Session 2

"Water Contamination and Purification"

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Water contamination and Purification

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As a country with numerous river systems, China has a total water resource of 2800 billion cubic meters, occupying the sixth place in the world. However, the water resource per capita in China is 2300 cubic meters, being approximately 1/4 of the average level in the world. China is faced with a serious problem of water pollution, which causes negative impact on the health of the residents and the sustainable growth of economy. According to the statistics, the total industrial and urban wastewater discharge in the whole country in1999 reached 40.1 billion ton, of which the industrial wastewater discharge was 19.7 billion ton, the urban wastewater was 20.4 billion ton. The total COD (Chemical oxygen demand) discharge reached 13.89 million ton. In 1999, 87.2% of the industrial wastewater was treated and 66.7% met the pollution control standard for the effluent. The main rivers in China are polluted by organic substances and the surface source pollution is increasingly serious. The rivers such as Liaohe River, Haihe River, Huaihe River and the Yellow River have been seriously polluted, the water quality of the lakes including Taihu, Dianchi and Caohu is obviously degraded. The groundwater in majority of the cities in China is polluted to some extent, the water quality is increasingly degraded.

In recent years, the Chinese Government has been paying more and more attention to water pollution control. Great effort has been made to strengthen the water environment management by means of legal, administrative, technical, economic and educational instruments.

Strengthening water environment management. Since 1984, 12 laws and regulations such as "Environmental Protection Law", "Water Pollution Prevention and Control Law"and 21 standards such as "Environmental Quality Standard for Surface Water" and "Integrated Wastewater Discharge Standard"on water pollution control have been promulgated. A water pollution control system under the socialist market economy has been established. On the other hand, high attention is being paid to the environmental protection enforcement. The competent departments of environmental protection have been granted with more authorities for inhibitting and control the water pollution.

Establishing comprehensive decision-making mechanism. Joint effort of different competent departments is encouraged for decision-making in water pollution prevention and control. For instance, a comprehensive policy system including industry, environmental protection, technical and economic instruments, finance and tax has been established for water pollution control in the Huaihe River.

Strengthening administrative supervision and technical service. Administrative instruments including construction project examination, environmental protection standard establishment and enforcement are utilized to make up the shortcomings of the market mechanism. In the meantime, the Chinese Government has made great effort to promote technical progress, develop environmental protection industry market and provide technical service for water pollution control.

Establishing market economy mechanism and paying attention to economic instruments. The Chinese Government has made great effort to develop the environmental resource market by establishing the socialist market economy system. For instance, the pollution levy system has been adopted for water pollution control.

The water pollution control in China has the following characteristics:

Unified target. In 1996, the unified target and tasks for water pollution control were proposed in "The Decisions of the State Council on Environmental Protection".

Focusing on water pollution control of the main water systems. "The Ninth-Five-Year Plan and the Long-term Target for National Economy and Social Development" were adopted at the Fourth Session of the Eighth National People's Congress. At this session the water pollution prevention and control in the so-called "Three rivers and three lakes" (i.e. Huaihe, Haihe, Liaohe, Taihu, Caohu and Dianchi) was listed in the key tasks in China's environmental protection in the period of 1995-2000.

Paying high attention to the safety and protection of drinking water areas. The competent departments of environmental protection of all levels have made great effort to strengthen the management and protection of drinking water areas. For example, 2244 drinking water wells have been drilled using the subsidy from the central finance in the heavily polluted areas of the Huaihe River basin. Approximately 4 million residents in the river basin benefit from the diversion works.

Strengthening urban wastewater treatment. In the past, almost little attention has been paid to the urban wastewater treatment in China. At present the total discharge of domestic wastewater is more than the industrial effluent. In many of the coastal cities, 70% of the total discharge is domestic wastewater. However, less than 30% of the urban wastewater has been treated. It is required by the State Council that wastewater treatment plants must be built in all the cities with the population of more than 500,000 people during the Ninth-Five-Year period. In 1998-1999, a total sum of 12.3 billion yuan RMB of subsidy from the central finance was used for the construction of urban wastewater plants in 202 cities. Upon the completion of the projects, a capacity of 22 million ton/day of domestic wastewater will be reached.

The Chinese Government is faced with enormous difficulties in water pollution prevention and control although great effort has been made. As a developing country, China is still weak in water pollution control facilities. The first problem to overcome is the shortage of funds. It is hoped that the foreign capital is available for the water pollution control in China. Wide international cooperation is needed in drinking water area protection, cleaner production, water pollution control technologies, water quality monitoring, water environment management, rural surface pollution source control and ecosystem restoration.

As we all know, water resource is the basis for the existence and development of the human beings. In the field of water environment protection, the whole northeast region has a common target and wide benefit. The governments of the related countries and the non-governmental organizations (NGO) have much to do in the field of water pollution control. I'd like to say that the Northeast Asia Environmental Protection Meeting has made great contribution to the regional environmental protection. I hope that, the Northeast Asia Environmental Protection Meeting as a forum, will play an increasingly important role in promoting the environmental protection and development in the Northeast Asia region. The Chinese Government will cordially cooperate with other countries to promote the water pollution control and sustainable development.

Thank you for your attention!

The current status, policy and water treatment with regard to water quality renovation system in Korea

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1. Introduction

In this century the growing challenge in all over the world is the awareness of increased contamination of water resources for drinking water. Previously, major surface water problems resulted from agricultural activities, so contaminants were predominantly organics and some other inorganic contaminants. More recently, however, due to natural resources development projects and fast industrialization, contamination of usable surface and groundwater by synthetic organic chemicals has been observed or experienced accidently, raising concerns that a major water resource will require to be treated by advanced water treatment.

In Korea, since the modern water treatment facility was built in 1908 water supply evolution reached to abundant development such as 585 supplying cities, 80% supplying ratio, 385L/cap./day supplying water, and 18 million ton/day supplying water until 1992. However, so far, there had been 182 water related episodes such as heavy metal incident in 1989, THM in 1990, phenol spill in 1991, and bad ordor problem at Nakdong river down stream in 1994, ..etc. which were occurred since 1988. Also, the raw water quality supplied to water treatment plant is continuously worse by increasing concentration and variety of contaminants due to population increase, urbanization and industrialization.

Accordingly, The quality of drinking water is losing its confidence because most of the water treatment plants are applying conventional treatment process like coagulation, sedimentation, sand filteration and disinfection, in spite of increased and sophisticated contaminants to be treated.

Also, modernization of living style and improvement of living standard have shifted public health concerns from acute illnesses to the chronic health effects of trace quantities of organic, inorganic and microbiological contaminants. This shift is reflected in the increasing number of regulated contaminants from 35 to about 50 water quality parameters. Therefore, the demand for new technology to produce better quality water is anticipated although the raw water quality is deteriorating.

In the United States, and other developed nations through the world, had already developed advanced water treatment processes incorporating with activated carbon filteration, ozonation, and microbiology treatment,..etc. and applied to the field where THM by-products and micropollutants are required to be removed. In Korea, activated carbon filteration was adopted first at Bupyung water treatment plant in 1986 and facility for ozonation was built at Whamyung water treatment plant. After the spill of phenols into the Nakdong River in 1994, the government formulated and announced the Water Quality Improvement Measures for the four major rivers running throughout the south part of the Korea peninsular. During 1993-1995 government implemented installing advanced water treatment systems for 18 water treatment plants as part of the Water Quality Improvement Measures.

However, Korea lags behind other developed countries in the technology evolution which is necessary to implement the Measures, so the project for the development of advanced water treatment system was included into the G-7 Environmental Engineering Technology Development Project which was launched by government as part of Highly Advanced National(HAN) Project in 1992. Accordingly, this study is to address the current status and future trends in advanced water treatment in Korea by focusing on G-7 Environmental Engineering Technology Development Project.

