Irrigation Water Pollution and Water Quality Conservation in Korea

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1. Introduction

Irrigation water is one of the most important elements that crops need. It is especially essential in Korea because of rice farming, which is the first priority in agriculture. It has been the foundation of Korea throughout its long history.

As of 2000, the total amount of water resources in Korea was 127.6 billion m^3. The available volume of water resources was 33.1 billion m^3 per year, out of which 15.8 billion m^3 (48%) was used for agriculture according to the figures reported by the Ministry of Construction & Transportation.

The demand for good quality water has surprisingly increased with high economic growth, rapid industrialization, population growth and urbanization for the past three decades in Korea. The government of Korea has made great efforts to develop water resources for producing food and securing water, but pollution of irrigation water has been aggravated by the industrial development and population growth along with Korea's preponderate rainfall and a small geographic size.

We need to pay closer attention to the fact that the pollution of irrigation water causes lower productivity and poorer quality of crops. It can aggravate land quality by polluting farmlands, thus threatening the safety of the crops. The government of Korea is now making various efforts to control the quality of the irrigation water by operating water quality monitoring networks, establishing the polluted water treatment plant, managing the non-point sources as well as supervising the pollutant sources.

This report will explain the general status of the irrigation water in Korea including its use, quality standard and quality management system, and quality status. Another points would be to suggest the alternatives to control the irrigation water. Finally as a case study, the Masan reservoir is introduced. Projects for the improvement of irrigation water quality are being put into practice, using the natural purification treatment technique that is considered to be highly applicable.

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2. Irrigation Water Use and Water Quality Management Status

2.1 Irrigation Water Use

The total amount of annual water resources in Korea is 127.6 billion m^3, out of which 33.1 billion m^3 (26%) is usable, consisting of 16.1 billion m^3 from the stream, 13.3 billion m^3 from the reservoir storage and 3.7 billion m^3 from the groundwater. The remainder evaporates or flows down to the sea. The 15.8 billion m^3 of agricultural water accounts for about 48 %, almost half of the usable water resources. The rest of it is used for domestic use, industry and in-stream. The agricultural water is defined as all of the water used for rearing livestock, cleaning stables as well as cultivating crops. Irrigation water for paddy farming takes about 12.9 billion m^3 annually, accounting for about 82% of the total agricultural water (Master plans of long term usage for agriculture and rural water, 1999, MAF).

2.2 Water Quality Management Status

1) Quality Standard for Irrigation Water: The standard for irrigation water quality in Korea is based on the Environmental Policy, Article 10, Act 2. The basic rule of Environmental Policy was constituted in 1990 and shows that the irrigation water standard was set up according to the various kinds of public waters (rivers, lakes and groundwater). Rivers and lakes fall into grade IV, and groundwater is classified depending upon the purpose of use. However, water quality standards are the provisions of the policy goal for the water quality management of public waters, but not for the intended use of water resources. These standards were not determined by considering the influ-

Table 1. Water resources in Korea (Ministry of Construction and Transportation, 2001, Water Vision 2020)

Total resources ($10^8 m^3$)	Usable water resources ($10^8 m^3$)				
	Total	Domestic	Industrial	Agricultural	In-stream
1,276	331	73	29	158	71
-	(100%)	(22%)	(9%)	(48%)	(21%)

Table 2. Irrigation water use in Korea (Ministry of Construction and Transportation in Korea, 2001, Water Vision 2020)

(unit : $10^8 m^3/yr$)

Classification	1997		2001	
	Water used	Rate (%)	Water used	Rate (%)
Total	158.1	100.0	158.8	100.0
Paddy	130.1	82.3	129.7	81.7
Upland	23.9	15.1	24.3	15.2
Livestock	4.1	2.6	4.8	3.1

Table 3. Quality standard for irrigation water classified (Ministry of Environment, 2002)

Classification	Public water	Grade	Standard						
			pH	COD (mg/L)	BOD (mg/L)	SS (mg/L)	DO (mg/L)	T-P (mg/L)	T-N (mg/L)
Living environment	Lake	Ⅳ	6.0-8.5	≤8	-	≤15	≥2	≤0.1	≤1.0
	River	Ⅳ	6.0-8.5	-	≤8	≤100	≥2	-	-
Human Health Protect	Entire water	Cd : ≤0.01mg/L As : ≤0.05mg/L, CN : N.D Hg : N.D Phosphorus : N.D, Pb : ≤0.1mg/L, Cr+6 : ≤0.05mg/L, PCB : N.D ABS : ≤0.5mg/L							

* When the ratio of T-P to T-N is less then 7, T-P is not considered as a quality standard by the law, when the ratio is bigger than 16, T-N is not considered.

