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Waste Assimilative Capacity and Total Emission Control of Daechong Reservoir in Korea

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대청호의 환경용량과 총량규제

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요 약

중부지방 3백만 주민의 상수원으로 이용되는 대청호는 부영양화가 심화되어 적절한 수질관리가 없으면 상수원수의 최저등급인 3급수를 만족할 수 없는 상태에 이르고 있다. 그래서 2002년 1월에 금강수계 물관리 및 주민지원 등에 관한 법률이 제정되었는 바, 오염총량제와 수변구역의 지정을 통한 수질보전 등을 주요한 내용으로 포함하고 있다. 오염총량제를 실천하기 위해서는 대청호의 환경용량을 추정하는 것이 필수 불가결하다. 환경용량의 추정은 장래 대청호 수질영향권역에서 개발사업이 이뤄질 때 환경영향평가 특히 누적영향평가를 위해 필요하다.

대청호의 환경용량을 추정하기 위해 오염부하량과 유량의 변화가 대청호의 총질소와 총인 농도에 미치는 영향을 WASP5모형으로 분석하였다. 총질소 부하량이 50%증가한다고 가정했을 때 갈수기, 평수기, 홍수기에 각각 0.14-0.29 mg/*l*, 0.12-0.16 mg/*l* and 0.03-0.05 mg/*l* 정도의 농도 변화가 예측되었다. 총질소 부하량이 지금의 반이하로 감소하더라도 총질소농도 5급수기준(1.0-1.5 mg/*l*)을 달성할 수가 없다. 대청호의 환경용량을 상수원수 3급수기준으로 산정한다면, 그것은 현재의 총질소 부하량의 반보다 훨씬 적다고 추정할 수 있으며 따라서 총질소 부하량은 지금의 반이하로 줄어들어야 할 것이다. 총인 부하량이 50%증가한다고 가정했을 때 갈수기, 평수기, 홍수기에 각각 0.005-0.011 mg/*l*, 0.004-0.006 mg/*l* and 0.001-0.002 mg/*l* 정도의 농도 변화가 예측되었다. 총인 부하량이 지금의 반이하로 감소하더라도 총인 농도 4급수기준(0.05-0.1 mg/*l*)을 간신히 달성할 수 있다. 따라서 대청호의 환경용량은 지금의 총인 부하량의 반정도로 추정할 수 있으며 총인 부하량은 지금의 반이하로 줄어들어야 할 것이다.

오염부하량을 줄이기 위한 방안을 점오염원과 비점오염원으로 나눠 제시하였고 오염총량제 실현방안을 제시하였다.

주요어 : waste assimilative capacity, total emission control, WASP5, water quality model, Daechong Reservoir

I. Introduction

Water quality management in Korea has been based upon the concentration-oriented regulations such as permissible wastewater discharge standards and discharged water quality standards rather than pollutant quantity-oriented regulations. But such concentration-oriented regulation does not assure the achievement of water quality standards in the water bodies, which have already many pollutant sources, and have been heavily polluted.

Water Supply Source Protection Areas and Special Measure Areas - the land use based regulations for the conservation of water quality which limit mainly the location and area of facilities near water supply source irrespective of pollutants quantities generated, does not attain the improvement of water quality, but result in the strong resistance from many local residents and related local governments. Especially the number of small facilities below the guideline area has lately increased and total pollutants discharged has increased much more than before.

In January 2002 is established Act Relating to Water Resources in Kum River and Community Support. The key points of the act are total emission control and river basin land use control. For the realization of total emission control, the estimation of waste assimilative capacity(WAC) of Daechong Reservoir in Kum River system is very important and directly related with cumulative impact assessment for future environmental impact assessment.

Therefore we need the more effective and efficient water quality management measures such as total emission control based upon WAC of water body. For such total emission control based upon WAC of water body, some researches have been done in Korea. Park suggested the application of total emission control to the Nakdong River with references to the water quality constituents and the selection of applicable watershed[18], Kim et al. estimated the environmental capacity in the Yellow Sea[7], Kim et al. suggested how to implement total emission control in the certain watershed[8], and Korea Environment Institute proposed the method for total emission control system in the Han River[14].

In this study, was estimated the WAC of Daechong Reservoir by predicting the impact of the change of pollutants loadings and flow rate upon the concentration of total nitrogen (T-N) and total phosphorus (T-P) with WASP5 model, and some water quality management measures including total emission control will be suggested.