2. Current Status and Related Policies on Water Quality Renovation System

2.1 Current status of water quality renovation system

In this part, current status of raw water quality, water quality renovation system, and applied treatment technologies are reviewed. 4 major rivers are Han River, Keumkang River, Nakdong River, and Youngsan River. One table and a figure are depicted to show data for 11 years of raw water quality at the specific place of each river. Figure 1. shows the water quality of rivers was at the stage of improving until 1988 but it turned into worse condition during 1994-1995.

Table 1. 4 major rivers BOD concentration status

(unit: mg/l)

watershed	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
Han River (Noryangjin)	4.	3.6	4.3	4.3	3.4	3.4	3.9	3.6	3.1	3.3	3.8
Keumkang River(Puyo)	2.5	3.0	2.9	3.2	3.5	3.1	3.0	3.2	3.1	3.7	4.3
Nakdong River (Mulgum)	3.7	3.6	3.6	3.9	3.6	3.0	4.0	3.3	3.4	4.6	5.1
Youngsan River(Naju)	5.2	5.2	4.2	7.0	6.6	6.7	5.6	5.6	4.5	7.3	7.0

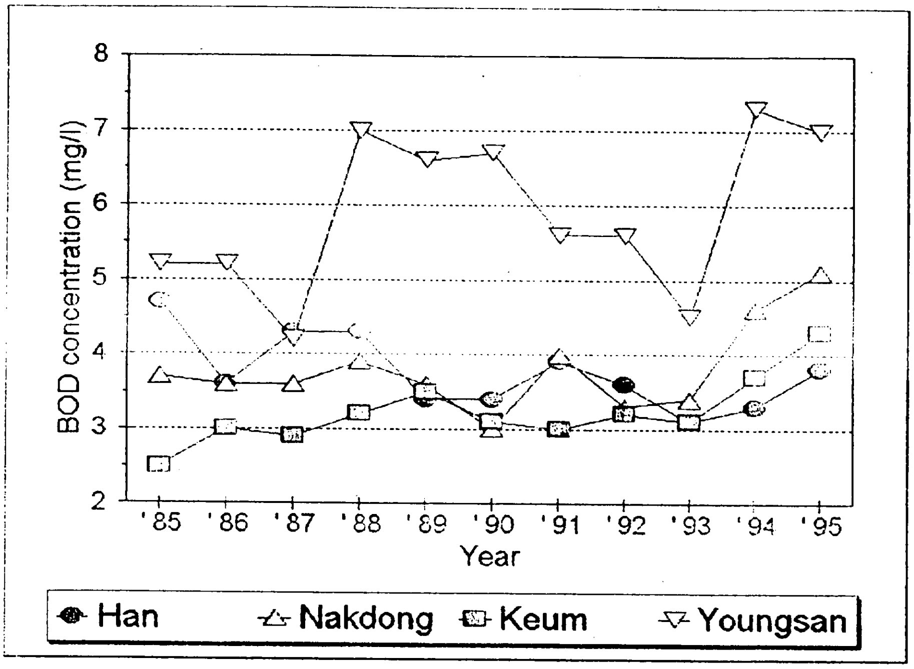

Figure 1. 4 major rivers BOD concentration trend

The government has placed priority on expanding infrastructure, so the number of water supply systems are increased from 489 in 1987 to 28,283 in 1994. The table 2 showed a 12.1% increase in the ratio of piped water service from 70% in 1987 to 82.1% in 1994 over the eight years.

Table 2. Current Status of Water Supply

classification \ year	'89	'90	'91	'92	'93	'94	'95	'96	unit
Water sevice ratio	77.7	78.4	80.1	80	81.1	82.1	82.9	83.6	%
Total population	42.4	42.9	43.3	44.6	45.1	45.5	46.0	46.4	million
Water serviced population	33.0	33.6	34.7	35.6	36.6	37.4	38.1	38.8	million
Facility capacity	15.7	16.3	16.9	18.8	20.1	21.0	21.8	22.9	$x10^6$ m^3/d
Per capita water service	339	369	376	385	394	398	406	409	L
Number of cities serviced	524	551	572	585	625	654	684	699	num. places

Figure 2 describes continuing increase in water service per capita from 102L in 1961 to 409L in 1996. It also showed three fold increasing in per capita water service over the 26 years between 1961 and 1987. During same period, per capita water service rose from 102 liters/cap.day to 311 liters/cap.day. At the end of 1996, the service rate reached 409 liters/cap.day, which was higher rate than the goal of 1995 which had been set as 400 liters/cap.day.

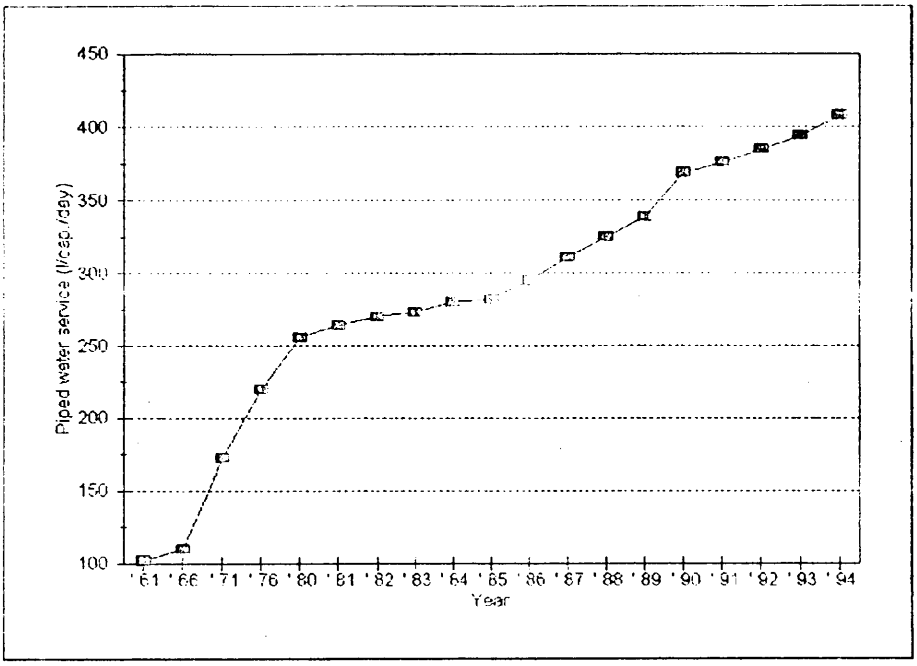

Figure 2. Trend for transmit of per capita water service per day

The ratio of each water treatment process type in the water treatment plants in Korea are diagramed in Figure 3. Rapid sand filteration process is applied to most of the plants and slow sand filteration is adopted by some of the plants.