Table 4. Quality standard for groundwater: Rule 6, Ground water quality control

		Water for living	Irrigation water	Industrial water
Normal contamination (5 indicators)	pH	5.8~8.5	6.0~8.5	5.0~9.0
	COD	≤6	≤8	≤10
	Coliform Col.	≤5,000 (MPN/100mℓ)	-	-
	NO_3-N	≤20	≤20	≤40
	Cl^-	≤250	≤250	≤500
Specific harmful contamination (10 indicators)	Cd	≤0.01	≤0.01	≤0.02
	As	≤0.05	≤0.05	≤0.1
	CN	N.D	N.D	≤0.2
	Hg	N.D	N.D	N.D
	Phosphorus	N.D	N.D	v0.2
	Phenol	≤0.005	≤0.005	≤0.01
	Pd	≤0.1	≤0.1	≤0.2
	Cr^{+6}	≤0.05	≤0.05	≤0.1
	Trichloloethylene	≤0.03	≤0.03	≤0.06
	Tetrachloloethylene	≤0.01	≤0.01	≤0.02

ence of water quality on the growth, yield and quality of agricultural crop.

2) Water Quality Management System:

Irrigation water quality management is currently under the control of Commission on Protection of the Quality and Supply of Fresh Water Resources (CPQS-FWR), which is involved in each respective department: Ministry of Agriculture and Forestry, Ministry of Construction and Transportation(MCT) and Ministry of Environment(MOE). The irrigation water is subjected to the Ministry of Agriculture and Forestry and also to the metropolitan and local autonomy government in practice for the planning of water quality improvement and water resources development.

3) Irrigation Water Quality:

a) Water Quality Monitoring

The Ministry of Agriculture and Forestry (MAF) and the Korea Agricultural and Rural Infrastructure Corporation

Table 5. Water quality management system (CPQSFWR , 2001, Water control statistics)

Function	MCT	MOE	MAF	MOGAHA (Local autonomy)	MCIE resources
Water resource control	• river control under jurisdiction • flood control • reservoir control • metropolitan water works • multi-purpose dam • estuary dam and banks	• measure water quality • regulate water quality • water purification • control drinking water • city sewage terminal • factory complex disposal sewage treatment plant	• irrigation water • river mouth developed for agriculture • fishery	• local, subsidiary river • flood warning • control and regulation of water resources • control water works and sewage facility (smaller size)	• Dams for hydropower • hot springs

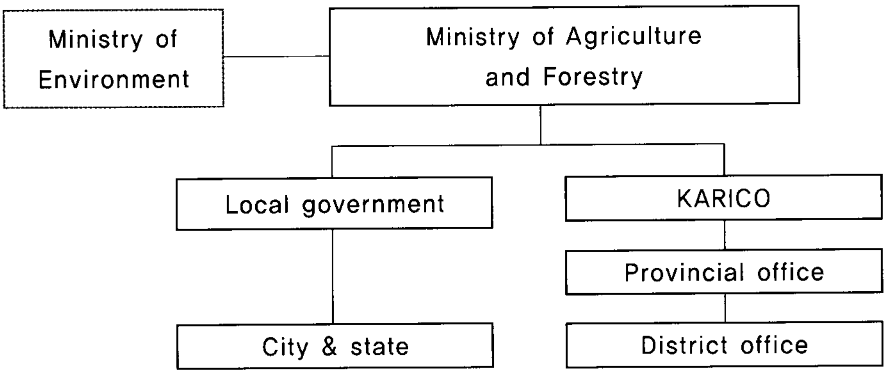

Fig. 1. Management system of irrigation water in Korea

(KARICO) are bringing research on water quality to all irrigation water resources across the nation, to obtain the basic data for water management by monitoring the irrigation water. The research is performed in two ways. One is 100% full observation for irrigational reservoirs in Korea, and the other is an inspection by monitoring networks for water quality. Full observation is taking place every 2 years for all the reservoirs in the nation. It is accurately analyzed the water quality of the heavily polluted facilities (reservoirs) in need of quality control. The monitoring networks for irrigation water quality are designated as the facilities in need of a check up for water pollution, the facilities with over 500 thousand tons of capacity likely to be polluted, and the facilities recommended to be in need of control by the facility manager. These regularly undergo a water quality test twice a year (irrigation period and non irrigation period) and a pollution source test once a year to improve their water quality.

b) Irrigation Water Quality Status

After a full observation of 17,913 reservoirs across the nation in 2000, 500 polluted facilities were selected for accurate analysis. As shown in Table 6, 297 facilities(1.6%) were found to exceed the required standard(COD 8mg/L) for the irrigation water quality. According to the Vollenweide's eutrophication analysis (Vollenweider, 1968), on the basis of total phosphorus and total nitrogen, the results show that there were 237(1.3%) meso-eutrophic reservoirs, and 144 (0.8%) eutrophic reservoirs. As shown in Table 7, the rate of the facilities exceeding the required standard for irrigation water (grade IV) is 0.3% in 1996, 0.2% in 1998 and 0.4 % in 2001. The 492 monitoring networks are made up only 2.4% of the entire reservoirs in the nation, but their effective storage accounts for 68.7% of the total effective storage of all reservoirs in Korea (MAF and KARICO, 2001). These results can represent the water quality status of the irrigation water management in Korea.