II. Waste Assimilative Capacity and Total Emission Control

The U.S. EPA has been promoting and enforcing the total maximum daily load (TMDL) process, which establishes the allowable loadings for a body of water based on its WAC, and thereby provides the basis for the states to establish water quality based controls.

TMDL is composed of waste load allocations (WLAs) for point sources, load allocations (LAs) for non-point sources(NPS), natural background loads (BL), and a margin of safety (MOS). The MOS accounts for scientific uncertainty involved in establishing the TMDL. TMDL is applied in case permissible waste water discharge standards and discharged water quality standards cannot be achieved.[17)]

In order to implement total emission control similar with TMDL, WAC of water body should be estimated. WAC is defined as the amount of contaminant load (expressed as mass per unit time) that can be discharged to a specific stream or river without exceeding water quality standards or criteria. Therefore it could be defined variously. Here it is defined as the amount of contaminant load that could keep the 3rd level of Korea Water Quality Standards (KWQS), the lowest level for water supply.

In Korea, the water quality in river, stream, reservoir, and lake has not been improved until now, because point sources such as domestic and industrial wastewater are not sufficiently treated due to the shortage of sewage pipe and sewage treatment plant; and NPS - farm land, forest, road, small scale livestock farm house are very difficult to control.

The eighty percentage of nutrients are originated from NPS and most organic toxic matters or heavy metals in the river of urban region are also from NPS. Therefore, the management of NPS is very important in enforcing total emission control, though the quantities of pollutants from NPS are variable and the route of transportation is not well known. In Korea, the water pollution by NPS such as land use is under investigation since 1994, and governmental planning for water quality management has included it.

III. Water Quality Modeling of Daechong Reservoir

1. Characteristics and Segmentation

Daechong Reservoir in South Korea, of which the total storage capacity is 1,490 million cubic meters, is used as water supply source for about three million people. The water quality of Daechong Reservoir is simulated by WASP5, which was developed by the U.S. EPA and consists of two stand-alone computer programs, DYNHYD5 and WASP5 that can be run in conjunction or separately.[1),2)] For the application of WASP5 model, the main body of Daechong Reservoir is horizontally divided into three parts: SEG1 (Okchon Water Intake Tower - junction of Okchon Stream and the reservoir), SEG2 (junction of Okchon Stream and the reservoir - Hoenam Bridge, and SEG4 (Hoenam Bridge - Dam site). The inflowing boundary is the site of Okchon Water Intake Tower and stream outflowing boundary is Dam site. The embayments of the reservoir are segmented into SEG3 (the environs of Shingok-Ri), SEG5 (the environs of Daejon Water Intake Tower), SEG6 (the environs of Chongju Water Intake Tower), and SEG7 (the environs of Shindae-Ri). The depth of the reservoir is in the range from 15 m through 50 m, and therefore the reservoir is vertically divided into two layers, which can reflect the difference of temperature between surface and bottom layers. As seen above the Daechong Reservoir is divided into 14 segments according to geometric characteristics and tributaries, where much pollutants inflows (Fig. 1) The segment of bottom layer versus surface layers(SEG1-SEG7) are SEG8-SEG14.

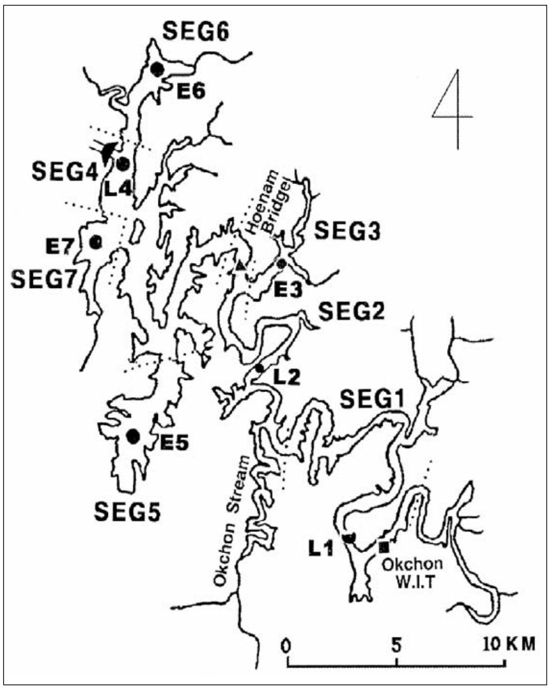

Fig. 1. Segmentation of Daechong Reservoir

L1: Odae-Ri
L2:Daejong-Ri
E3: Shingok-Ri L4: Dam
E5: Daejon Water Intake Tower
E6: Chongju Water Intake Tower
E7: Shindae-Ri