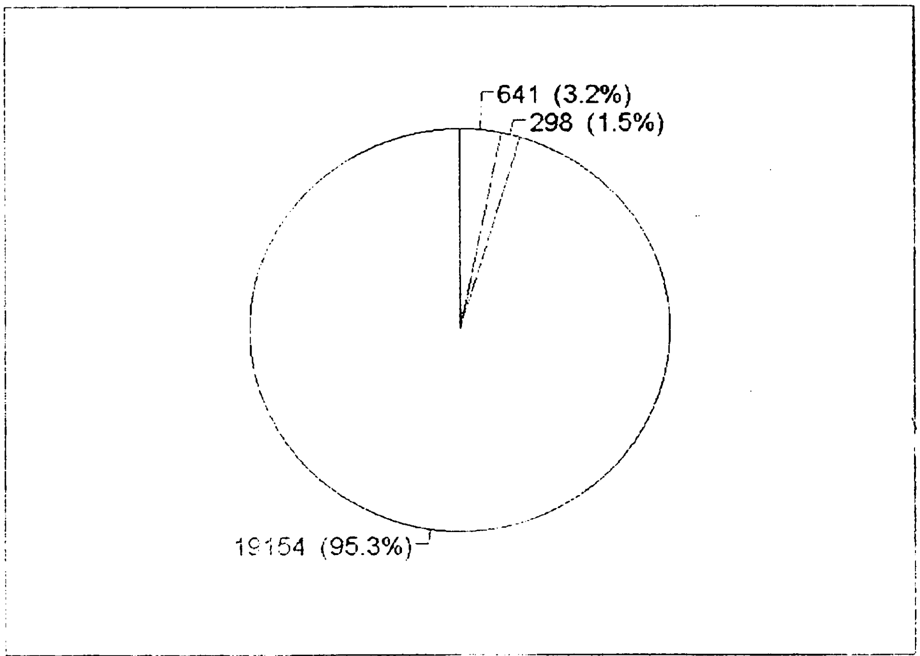

Figure 3. The ratio of filtration type in water treatment plants in Korea

For the current status of advanced water treatment facilities, the 18 water treatment plants which adopt advanced water treatment processes are listed in table 3. After the water pollution accidents occurred in the Nakdong and Youngsan River in 1994, the government planned to reinforce 18 water treatment plants in which the raw water quality was the worst with advanced water treatment facilities. As in the table 3. three water treatment plants around Han River basin, twelve plants around Nakdong River basin, two plants around Keum River basin, and one plant around Youngsan River basin are included in this project.

The government established the "Advisory Committee on Technologies of Advanced Treatment Facilities," consisting of 30 experts by Prime Minister Directive No. 297, on May 28, 1994. The committee is incharge of reviewing governmental projects and providing advices on the size and the installation of advanced treatment facilities, the optimum model process for advanced treatment system, and the design of treatment facilities.

Table 4. The current status of water treatment plants operating advanced treatment process

classification	capacity (x10^3 m^3/d)	total budget (million won)	project period	regional specification
total(18 places)	3,944.7	349,330		
Han River(3 pla.)	128.4	14,390		
Dongduchun	38.5	5,390	'94-'96	drought, eutrophication
Wonju2	85	8,500	'94-'96	serious contamination (sewage inflow)
Wonjumunmak	4.9	500	'94-'95	serious contamination (wastewater inf.)
Nakdong River(12 pla.)	3636.3	316,580		
Nakdongkang 1	310	30,400	'94-'95	midstream(industrial complex at upstream)
Nakdongkang 2	800	67,200	'94-'97	midstream(industrial complex at upstream)
Kyungsan Hayang	10	980	'92-'94	downstream intake at contaminated river
Masan Chilseo	400	41,000	'94-'97	downstream at Nakdong River
Chinhae Seokdong	70	6,200	'94-'96	"
Kimhae Samkyue	136.8	5,800	'94-'96	"
Yangsan [illegible]	37.5	5,000	'94-'96	"
Wulsan Whaeya	420	42,000	'94-'98	raw water quality worse, city expansion
Wulsan Seonam	60	5,000	'94-'96	intake at Wondong on downstream
Busan Duksan	1,055	89,500	'92-'97	downstream at Nakdong River
Busan [illegible]	277	19,300	'94-'96	water quality worse in Whaedong reservoir
Busan [illegible]	60	4,200	'94-'96	
Keum River(2 pla.)	60	7,160		
Kongju [illegible]	22	2,360	'94-'97	bad quality on downstream at Keum River
Kunsan 2	38	2,800	'94-'97	
Youngsan River(1 pla.)	[illegible]	11,200		
Mokpo [illegible]	120	11,200	[illegible]	downstream of Youngsan River

2.2 National projects for environmental technology development policies

The government promotes Highly Advance National Project(HAN Project), so called G-7 Project, to elevate Korea's science technology to the level of western 7 developed countries, and G-7 Environmental Engineering Development Project(G-7 EEDP), which is one of the project among 18 G-7 Projects, is managed by the Ministry of Environment.

The final goal of G-7 EEDP is focused on the elevation of public living quality and ability of environmental industry for international competition through preserving environment by developing competitive high environmental technology and securing basic fundamental technology. Also, it is focused on bringing up environmental industry as strategic export industry.

The G-7 Project is divided into 3 stage for 10 years of project period. At the first stage(1992-1994), it was promoted by emphasizing early secure and development of environmental basic technology. For the second stage, research is being performed to achieve development of core technology and establishment of utility base on the basis of technology developed at the first stage. During third stage(1998-2001) the Project will be derived to gain practical use, merchandising, and export industrialization. Also, the progress of the projects will be analyzed thoroughly and evaluated carefully during same period. The full Project is being modified and reinforced within every two or three years intervals for the rolling plan. The promoting goal of each stage for the Project is listed in the Table 5.

Table 5. The promoting goal of each stage of G-7 Project

classification	1st stage (1992 - 1994)	2nd stage (1995 - 1997)	3rd stage (1998 - 2001)
Basic Goal	secure basic technology	core technology development and establishment of basis for practical use	practical use, merchandizing, establishment of integrated control system for environment
Emphasized Technology Development	technology development for pollution prevention		clean technology, technology for remediation and regeneration
Industrialization	self-supporting environmental technology		industrialization for exporting environmental technology

During 3 years of first stage for G-7 Project, government invested 25.5 billion won(Ministry of Environment: 14.8, Ministry of Science and Technology: 6.9, Ministry of Trade, Industry and Energy: 3.8) and private sector invested 30.1 billion. The planning of the past and future investment for G-7 Project is described in the Table 6. The table showed total investment of 431.5 billion won by government and private sector by the year of 2001.

Table 6. The planning of the past and future investment for G-7 Project

(unit: billion won)

classification	Total	1992 - 1995	1996	1997 - 2001
Total	431.5	93.8	42.2	295.5
Government Private sector	249.5 182	42.1 51.7	23.7 18.5	183.7 111.8

G-7 Project, which is composed of 23 major group projects, is promoted to develop innovative technologies in the areas of air pollution prevention , water pollution prevention, waste treatment, clean technology, global environment preservation, marine environment preservation, ecological control, and environmental health. Those 23 major group projects include the following projects such as stack gas desulfurization & denitrification, advanced water treatment, low or non-pollution processes, and ecological restoration,..etc.

Among 23 major group projects, the advanced water treatment technologies developed by the cooperation of government and private sector are expected to contribute to relieving public diffidence in water treatment and service. Also, THM, nitrogen, phenol, and other contaminants can be removed over 90% by that technology. Once the advanced water treatment technology is developed, competitive ability for environmental technology export will be sustained strongly to attain superiority over other country because other developed countries are also on the way of developing technologies.

2.3 Advanced technology development for water renovation system

The project for advanced water treatment technology continued its development for 3 years from 1992 so far. In 1993 the current status of domestic technology was analyzed to investigate potential for new advanced water treatment technology and innovative unit processes. Processes capable of removing contaminants according to raw water quality were also suggested. In 1994 processes possible for realization of practical use and new unit processes requiring additional research were studied to examine the treatability of surface and groundwater among potential unit processes and systems selected for development in the first year. In 1995 demonstration plant selected as most suitable system out of 10 system evaluated by pilot scale test was built and operated. According to the results from demonstration plant test the research was focused on development of technology for design, construction, and maintenance of advanced water treatment system adequate for domestic water treatment plants.

The current status of technology development at each year of period during first stage of project were reported and evaluated. During 1993 conventional water treatment system(CWTS) combined with advanced water treatment system applied in other developed countries were investigated and some adequate advanced water treatment system, which are suitable to seasonally distinct condition, were suggested in Table 7 around activated carbon, AOP, and membrane filteration.