c) Pollution Sources of Irrigation Water

Table 8 reveals the distribution of pollution sources to irrigation water. Under full observation and monitoring networks same loading units were applied. In 2000, the analysis for pollution sources of 17,934 reservoirs across the nation shows that non-point source was the main source (84.4%). Data analysis from the water quality networks obtained in 2001 shows that 43.7% was from domestic wastewater, 29.1% from non-point source, 24.8% from livestock wastewater, 2% from fish nurseries and 0.4% from industry wastewater. These results show that main pollution sources of irrigation

Table 6. Number and ratio of the reservoirs exceeding each grade (500 polluted reservoirs were investigated)

Grade	I	II	III	IV	V	Higher than V
Number of reservoirs	-	25	94	84	99	198
Percent of total reservoirs (%)	-	0.1	0.5	0.4	0.5	1.1

Table 7. Number and ratio of the reservoirs exceeding the required standard for grade IV

Grade	'96	'97	'98	'99	'00	'01
Total number of irrigation reservoirs (A)	18,095	18,034	18,000	17,956	17,913	17,934
Monitored number of reservoirs	150	161	186	336	436	492
No. of the reservoirs exceeding required standard (B)	59	61	44	75	91	85
Ratio of the exceeding standard (B/A) (%)	0.3	0.3	0.2	0.4	0.5	0.4

Table 8. Distribution of pollution sources to irrigation water

Classification	Full observation		Monitoring networks	
	No. of facilities	%	No. of facilities	%
Total	17,934	100	492	100
Domestic	1,888	10.5	215	43.7
Livestock	615	3.4	122	24.8
Industrial	185	1.0	2	0.4
Fish nurseries	114	0.7	10	2.0
Non point source	15,132	84.4	143	29.1

water being heavily polluted are left unattended domestic and livestock wastewater.

3. Water Quality Conservation and Case Study

3.1 Water Quality Conservation

Many agricultural reservoirs in Korea are small sized lakes that have effective storage of less than 500 thousand m^3. The attentive management of these irrigation water facilities is very difficult because many of them are located at the valley of upper basin, and scattered throughout the nation. The main pollutant sources are non-point sources such as land use, chemicals, agricultural drainage and so on.

1) Establishment of Environmental Facilities:

It is essential to increase of environmental treatment facilities depending on the characteristics of wastewater and treatment out of rural area, for example, small-scale sewage treatment plant or a septic tank for animal wastes. Government has invested $813million to treat livestock disposal out of each farmhouse from 1991 to 1998 and funded $272million to set up public livestock wastewater treatment plants from 1993 to 2001. As of 2001, the ratio of sewerage supply is 73.5%, showing high level and government adopted a proper financial support program to rise the ratios of sewerage supply to 80% until 2005(Ministry of Environment, 2002).

2) Expansion of Monitoring Networks:

Monitoring system for agricultural water has been operated all over the country reaching up to 500 sites. The sites have been monitored two times in a year, however, the frequency of the investigation needs to extend in order to establish database for accurate water management. The government of Korea is preparing a financial aid to monitoring the water quality four times a year.

3) Implementation of Water Quality Improvement Projects:

As a result of monitoring and analysis of the water quality, an improvement project is to be carried out for the irrigation facilities appeared to be over a certain criteria. According to rising social interest for agricultural water quality, government set up the project of agricultural water quality improvement for about dozens of main reservoirs. This project needs $ 125 millions from 1999 to 2021 (MAF, 2002). Evaluating priority in this project, government has conducted test and research for various fields from 1997. For the first step pilot test was launched in 1997 to find out and verify proper methods of water quality purification applying to contaminated rural areas and this test is going on now. As a next step, government launched actual scale project of water quality improvement from 2001 and one of them will be completed this year.

4) Environmental Farming:

The main cause of polluted reservoirs is non-point source such as drainage water from paddy field and application of chemical fertilizer. The focus of the environmental farming is on the shift of traditional practice to environmentally friendly practice by using a natural check and compost. Considering deteriorating agricultural environment, government has supported livestock disposal treatment and recycling, production and sale of environmental sound agricultural products and development of environmentally friendly technology from early 1990s and legislated the Act of environmental agriculture rearing in 1997. Government goes ahead with policy of environmental agriculture rearing including four items. First, reducing contamination sources such as agricultural chemicals, chemical fertilizer and livestock disposal from farming activity. Second, going ahead with maintenance and improvement of environmental agriculture foundation such as soils and water quality. Third, rearing farmhouse to try to practice environmentally friendly farming. Last, making distribution structure with producer and consumer. As a making of harmony agriculture with environment, the last goals of government promoting environmental agriculture are securing of economical efficiency for agricultural production, conservation of sound environment for agriculture and securing of safety of agricultural products.