2. Pollutants Loading

The pollutant sources of Daechong Reservoir are classified as population, industry, livestock, nursery and land use. This study used the data on the pollutant sources of the reservoir per segment and generating pollutant quantity per unit pollutant.[12)]

The pollutants loads from point sources such as population and industry occupy 39% of BOD generated, 28.6% of T-N generated, and 42% of T-N generated.[12)] Because, the portion of point sources decreases after being treated at wastewater treatment facilities diminished, the portion of NPS increases.

The water quality constituents of which loading quantities can be identified are BOD, T-N and T-P. The loads of NH_3-N, NO_3-N and Organic-N are calculated from T-N loads multiplied by the portion of concentration of NH_3-N, NO_3-N, and Organic-N to the concentration of T-N; and the loads of PO_4-P and Organic-P are calculated from T-P loads multiplied by the portion of concentration of PO_4-P and Organic-P to the concentration of T-P. The loads of DO and Chl-a are calculated from the concentration of them multiplied by the flow rate at the site (Table 1)[13)].

Table 2 shows the effluent loading derived from multiplying pollutant loads by effluent ratio. The effluent ratios of BOD, T-N are estimated as 10% and 40%; and those of PO_4-P and O-P are estimated as 15% and 5% according to the related previous studies.

In the estimation of the effluent ratios, the self-purification coefficient, k to calculate the pollution loads delivered should be applied[6)], but this

Table 1. Pollutant Loading generated per each segment (kg / day)

Segment	BOD	NH_3-N	NO_3-N	O-N	PO_4-P	O-P
SEG 1 (Janggye Bridge)	40,972	526.5	4,749.6	1,886.4	311.7	727.3
SEG 2 (Daejong-Ri)	4,489	47.9	431.8	171.5	32.1	74.9
SEG 4 (Dam)	4,313	55.7	502.2	199.5	31.8	74.2
Sub-total	49,774	630.1	5,683.6	2,257.4	375.6	876.4
Total	49,774		8,571.1		1,252.0	

Table 2. Effluent Loading per each segment (kg / day)

Segment	BOD	NH_3-N	NO_3-N	O-N	PO_4-P	O-P
SEG 1 (Janggye Bridge)	4,097.1	210.6	1,899.8	754.4	46.8	36.4
SEG 2 (Daejong-Ri)	448.9	19.2	172.8	68.6	4.8	3.8
SEG 4 (Dam)	431.4	22.4	200.8	80.0	4.8	3.7
SEG 6 * (Chongju Water Intake Tower)	103.8	29.1	275.2	25.1	17.0	1.3
Sub-total	5,081.2	281.3	2,548.6	928.1	73.4	45.2
Total	5,081.2	3,758.0			118.6	

* Ha, Sung-Ryong, 1996, *GIS-Based Model for Agricultural Non-Point Source Pollution Wash off Analysis,* Korea Science and Engineering Foundation : 27.

study used the effluent ratio used in the previous researches.[11)]

3. Calibration and Verification

The data collected during Sep. 1995 was used for calibration, because of frequent algae bloom of Daechong Reservoir in September. For verification was used the data collected during Sep. 1997(Table 3).

The RI(Reliability Index) was used for the statistical comparison between observed and predicted values during calibration and verification. If the observed values and the predicted ones become similar, the value of RI approaches to one. The predicted values of NH_3-N, NO_3-N, PO_4-P reflect the observed ones similarly, but the predicted ones of CBOD and DO are a little more than the observed ones in case of verification.

$$RI = \frac{1+\sqrt{\frac{1}{N}\sum_t\sum_n\left(\frac{1-\frac{O_{tn}}{P_{tn}}}{1+\frac{O_{tn}}{P_{tn}}}\right)^2}}{1-\sqrt{\frac{1}{N}\sum_t\sum_n\left(\frac{1-\frac{O_{tn}}{P_{tn}}}{1+\frac{O_{tn}}{P_{tn}}}\right)^2}}$$

