertilizers reaching a watershed (Oglesby & Edmondson 1966). The average CTSI (39.9) during 2009 – 2015 indicated organic farming could minimize nonpoint pollution to the environment. The efforts of the Tse-Xin Organic Agriculture Foundation have prevented the Feitsui reservoir from eutrophication. The average CTSI (38.1) during 2016 – 2018 showed the nutrient phosphorus travels directly from source to water is easy to be regulated. The activity that offering non- phosphorus sanitizer to the citizens was efficient. The diminished CTSIs agreed with the effects of the 4 major measures by time serious.

5. Conclusion

Eutrophication could be prevented by measures. The best management practices (BMP) does the effect of the Carlson trophic state index (CTSI) that improve the water quality. The experiences of Feitsui reservoir can be the model for the other reservoir.

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