5) Reinforcement of Clean Water Campaigns:

In addition, the local governments and water managers support the water control system using the help of volunteers in environment control programs that promote clean water campaigns

3.2 Case study of Irrigation Water Quality Control

1) Study Site

The study site was Masan reservoir that is located in Asan-si in Chung-nam province. This reservoir has a watershed area of 1,776 hectares and a volume of 3,037 thousand m^3. The water quality analysis of this reservoir showed that dissolved oxygen (DO) was in the range of 9.4~11.6mg/L, Chemical oxygen demand (COD) was 6.6~18.3mg/L, exceeding

Table 9. Operating conditions and pollutant removal efficiency

Facilities	Area(m²)	Operating conditions	Efficiency
Natural wetland	5,500	• Depth: 0.1~0.5m • HRT: 0.1~2.7 days	BOD 59.8%, SS 38.2%, TN 26.9%, TP 16.6%
Sedimentation pool	140,000	HRT: 18.4 days	BOD 20.6%, SS 35.0%, TN 26.1%, TP 39.1%
Artificial wetland	7,640	• Depth: 0.1~0.3m • HRT: 1~6 hrs	BOD 25.7%, TN 20.4%, TP17.8%, SS 45.4%
3 artificial plant islands	480	• Reservoir depth: 3~5m • Open water	BOD 19.2%, SS 47.4%, TN 30.7%, TP21.3%

* HRT : hydraulic Retention Time

Grade IV of the lake water quality standard (8 mg/L). As for total nitrogen (T-N), it ranged between 1.401~5.920 mg/L, also exceeding the Grade IV(1.0 mg/L). Total phosphorus (T-P) ranged in 0.094~0.956 mg/L, significantly exceeding the Grade IV(0.10 mg/L). These results were needed for the countermeasure of the water quality improvement. Thus, KARICO had constructed water purification facilities using natural purification techniques such as wetlands, bio-parks, biotope, sedimentation pool and artificial plant islands.

2) Operating Conditions and Pollutant Removal Efficiency

To analyze pollution removal efficiency of each facility, a test was taken from input and output sites in every month. The operating conditions and results of the purification effectiveness each facility is as follows.

3) Water Quality Improvement in Masan Reservoir

The changes of water quality after establishment of natural purification facilities were as follows : annual mean COD (19.9mg /L → 10.5~12.1mg/L), TP(0.426mg/L → 0.176 ~0.208mg/L), SS(310.8mg /L → 14.6~21.6mg /L). This data shows that water quality of Masan reservoir has gradually improved since construction of purification facilities. However, they do not imply that improvement of water quality of Masan reservoir is caused by only those facilities. The improvement can be from various components such as physical, chemical and biological processes in the reservoir.

4. Conclusions

In agriculture, water is the most essential element for paddy rice farming. This requires good quality water in large quantities.

Table 10. Water quality change in Masan reservoir

Year	PH	EC	COD(mg/L)	T-N(mg/L)	T-P(mg/L)	SS(mg/L)
1997	7.5	205	19.9	1.858	0.426	-
1998	8.5	178	11.7	1.604	0.177	34.0
1999*	8.4	176	10.7	2.645	0.183	21.6
2000*	8.4	174	10.5	2.714	0.176	14.6
2001*	8.0	188	12.1	2.188	0.208	19.7

* data acquired after the construction of purification facilities.

At the end of 2000, agricultural water is used as much as 15.8 billion m^3 of water which accounts for 48% of the total amount of available freshwater in Korea. The irrigation water of paddy rice farming accounts for 880 thousands ha, which annually deposits 12.9 billion m^3 (82%)of the total agricultural water. For the past six years, water quality monitoring data shows that about 0.1~0.5 % of irrigation water reservoirs in Korea are exceeding the irrigation water quality standard (grade IV) and 0.8% of them were already found to be eutrophic reservoirs.

Water pollution does not yet comprehensively spread in irrigation water reservoirs in Korea, but the polluted irrigation facilities need to be implementation to improve of water quality as soon as possible. Securing good quality of irrigation water is very important in keeping people healthy, ecosystem and landscape. Additionally, it ensures good quality of agricultural products that have competitiveness in an unlimited food market. The government of Korea is also making great efforts to manage and conserve irrigation water quality by actively investing in the environmental facilities for domestic and livestock wastewater treatment. Providing out the best management practices to control of pollutant sources, and promoting public campaigns for clean water.

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