Table 7. Advanced unit processes suitable to domestic water treatment system

Type	Advanced water treatment system
combined with activated carbon process	Inflow→CWTS→AOP→GAC, BAC Inflow→CWTS→BF→O_3→GAC Inflow→CWTS→O_3→GAC, BAC Inflow→CWTS→Ion Exchange→GAC
combined with AOP process	Inflow→CWTS→AOP→Membrane Inflow→CWTS→TiO_2/AOP→GAC, BAC Inflow (Inflow→CWTS)→DAF→TiO_2/AOP→BAC
combined with Membrane process	Inflow, (Inflow→CWTS)→Membrane Inflow→CWTS→BAC→Membrane Inflow→CWTS→PAC→Membrane

In 1994 the unit processes, which are related to activated carbon and ozone process, selected from the last year research were tested to find feasibility with raw water of major rivers. Accordingly, during 1994 and 1995, activated carbon (GAC/BAC) process, ozone/AOP process, and membrane process were screened to formulate systems additive to conventional treatment plants.

Table 8. Feasible advanced unit processes suitable to domestic water treatment system

Type	Advanced water treatment system
combined with activated carbon process	Inflow→ ozone, AOP → CWTS → AOP → GAC, BAC→disinfection coagulation BF sedimentation Ion Exchange
combined with AOP process	Inflow→ ozone, AOP → CWTS → AOP → GAC, BAC→disinfection coagulation membrane sedimentation sand filteration
combined with Membrane process	Inflow→ ozone, AOP→ CWTS → GAC, BAC→Membrane→disinfection coagulation BAC sedimentation PAC sand filteration

Also, unit processes such as ozone/AOP, GAC/BAC, PAC, Membrane process, Air stripping, DAF, Ion Exchange, and biological process are possible processes to be developed for advanced water treatment. Among these processes, ozone/AOP, GAC/BAC, and Membrane process showed prominent results in removing variable contaminants and treatment efficiency. Especially trace organics, taste and odor causing substance, THMFP, and ammonia nitrogen are commonly related to raising water quality problem in Korea, so GAC/BAC and ozone/AOP unit process resulted in most optimum process with consideration about adapting to old system, simplicity, easy operation, economic benefit, and produced water safety,..etc.

Accordingly, to accomplish maximum treatment efficiency, adequate advanced water treatment systems are categorized according to raw water quality and characteristic of water supply resources in Table 9.

Table 9. Advanced water treatment system compatible to raw water quality

Classification	adequate systems suitable to water quality and characteristic
Category I	Inflow - coagulation/sedmentation - sand filteration - AC filteration
	Inflow - preozone - coagulation/sedmentation - sand filteration - AC filteration(GAC/BAC)
Category II	Inflow - coagulation/sedmentation - sand filteration - postozone - BAC
	Inflow - coagulation/sedmentation - midozone - sand filteration - AC filteration(GAC/BAC)
	Inflow - preozone - coagulation/sedmentation - sand filteration - postozone - AC filteration(GAC/BAC) - (sand filteration)
Category III	Inflow - preAOP - coagulation/sedmentation - sand filteration - AC filteration(GAC/BAC)
	Inflow - coagulation/sedmentation - sand filteration - postAOP - BAC
	Inflow - preozone - coagulation/sedmentation - sand filteration - postAOP - AC filteration(GAC/BAC)

※ category I denotes : less contaminated up and midstream region
category II denotes : medium contaminated midstream region
category III denotes : highly contaminated downstream region

3. Future Trend in Water Quality Renovation Systems

3.1 Trend in the technology development policies

In recent years many water treatment plants belonging to local governments are planning to adopt advanced water treatment processes through pilot scale test because due to frequent accidental water pollution, central government announced master investment plan supporting development of advanced water treatment system in January 1994. However, most of these pilot test tend to focus on optimizing parameters for design and operation of ozone and activated carbon process, so it is inefficient if the test is performed without combining to existing plants and without developing systems related to economic processes.

Consequently, the future prospective technology development programm for advanced water treatment system is suggested to focus on adapting tested and evaluated systems by the technology development research to existing water treatment plant and on studying technology development for removal of secondary contaminants in piped service water. The suggesting scope for the future research are listed in the Table 10.

Table 10. Scope for the future research concern

Classification	1995 - 1997	1998 - 2001
Research focus	Adaptation developed advance water treatment technology to water treatment plants	developing and exporting advanced water treatment technology
Technology development	- development of technology to elevate the efficiency of existing water treatemtn plant - development of technology to prevent secondary contamination of piped service water - development of technology to disinfect and remove byproducts - development of materials used for water treatment	- development of technology for operation and management to control byproducts - development of technology for water quality control and improvement in the water distributing mains - development of innovative advanced water treatment technology - development of optimum management techniques for automation

3.2 Investment policies

The Ministry of Environment and other seven ministries established the Comprehensive Plan for Clear Water Supply and finalized it at the Environmental Preservation Council in July 22, 1993. After the phenol spill accident at Nakdong River in early 1994, central government formulated the Water Quality Improvement Measures for the four major rivers. Under this Measures the investment plan for basic environmental facilities, and expansion of the large-scale water supply networks was implemented earlier than originally scheduled. Table 11 presents the investment status to the area of advanced water treatment under the Comprehensive Plan for Clear Water Supply.

Table 11. Investment status for advanced water treatment (unit: billion won)

Classification	1993 - 1995	1996
Advanced water treatment	156.7	108.9

The investment status for the development of advanced water treatment technology in the G-7 Project, so far, is listed in the Table 12.

Table 12. Investment status in the G-7 Project (unit: million won)

Classification	1992	1993	1994	1995	1996
Advanced water treatment	495	1,000	1,654	2,632	3,858

4. Conclusion

In the United States, Safe Drinking Water Act was amended in 1986, so EPA established Maximum Contaminants Level(MCL) and Maximum Contaminants Level Goal(MCLG) regard to 83 pollutants (180 pollutants in the long run) to regulate serviced water quality step by step.

In Korea two more pollutants such as CCl4 and 1,1-dichloroethylene were added to 43 pollutants of Drinking water Standard in 1996. Also, by the end of 2002, 147 more pollutants among materials recommended by WHO and investigated by US-EPA are to be examined and added to the number of parameters for sustaining adequate water quality standard suitable to this country. The current number of pollutants regulated by the water quality act to meet the established standards in the developed countries are listed in the Table 13.

Table 13. Comparison of Korea's water quality standard parameters with developed countries

Country	WHO	U.S.A.	U.K.	German	Japan	Australia	Korea
number of standard parameter	121	85	56	49	46	44	45

The development of advanced water treatment technology is suggested to promote with the integrated analysis of our own water quality characteristic and specification of water quality problem. New strategies to adapt the developed unit processes or systems to the existing water treatment plants are also required to accomplish efficient development goal for advanced water treatment technologies.

The secondary contamination of piped service water is also necessary to be addressed for optimum public health safety. There are demands to develop the technology for disinfection and removal of byproducts to meet these current conditions.

Conclusively, the objectives of developing advanced water treatment technologies are to attain economic benefit from technology export by technical renovation and independence and to preserve water quality for our safety. Accordingly, to achieve these goals, the technology development for advanced water treatment need to be carried on the basis of integral analysis about our current status of water treatment, development of suitable innovative unit processes, and implementation of adapting developed technology to current water treatment technology.