Table 3. Calibration and Verification of Model (unit : mg/l)

Water Quality Consti-tuents	Segment No.	SEG 1 (Janggye Bridge)		SEG 2 (Daejong-Ri)		SEG 4 (Dam)		SEG 5 (Daejon Water Intake Tower)		SEG 6 (Chongju Water Intake Tower)	
		Cali-bration	Verifi-cation	Cali-bration	Verifi-cation	Cali-bration	Verifi-cation	Cali-bration	Verifi-cation	Cali-bration	Verifi-cation
NH_3-N	Observed	0.278	0.054	0.088	0.037	0.062	0.057	0.031	0.068	0.108	0.062
	Predicted	0.089	0.045	0.041	0.033	0.055	0.049	0.058	0.054	0.057	0.051
NO_3-N	Observed	1.410	1.949	1.230	1.913	1.060	1.736	0.800	1.012	1.020	1.813
	Predicted	1.610	2.000	1.400	1.740	1.040	1.270	0.980	1.170	1.030	1.220
PO_4-P	Observed	0.016	0.039	0.025	0.033	0.028	0.023	0.013	0.011	0.026	0.050
	Predicted	0.020	0.041	0.019	0.036	0.018	0.026	0.018	0.024	0.019	0.025
CBOD	Observed	1.6	1.5	1.5	1.7	1.9	1.3	2.3	1.3	1.6	1.5
	Predicted	1.7	1.5	1.8	1.9	2.1	2.6	2.2	2.7	2.2	2.6
DOO	Observed	8.2	4.7	8.2	5.3	8.2	4.8	8.3	6.9	8.1	5.6
	Predicted	9.0	8.8	8.8	8.8	8.4	8.4	8.1	8.1	8.1	8.1

Table 4. Reliability Index

\	CBOD	DO	NH_3-N	NO_3-N	PO_4-P
Calibration	1.349	2.051	2.838	1.589	1.714
Verification	1.653	1.604	1.099	1.268	1.584

t = number of sampling time
n = number of sampling site
$O\ tn$= observed value at n-th site in t- th time
$P\ tn$= predicted value at n-th site in t- th time

IV. Estimation of Waste Assimilative Capacity of Daechong Reservoir

1. Effect of Pollutants Loading and Flow rate upon Water Quality

The fluctuation of pollutant loading is due to the changes of pollutant sources, flow rate, effluent ratio, and due to the operation of wastewater treatment plant. In order to predict the effect of the change of flow rate and pollutant loads on water quality, the water quality under the flow rate of 50 m^3/sec, 120 m^3/sec, and 500 m^3/sec were estimated when pollutants loads decreased by 50%, and increased by 50% and 100%.

The simulation predicted that T-N concentration increases by 0.14-0.29 mg/l in the dry sea son, and by 0.12-0.16 mg/l in the normal season, and by 0.03-0.05 mg/l in the flooding season, when the present loads increases by 50%. T-P concentration increases by 0.005-0.011 mg/l, 0.004-0.006 mg/l, and 0.001-0.002 mg/l in the dry, normal and flooding season, when the present loads increases by 50%. And the additional increase by 50% of the present CBOD loads results in the increase of concentration by 0.24-0.37 mg/l, 0.08-0.18 mg/l, and 0.03-0.06 mg/l in the dry, normal, and flooding season (Table 5).

2. Estimation of Waste Assimilative Capacity

Because the water quality problem of Daechong Reservoir could be summarized as eutrophication, the water quality management of the reservoir should be focused upon T-N, T-P, and COD, and it is essential to estimate their WAC of the reservoir. In this study, WAC is

Table 5. Concentration Change due to Change of Loading

Water Quality Constituents	Concentration Change due to Change of Loading by 50 % (mg/l)		
	Dry Season (Flow rate = 50 m^3/sec)	Normal(Average) Season (Flow rate = 120 m^3/sec)	Flooding Season (Flow rate = 500 m^3/sec)
T-N	0.14 - 0.29	0.12 - 0.16	0.03 - 0.05
T-P	0.005 - 0.011	0.004 - 0.006	0.001 - 0.002
CBOD	0.24 - 0.37	0.08 - 0.18	0.03 - 0.06

defined as the amount of contaminant loading that can be discharged to a water body without exceeding the 3rd grade level of Korean Water Quality Standards (KWQS), the lowest level for water supply.

Because the reduction of present T-N load by 50% cannot achieve even the 5th level of KWQS, the WAC of the reservoir is estimated as much smaller than the half of the present T-N load. Given the reduction of present T-P loading by 50%, not the 3rd level of KWQS but the 4th level of KWQS can be kept. So the WAC of the reservoir is also estimated as smaller than the half of the present T-P load.

Though the index of KWQS on organic matters in lake and reservoir is COD, WASP5 cannot simulate COD. So CBOD similar with COD, is used as indicator of organics. The reduction of present CBOD load by 50% in the dry season, could make the 2nd level of KWQS achieved, and even the increase of present CBOD load by 100% in the normal and flooding seasons, can still keep the 2nd level of KWQS achieved. Therefore, the WAC of the reservoir could be also estimated as twice as the present CBOD loading.

V. Water Quality Management

1. Management of Pollutant Sources

1) Point Sources

The major water quality problem of the reservoir is eutrophication, so T-N and T-P loads should be reduced to, at least, the half of the present loading. Pollutants sources of Daechong Reservoir can be classified as point sources such as population, industry and large-scale livestock farming; and NPS such as small-scale livestock farming and land use

Because more than 80% of T-N, T-P, and CBOD loads are inflowing to SEG1 and SEG8 (Okchon Water Intake Tower - junction of Okchon Stream and the reservoir), the reduction of loading here (SEG1) is very important, and so wastewater treatment facilities should be established (Table 6) [12),14)]. ESSD (environmentally sound and sustainable development) is required to consider the kinds, scale and location of development projects and tertiary treatment treating T-N and T-P should be additionally installed and operated in the present wastewater treatment process.

Table 6. Wastewater Quantity and Treatment Capacity in Daechong Reservoir (m^3/day)

Segment	Total Waste-water (m^3/day) A1+A2+A3	Population			Industry			Livestock		
		Waste-water (m^3/day) A1	Treatment Capacity B1	$\frac{B1}{A1}$ (%)	Waste-water (m^3/day) A2	Treatment Capacity B2	$\frac{B2}{A2}$ (%)	Waste-water (m^3/day) A3	Treatment Capacity B3	$\frac{B3}{A3}$ (%)
SEG 1	86,282	77,688	29,830	38.4	4,679	10,020	214.1	3,915	6,059	154.8
SEG 2	16,811	14,122	18,210	128.9	2,399	5,150	214.7	290	620	213.8
SEG 4	5,914	5,571	990	17.8	13	0	0.0	330	760	230.3
Total	109,007	97,381	49,030	50.3	7,091	15,170	213.9	4,535	7,439	164.0

2) Non-point Sources

BOD, T-N, and T-P loads from livestock farmhouses have the 25.9%, 23.5%, and 33.9% of total loading. For example in case of Chungbuk province, Korea, the ratio of cattle and cows raised by not-regulated livestock farmhouses is 91%, and the ratio of pigs by them is 29.4%. And even the 66.0% of regulated livestock farmhouses raising cattle and cows and the 33.5% of regulated livestock farmhouses raising pigs do not have livestock waste treatment facilities.[4] Such untreated livestock waste sources scattered can result in NPS loadings. So are required the livestock wastes treatment facilities and purifying facilities together with the management of shed, pasture, livestock waste storage site and composting site.

Land use is the NPS, which occupies 26% of total BOD loads, 41.0% of T-N loads, and 13.3%

Table 7. Water Quality Policy Measures

Category		Policy Measures	Related Laws
Regulatory Measures	Concentration	• Environmental Standards • Regional Environmental Standards	-Basic Environmental Policy Act
		• Effluents Permission Standards(EPS) -Strict EPS : Polluter in Special Management Region -Special EPS: New Polluter in Special Management Region	-Water Quality Preservation Act
		• Effluent Water Standards -domestic wastewater : sewage, night soil -industrial wastewater -livestock wastewater	-Act Relating to the Treatment of Sewage, Night Soil, and Livestock Wastewater
	Quantity	• Total Emission Control	-Basic Environmental Policy Act -Act Relating to Water Resources in Han River and Community Support
	Land use	• Water Quality Preservation Special Management Region	-Basic Environmental Policy Act 22
		• Water Supply Source Preservation Area	-Water Supply Act 5
		• Effluent Facilities Permission Area	-Water Quality Preservation Act10
		• Waterfront Area	-Act Relating to Water Resources in Han River and Community Support
		• Natural Environment Preservation Region	-Act on the Utilization and Management of the National Territory
		• Natural Environment Preservation Area • Total Quantity Regulation of Factory	-Seoul Metropolitan Area Readjustment Act
		• Green Belt	-Urban Planning Act
		• Conservative Forest Land, Safety Forestry	-Forestry Act
Economic Measures		• Effluent Charges - Basic Charges : BOD or COD, SS - Extra Charges : 17 pollutants including BOD or COD, SS, Cd	-Water Quality Preservation Act
		• Environmental Improvement Charges : Charges levied on polluter according to polluter pay principles	-Act Relating to Environmental Improvement Charges
		• Water Quality Improvement Charges : Charges levied on developer, dealer and importer of spring water	-Drinking Water Management Act