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Prospects of Water Environment Restoration Using Ecotechnology and Biotechnology in Japan

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1. Introduction

The water pollution problems in Japan have shown an overall improvement and grown out of what was so serious as before, but there still exist areas which further improvements must be made. For instance, Japanese government promulgated the environmental quality standards for water in 1970, these standards are consisting of two major categories: one for the protection of human health and the other for the conservation of living environment (Table 1, 2). The environmental quality standards relating to the protection of human health were amended from nine items into twenty three items in March 1993, and the compliance ratios were more than 99.5% in 1999. However, for the second category including BOD, COD, the compliance ratios for rivers, lakes and coastal waters were 81.0%, 40.9% and 73.6%, respectively, which still remains in low levels. Especially in urban rivers, lakes, inland sea and bays, the water bodies are extremely eutrophicated because of the direct discharging of gray water, which represents a substantial portion of the total household effluents, and the wastewater from the small scale factories. They are almost 70 % of the total pollutants in public water areas. On the other hand, as for the environmental quality standards relating to nitrogen and phosphorus in 60 determined lakes and 112 sea aeras were 38.3% and 70.5%. The removal of nitrogen and phosphorus in effluent from domestic and industrial wastewater treatment facilities is most important to control the eutrophication.

The extreme growth of poisonous picoplankton and the occurrence of water bloom even caused the crisis of water supply systems. The control of micro pollutants such as organochloride and agricultural pesticides is also an urgent problem. For these reasons, Japanese government including the Environment Agency, has made great efforts in the research and control projects concerning the household wastewater treatment, not only for the removal of BOD, COD, but also for nitrogen and phosphorus removal. And a series of laws and regulations have been established. The regulation concerning the prohibition of the penetration of harmful substance through soil, nitrogen and phosphorus effluent standard for coastal area, Basic Law on Environment and Law concerning the Conservation of Water Resources were enacted in September 1989, October 1992, November 1993 and February 1993. With the people's rising conscious about the deterioration of the global environment, the awareness about the need to overcome the crisis that humankind faces regarding " sustainability", and to ensure development of human society, has begun to be used at various international conferences as key concept related to global environmental issues. Thus, the policy concerning sustainability, self-support, coexistence with environment and international cooperation has been emphasized in Basic Law on Environment.

Some successful results have been reached through the cooperative studies of government, companies and research institutes. Some of the acquired new technologies have been applied to the practical use. At the meantime these technologies are adopted as advanced treatment methods and begun to spread to whole country. Among them the application of the ecotechnology and biotechnology is one of the important tasks for the treatment of wastewater and the conservation of water environment. However, the new biotechnology such as using the genetically engineered microorganisms (GEMs) is not applied yet.

The purpose of this study is to introduce the present state of the application of ecotechnology and biotechnology to the restoration of water environment field in Japan, and to prospect the new technology which is applicable to other countries(Inamori et al, 1995).

Table 1 Standards related to the conservation of the living environment in Japan (BOD, COD)

1)Rivers (BOD) (mg · l^{-1})

	Category					
	AA	A	B	C	D	E
BOD	1 or less	2 or less	3 or less	5 or less	8 or less	10 or less

Purposes of water use
AA: Water supply, class 1; conservation of natural environment, and uses listed in A-E
A: Water supply, class 2; fishery, class 1; bathing and uses listed in B-E
B: Water supply, class 3; fishery, class 2; and uses listed in C-E
C: Fishery, class 3; industrial water, class 1; and uses listed in D-E
D: Industrial water, class 2; agricultural water, and uses listed in E
E: Industrial water, class 3; conservation of the environment

2)Lakes and reservoirs (COD) (mg · l^{-1})

	Category			
	AA	A	B	C
COD	1 or less	3 or less	5 or less	8 or less

Purposes of water use
AA: Water supply, class 1; fishery, class 1; conservation of natural environment, and uses listed in A-C
A: Water supply, classes 2; and 3; fishery, class 2; bathing, and uses listed in B-C
B: Fishery, class 3; industrial water, class 1; agricultural water, and uses listed in C
C: Industrial water, class 2; conservation of the environment

3)Coastal waters (COD) (mg · l^{-1})

	Category		
	A	B	C
COD	2 or less	3 or less	8 or less

Purposes of water use
A: Fishery class 1; bathing; conservation of natural environment and the uses listed in B-C
B: Fishery class 2; industrial water and uses listed in C
C: Conservation of environment

Table 2 Standards related to the conservation of the living environment in Japan (nitrogen and phosphorus)

1) Lakes and reservoirs (mg · l^{-1})

	Category				
	I	II	III	IV	V
Total nitrogen	0.1 or less	0.2 or less	0.4 or less	0.6 or less	1 or less
Total phosphorus	0.005 or less	0.01 or less	0.03 or less	0.05 or less	0.1 or less

Purposes of water use
I : Conservation of natural environment and uses listed in II - V
II : Water supply classes-1.2 and 3 (excluding special types); fishery class 1; bathing and uses listed in III - V
III : Water supply class 3 (special types) and uses listed in IV - V
IV : Fishery class 2 and uses listed in V
V : Fishery class 3; industrial water; agricultural water; conservation of the environment

2) Coastal waters (mg · l^{-1})

	Category			
	I	II	III	IV
Total nitrogen	0.2 or less	0.3 or less	0.6 or less	1 or less
Total phosphorus	0.02 or less	0.03 or less	0.05 or less	0.09 or less

Purposes of water use
I : Conservation of natural environment and uses listed in II - IV (excluding fishery classes 1 and 2)
II : Fishery class 1; bathing and uses listed in III - IV (excluding fishery classes 2 and 3)
III : Fishery class 2 and uses listed in IV (excluding fishery class 3)
IV : Fishery class 3; industrial water; conservation of biotic environment

2. Ecotechnology for Conservation of Environment

Pollution problems became widely recognized during 1960s. Although many billions of dollars have been invested all over the world in solving these problems, it is still far from an acceptable solution to many serious problems, which threaten the survival of Homo sapiens. Some even claim that we are further from a total solution of our environmental problems today than we were 10 to 20 years ago, owing to the continuous growth of population and continuous disappearance of natural resources. As industry and society become more complicated, clean, safe water is more necessary both for everyday life and for industry. Sewage treatment facilities, plants play an important role in environmental conservation. But the high cost of constructing and operating these plants, in addition to potential for inadequative wastewater treatment and disposal, has led to the demand for and creation of innovative technologies designed to treat wastewater. In the forefront of these alternative technologies is biological treatment using ecotechnology.

Ecological engineering and ecotechnology is defined as the design of human society with its natural environment for the benefit of both (Mitsch, 1988). It is engineering in the sense that it involves the design of this natural environment using quantitative approaches and basing our approaches on basic science. It is a technology with primary tool being self-designing ecosystems. The components are all of the biological species of the world. On the other hand, biotechnology is the commercial exploitation of existing and novel biological techniques and processes. Clearly, man has exploited biological processes for centuries in such activities as brewing, wine making, bread making, food preservation and modification (e.g., cheese, vinegar, soy sauce), and waste treatment. Some of the contrasts between the approaches of ecological engineering (ecotechnology) and bioengineering (biotechnology) are shown in Table 3.

Table 3 Comparison of ecotechnology and biotechnology

Characteristics	Ecotechnology	Biotechnology
Basic unit	Ecosystem	Cell
Basic principles	Ecology	Genetics; cell biology
Control	Forcing functions, organisms	Genetic structure
Design	Self-design with some human help	Human design
Biotic diversity	Protected	Changed
Maintenance and development costs	Reasonable	Enormous
Energy basis	Solar based	Fossil fuel based

Natural Self-purification of water bodies is a well-known process. Untreated wastewater maybe directly discharged into natural water bodies such as streams, rivers, ponds, lakes, and seas. Although it is very convenient and is usually practiced in most regions, the actual result of implementation of this method is mostly negative, with respect to both environmental social efficiency and economic benefits. Most of the streams, rivers, ponds, and lakes in the vicinity of cities or towns are regarded as unlimited sewers. This kind of pathway for treating wastewater is unaccommodating and should be improved.