of T-P loads. Therefore the kinds, quantities and timing of fertilizer, insecticide and herbicide should be consistent with the characteristics of the crops and soils. The grassland or land covered with plant is required to prevent erosion, which brings about SS and release of phosphorus and so on.

The loads from NPS such as land use should be identified through multiplying the scale of pollutants by generating pollutants quantities per unit pollutant, and through observing the pollutants loadings.

In order to control NPS in Korea, there are various kinds of land use based regulations such as Water Supply Source Preservation Area, Water Quality Preservation Special Management Region, Waterfront Area, Natural Environment Preservation Area, Natural Environment Preservation Region, Effluent Facilities Permission Area and Green Belt etc.(Table 7) [15),16)].

Especially the waterfront area of Act Relating to Water Resources in Kum River and Community Support is defined the areas: (1) inner areas one kilometer away from dam reservoir for water supply and water quality special management region, (2) inner areas 500 meters away from main Kum River excluding the former areas, and (3) inner areas 300 meters away from stream inflowing to main Kum River.

For the management of NPS, it is necessary to investigate the distribution, the area, effluent process and other characteristics of NPS in the reservoir watershed with satellite imagery and the spatial analysis to route the wash off process of the loads along to a stream network by GIS under consideration of self-purification(Fig. 2).

2. Implementation of Total Emission Control

1) Total Emission Control and Cumulative Impact Assessment

In Korea, there are two kinds of policy measures for water quality management: the regulatory measures and the economic ones. The regulatory measures consist of concentration based, quantity based and land use based ones(Fig. 2). Total emission control could be included in the quantity based policy measures(Table 7). In case of Kum River including Daechong Reservoir, it is supposed to be implemented based on Act Relating to Water Resources in Kum River and Community Support. Likewise there are Act Relating to Water Resources in Nakdong River and Community Support for Nakdong River and Act Relating to Water Resources in Youngsan River/Sumjin River and Community Support for Youngsan River/Sumjin River.

Cumulative impact is the impact on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (governmental or non governmental) or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time. [3)]

Therefore the implementation of Total Emission Control makes cumulative impact considered in environmental impact assessment of development project. The estimation of WAC is essential for the implementation of total emission control.

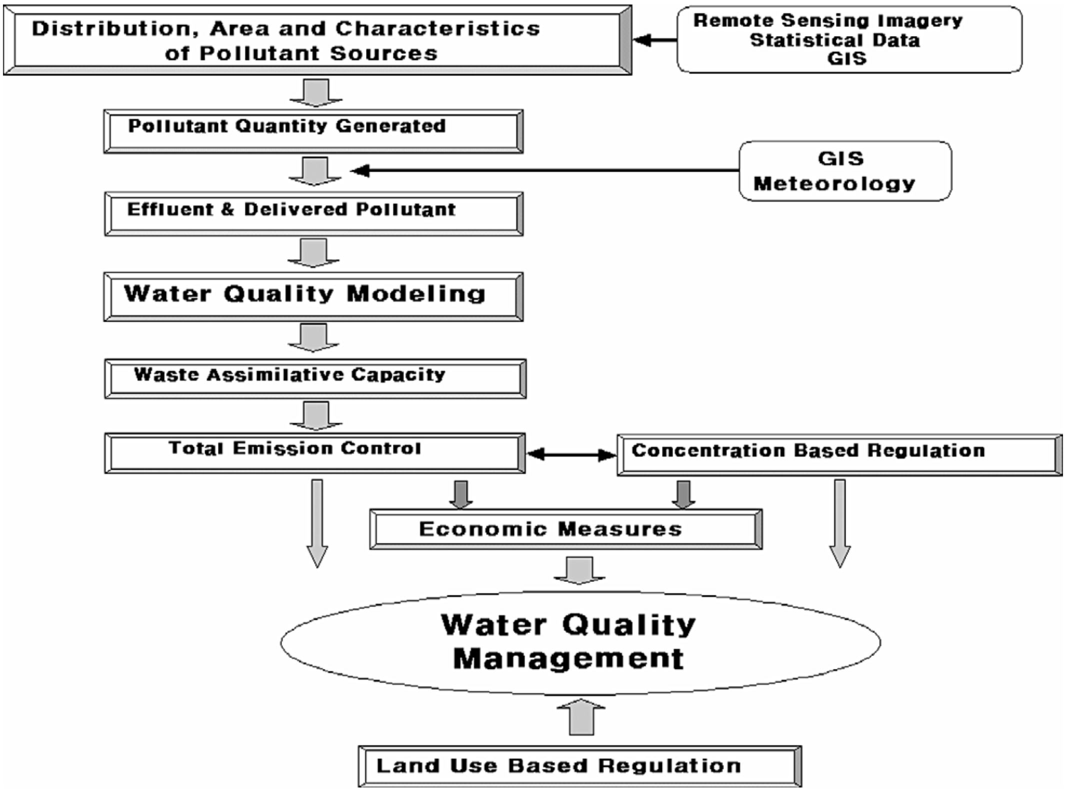

Fig. 2. Water Quality Management

2) Water Quality Constituents

Total emission control had better be applied to T-N, T-P, and COD. It is due to that eutrophication or algae bloom, the most important water quality problem, is brought about by the inflow of T-N and T-P, and at the result dead algae finally become decomposable organics, which can be measured as COD.

3) Pollutants Sources

The total emission control should be applied, above all, to the point sources: wastewater treatment facilities for domestic wastewater, industrial wastewater, and livestock wastewater from large-scale livestock farmhouses. And the quantities of pollutants from point sources should be allocated according to their present characteristics and conditions of pollutant loadings. Because the quantity of pollutant from industrial wastewater occupies only the portion of 1.4% of the total[14)], the domestic wastewater and livestock wastewater from large-scale livestock farmhouses become more important at present.

Most domestic wastewater is treated by activated sludge treatment, which removes, in most case, 90% of BOD and SS loads, and 30% of T-N load, and 20% of T-P load. So the effluents from domestic wastewater treatment facilities including industrial wastewater treatment facilities could also be the objective of total emission control.

4) Cost & Implementation Measures

To implement the total emission control, are necessary the various equipments, facilities and manpower for monitoring the quantity and concentration of pollutants.

There are many measures for implementation of total emission control such as direct regulation allocating permissible pollutant loading, transferable pollution right, and effluent charges etc. The transferable pollution right system may be suggested, where the related authorities have the right to sell the pollution right based on WAC.

VI. Conclusion

The estimation of WAC of the reservoir by WASP5 shows that present T-N load is much more than twice of the WAC, and present T-P load is a little more than twice of the WAC, and BOD load is about the half of the WAC. Therefore, T-N and T-P loads should be reduced at least to the half of the present loads through the construction and operation of wastewater treatment facilities. In order to reduce the loads from NPS, wastewater from small-scale livestock farmhouses should be treated; and the kinds, quantities and timing of fertilizer, insecticide and herbicide should be consistent with the characteristics of the crops and soil conditions.

The total emission control, which has the objectives to reduce the half of present T-N and T-P loads, should be implemented, above all, to the point sources such as wastewater treatment facilities for domestic wastewater, industrial wastewater, and livestock wastewater from large-scale livestock farmhouses.

But it is very difficult to estimate the WAC of water body and to efficiently and effectively implement the total emission control, because the seasonal variation of rainfall causes the fluctuation of the flow rate in Korea. It could be possible to apply the different WAC based upon the fluctuating flow rate in order to prevent the worst degradation of water quality.

This study could be expanded to the application of total emission control, which establishes the allowable loadings for a body of water based on its WAC, and it could be useful for the decision of alternatives with various characteristics, scale, and location in the process of the environmental impact assessment of development projects which applies cumulative impact assessment.

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