Current philosophy suggests that ecotechnology, utilizing biological systems, wetland, algae and higher plants, soil, stream purification process depends on the natural self-purification ability and it requires a minimum of hardware, energy, and chemicals. Furthermore, a great deal of material wealth and many other economic benefits can be obtained by regeneration and retrieval from wastewater of many abandoned resources. Through its operation, a local section of non-point pollution can be controlled.Each system has different constrains, operating conditions, and design criteria.

An overview of the ecological methods is given below.

1) Wetland systems

Wetlands are defined as land in which the water table is at (or above) the ground surface long enough each year to maintain saturated soil conditions and the growth of related vegetation. The capability for wastewater renovation in wetlands has been verified in a number of studies in a variety of geographic settings. Pollutants are removed in both natural and constructed wetlands by physical and chemical mechanisms including adsorption, precipitation, sedimentation, and most importantly, bacterial transformation. Wetlands used in this manner have included preexisting natural marshes, swamps, strands, bogs, peat lands, cypress domes, and systems especially constructed for wastewater treatment. Vegetation in the water column-stems, leaves, and detritus provides suitable sites for microbial growth. In addition, wetland plants diffuse oxygen through aerenchyma tissue to the root tips where, depending on the permeability of the root tissue, an oxidized zone can exist in an otherwise anaerobic substrate. This rhizosphere provides a unique environment that supports aerobic microorganisms that conduct desirable modifications of nutrients, metallic ions, and other compounds. As an example (Hosomi, 1994), from a 1200 m^2 field wetland experiment in Ibaraki, Japan, where gray water (BOD=77, TN=6.2, TP=0.97 mg · l^{-1}) was discharged in this wetland system, the removal of BOD, total nitrogen and total phosphorus was found to be 60-90%, 30-70% and 10-60%, respectively. It can be seen from this example that wetland system can be also used for advanced wastewater treatment.

Table 4 summaries the design features and expected performance for the three basic wetland categories (Reed, 1988). A major constraint on the use of many natural marshes is the fact that they are considered part of the receiving water by most regulatory authorities. As a result, the wastewater discharged to the wetland has to meet discharge standards prior to application to the wetland. Constructed wetland systems avoid the special requirements on influent quality; they can also ensure much more reliable control over the hydraulic regime in the system and therefore perform more reliably than natural marshes.

Table 4 Design features and expected performance for wetland systems

Concepts	Treatment goals	Typical criteria				Effluent characteristics mg · l^{-1}	
		Climate needs	HRT days	Depth m	Hydraulic Loading $m^3 \cdot ha^{-1} \cdot day^{-1}$		
Natural marshes	Polishing, AWT with secondary input	Warm	10	0.2-1	100	BOD TSS TN	5-10 5-15 5-10
Constructed wetland	Secondary, or AWT	None	7	0.1-0.3	200	BOD TSS TN	5-10 5-15 5-10
Rush or reed beds	Secondary, or AWT	Warm	0.3	—	600	BOD TSS TN	5-40 5-20 5-20

AWT: Advanced Wastewater Treatment

2) Aquatic plant/aquaculture systems

Macrophyte-based aquatic treatment systems use submerged, emergent, or rooted aquatic vascular plants and their associated algal and microbial epiphytes to effect wastewater restoration in managed pond or wetland systems. In most applications they consist of macro-phyte-filled ponds or of natural/artificial wetlands through which secondary effluent passes. The most commonly used plant in these systems is the emergent floating macrophyte *Eichornia crassipes*, the water hyacinth. Full-scale water hyacinth treatment systems have been operating successfully in China, the Philippines, Burma, the United States, India, and Thailand, and other subtropical locations for years. They are efficient not only in removing biochemical oxygen demand (BOD) and total suspended solids (TSS), as in conventional secondary treatment systems, but also in removing large amounts of nutrients (nitrogen and phosphorus), heavy metals, and trace organics (Bishop 1989).

Aquaculture, or the production of aquatic organisms (both flora and fauna) under controlled conditions, has been practiced for centuries primarily for the generation of food, fiber, and fertilizer. The water hyacinth (*Eichornia crassipes*) is a promising plant for wastewater treatment and has attracted the attention. Other flora, however, are also being studied. Among them are duckweed, seaweed, midge larve, and alligator weeds. Water hyacinths are large fast-growing floating aquatic plants with broad, grassy green leaves and light lavender flowers. Hyacinth harvested from these systems has been investigated as a fertilizer/soil conditioner after composting, animal feed, and as a source of methane when anaerobically digested, and was used to make shochu (a kind of Japanese spirits) in Japan.

Aquaculture utilization has also been demonstrated by applying sewage stabilization pond systems including anaerobic ponds, facultative ponds, aerobic ponds, and fish culture ponds. In order to mobilize fully the self-purification of a water body for sewage treatment, the main principle is to utilize the coordination among four kinds of chief factors in the aquatic ecosystem, namely, producers (algae, aquatic vegetation), consumers (fish and other aquatic animals), decomposers (bacteria), and abiotic factors (solar energy, water with other chemical components). The bacteria-algae symbiotic system plays an important role in this sewage stabilization pond system. Bacteria decompose and biodegrade organic materials, including organophosphates and chlorides, and purify the wastewater in a preliminary fashion. In this procedure, bacteria produce CO_2, NH_4^+ PO_4^{3-}, and so on, which are absorbed by algae and other aquatic vegetation and assimilated in their bodies under sunlight. The oxygen released by the photosynthesis of algae is supplied for the needs of oxidizing organic materials by bacteria. Then through transfer and transformation among various trophic levels, a great quantity of algae and other plankton is utilized in the procedure of purification by rearing fries. The energy fixed by algae appears finally in the form of fish harvesting, and the water is further purified.

This system may be more effective if the aquatic plants can grow up whole year. Therefore it is most suitable to the tropical countries.

3) Treatment and utilization of sewage by land treatment systems (LTS) *or soil systems*

Soil ecosystems include various types of soil organisms such as bacteria, fungi, protozoa, and metazoa. Organic material is generally decomposed into inorganic compounds by the actions of these soil organisms. The farmland, grassland, and forest ecosystems, all based on soil, not only can degrade and purify many kinds of pollutants in sewage, but also can produce many useful products by utilizing these pollutants. Inorganic salts, especially nutrient salts decomposed from organic materials and contained in sewage, then are absorbed by plants that grow in soil. The soil itself also seems to be a natural sieve, effectively filtering out most of the pollutants in sewage, namely SS, degradable organic pollutants, nutrient salts, and some pathogenic bacteria and viruses. The removal rate may exceed 90% for BOD, total nitrogen, SS and colon bacilli, and nearly 50-80% for phosphorus.

Table 5 Design features and expected performance for land treatment systems

Concepts	Treatment goals	Typical criteria: Climate needs	Vegetation	Area ha	Hydraulic Loading $m^3 \cdot m^{-2} \cdot year^{-1}$	Effluent characteristics $mg \cdot l^{-1}$	
Slow rate	Secondary, or AWT	Warmer season	Yes	23-280	0.5-6	BOD	<2
						TSS	<1
						TN	<3
						TP	<0.1
						FC	0
Rapid in filtration	Secondary, or AWT, or groundwater recharge	None	No	3-23	6-125	BOD	5
						TSS	2
						TN	10
						TP	<1
						FC	10
Overland flow	Secondary, nitrogen removal	Warmer season	Yes	6-40	3-20	BOD	10
						TSS	10
						TN	<10
						TP	<6

AWT: Advanced Wastewater Treatment; FC:Fecal Coliform, numberper 100ml.

Land treatment systems (LTS) are defined as the controlled application of wastewater onto surface to achieve a designed degree of treatment through natural physical, chemical and biological processes within the plant-soil-water matrix (US. EPA 1981). There are five main types of LTSs, i.e. slow-rate infiltration (SR), rapid infiltration (RI), overland flow (OF), wetland (WL) and soil capillary (SC). Table 5 presents the typical design features and performance expectations for the three basic LTSs (Reed 1988). LTSs should be regarded as an ecological engineering which combines ecological principals and engineering techniques.

4) Stream purification process

The stream purification process with packed medium is one of the effective domestic wastewater treatment systems. The stream purification process strengthening the self-purification ability with large amount of biofilm attached on the packed media has been spotlighted to improve the water quality. Self-purification in the river; permeating treatment; purification facility using submerged biological film process with packed stone in the stream, the stream with packed string media (with packed wave-shaped plastic board media; charcoal and so on) are considered as an effective ecological approach to restore the polluted water in the stream. In this stream bacteria, fungi, protozoa and small metazoa, small animals such as Rotatoria, Oligochaeta and Tubellaria contribute well to water purification.

Many river banks in Japan were covered by concrete for flood control purpose before. But recently, Environment Agency and the Ministry of Construction have changed the old river banks into so called "multi-natural type" riverfront and river banks instead of three-side concrete blocks. Waste plastic, charcoal and stone are being used for stream purification processes.

Pilot scale and full scale stream purification processes have been operated in Japan, but there still have some problems to be overcome such as decrease of purification efficiency by clogging of packed media, occurrence of harmful insect and so on.

Table 6 shows the efficiency of purification facility using submerged biological film process with packed stone in some rivers in Japan. 50-80% removal of BOD was obtained. Further development of this system is being carried out.

Table 6 BOD removal of purification facility using submerged biological film process with packed stone in some rivers in Japan

Rivers	Discharge ($m^3 \cdot min.^{-1}$)	BOD ($mg \cdot l^{-1}$) Influent	Effluent
Nogawa	90,000	13	4
Kuwanou	70,000	20	5
Ohori	100,000	25	5
Hisade	40,000	30	10
Koukakuike	1,000	30	10
Hirase	10,000	20	5
Mitinoku Park	9,500	2	1
Arakawa	260,000	15	3

5) Artificial aeration of lakes

The most effective method of solving the problem of oxygen depletion in streams is to remove organic matters of discharged wastewater. The biological treatment should preferably take place at wastewater plants, not in the streams. However, if the streams have an accumulation of organic sludge, aeration may

Table 7 Ecotechnological methods applied in lake restoration

Method	Problem to Solve
Wetland system	Removal of nitrogen and phosphorus from nonpoint sources
Aeration with circulation	Depression of algae growth, reduce release of phosphorus and Fe from sediment; oxygen depletion in hypolimnion
Siphon of hypolimnion water	Removal of phosphorus and oxygen-poor water
Adding nitrate to sediment	Reduce release of phosphorus from sediment
Coverage of sediment	Eutrophication
Removal of upper sediment layer	Reduce release of phosphorus from sediment or remove toxic substances
Removal of phosphorus of algae from water	Eutrophication (reduce P/algae in water)
Decreased retention time	Reduce P and toxic substance concentration
Precipitation of phosphorus in lake	Reduce Phosphorus in water
Precipitation of phosphorus in inflowing water	Reduce Phosphorus input

be needed to accelerate the decomposition (oxidation) of the sludge. For lakes the problem is more complex. First of all, the oxygen depletion is most often caused by eutrophication, not by discharge of biological oxygen demand. Secondly, the high concentration of nutrients cannot be reduced rapidly, owing to the long retention time of water in lakes. Therefore artificial aeration has been used more for lakes than for streams and it has been used mainly to prevent anaerobic conditions at the sediment surface. The ecological methods applied in lake restoration methods are summarized in Table 7.

Intermitted artificial aerations have been practically used in many drinking-water reservoirs in Japan to solved the massive growth of planktonic algae, odor and taste problems, and other eutrophication problems. Reservoirs Sagami, Kamafusa, Shimonohara, Muroi, Sakuna and so on, start to introduce this techniques in the early of 1980s. Effective results have been obtained. The artificial aerations make water circulation, and have an inhibitory effect on algal growth due to light limitation, since it transports planktonic algae to greater depths. The more pronounced the coloration of the water of non-algal origin, the more the biological productivity will be inhibited by this means.

Our experience with ecotechnology and its possibilities is limited today. Although the results we do have look very promising, we need to integrate the application of ecotechnology much more in our pollution control and environmental planning in the future. This require a continuous development of ecology, applied ecology, ecological modeling, and ecological engineering. Ecotechnology offers us a very useful tool for better planning in the future. It is a real challenge to humankind to use this tool properly.

The application of ecotechnology and biotechnology for the restoration of water environment is very illustrative, because these methods have been widely applied to polluted water bodies. It can be clearly demonstrated that to achieve good results in water environmental management one must combine several methods: environmental technological as well as ecotechnological and biotechnological methods simultaneously. For example, pollution of lakes is a very complex problem and it can rarely be solved by the use of one (simple) method. Figure 1 shows the applications of ecotechnology and biotechnology to the restoration of water environment.

All the applications of technologies, whether of ecotechnology, biotechnology, chemical and environmentally technology, require quantification. Because ecosystems are complex systems, the quantification of their reactions becomes complex.

It is well-known fact that there are a lot of problems to be solved for environmental conservation using ecotechnology and biotechnology. Table 8 shows the subjects concerning the development of ecotechnology and biotechnology for the environmental conservation field.

Table 8 Subjects concerning the development of ecotechnology and biotechnology for the environmental conservation field.

1 Use of biomass and unused resources
- (1) cultivation by using specific algae and aquatic plant
- (2) technology for effective fertilization
- (3) feeding technology
- (4) technology for methane fermentation
- (5) technology for alcohol fermentation

2 Environmental purification and wastewater treatment
- (1) biological decomposition of organic substances
- (2) treatment of liquid waste
- (3) treatment and reuse of food and fish processing wastewater
- (4) improvement of biological removal of nitrogen and phosphorus
- (5) microbiological accumulation of heavy metal
- (6) treatment and effective reuse of sludge, solid-waste and live-stock waste
- (7) improvement of gray water
- (8) decreasing of the sludge from the wastewater treatment process
- (9) biological prevention of water bloom and red tide
- (10) development of microbial immobilization and bioreactor
- (11) development of biological desulfurization and deodorization
- (12) wastewater treatment by specific microorganism

3 Biosensor
- (1) development of environmental indicator organism and microorganism
- (2) measuring technology for BOD, ammonia, nitrite and nitrate nitrogen
- (3) measuring technology for respiration of microorganisms

3. The Role of Effective Organisms in the Restoration of Water Environment

In natural ecosystems, microorganisms play a major role in mineralizing various organic pollutants. Engineered biological wastewater treatment systems accelerate this ubiquitous microbial activity by

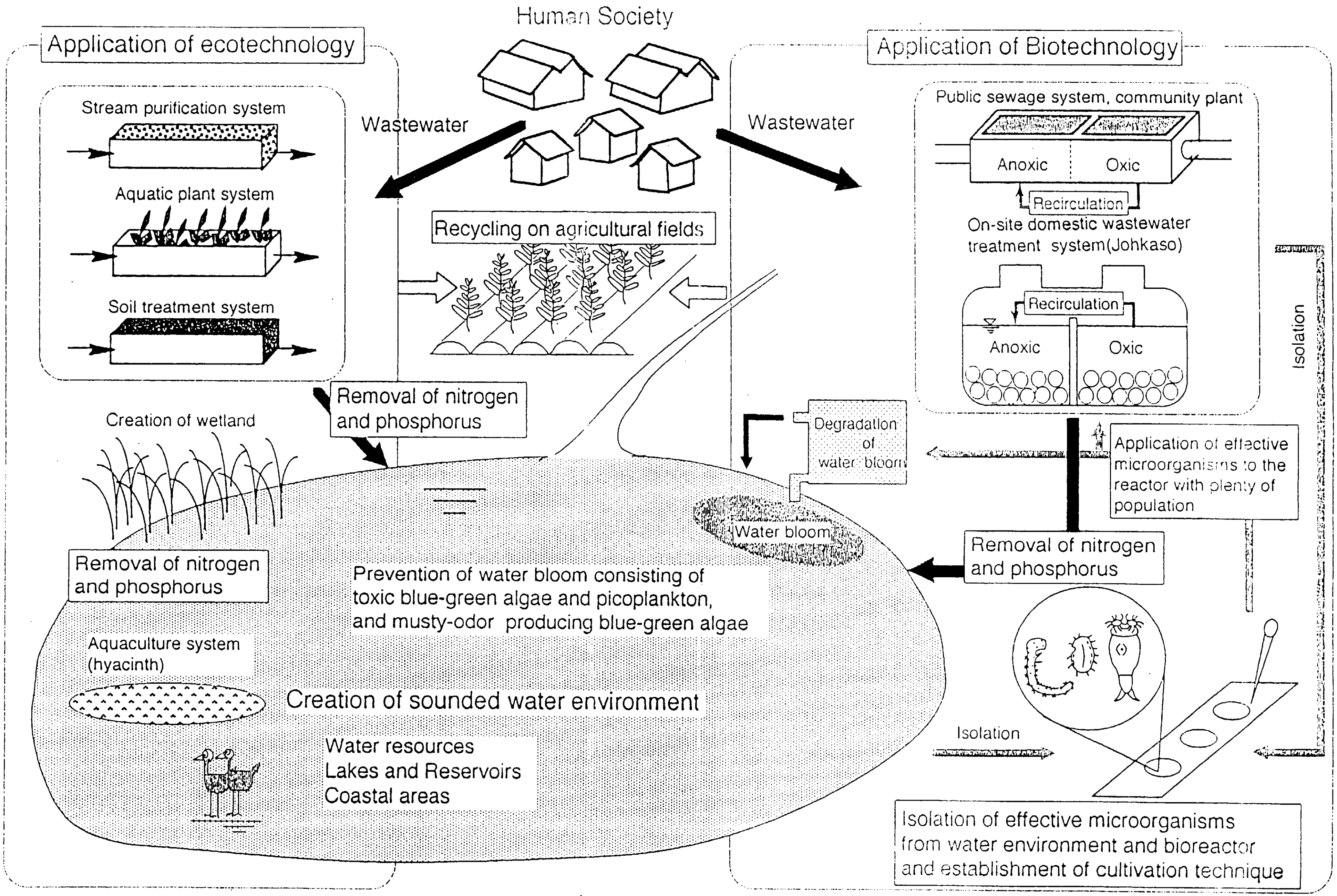

Figure 1 Application of ecotechnology and biotechnology to the restoration of water environment

providing a favorable artificial environment. The microorganisms retained in such systems may be in suspended growth form, as in the activated sludge process, or in the attached growth form, as in trickling filters and rotating biological contactors (RBC). Some treatment systems such as fluidized bed systems and activated sludge systems using substantial amounts of solid carriers contain both suspended and attached biomass and can be called hybrid growth systems. A possible general classification of biological growth systems is shown in Figure 2 (Tyagi 1990).

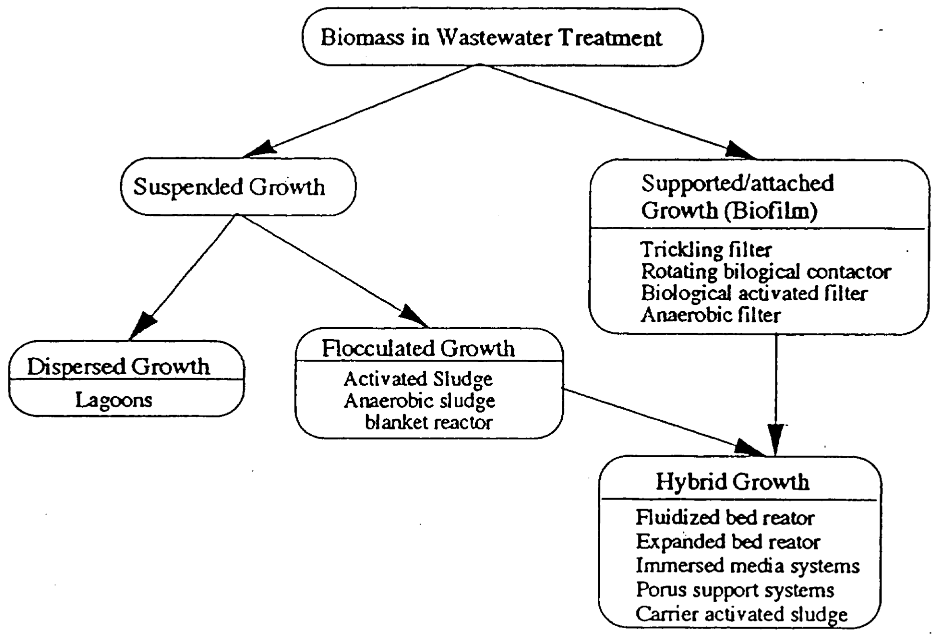

Figure 2 Systematics of biomass form in wastewater treatment systems

In biological wastewater treatment systems, substrate degradation rates per unit volume could be maximized by retaining the highest possible concentration of active biomass. The various means of increasing the active microbial concentration are (1) promoting the growth and activity of organisms in general, (2) fostering the growth of microorganisms capable of forming dense flocs or films, (3) minimization of loss/washout of microorganisms, and (4) utilization of genetically engineered organisms possessing higher than usual growth rate and/or substrate uptake rate and dense growth forms.

The growth and activity of microorganisms could be maximized by (1) enhancing the availability of substrates, nutrients, and electron acceptors to microorganisms, (2) providing optimum environmental conditions (temperature, pH, etc.), and (3) suppressing the inhibitory conditions. The density of microbial flocs or films can be increased by providing proper selection conditions (e.g., dissolved oxygen concentration and hydrodynamic conditions) for the organisms which possess dense growth characteristics. The loss or washout of microorganisms can be minimized by recycling biomass after effective separation from the effluent and/or by immobilizing them on solid surface. Utilization of engineered microorganisms, at present, is yet uncommon. Even if it would be applied to wastewater treatment, the effective use of such organisms would still depend on the means of the maintaining the biomass with the system.

In addition to obtaining rapid and efficient treatment, the goal is design wastewater treatment systems which are reliable, cost-effective, and simple to operate. A comparison of different systems could be based on these points.

If the physical and chemical parameters are maintained at optimum levels, then the limiting factor to degradation seems to be biological.

The following conditions are required for the facilities of biological treatment process;

1) getting stable and good quality water;

2) possible to remove nitrogen and phosphorus in addition to organic substances;

3) with small amount of excess sludge, and the sludge can be reused;

4) ease of operation with least work for maintenance;

5) cheap construction cost, long life and small plant space;

6) consuming little energy and chemicals;

7) the facilities are small and compact;

8) safety in sanitary, and without second pollution;

It is common to either large scale or small scale biological treatment process for these requirements. The anaerobic-aerobic activated sludge process is being treated as a popular treatment process due to its simultaneous removal of nitrogen and phosphorus. The common conventional biological treatment process has following characteristics:

1) the treated water is unstable;

2) it is difficulty to remove nitrogen an d phosphorus;

3) the amount of the sludge is large;

4) the consumption of the energy is gre at;

5) it is not easy to operate;

6) it is easy to cause the bulking proble m.

Table 9 The subjects expecting to be solved in biological treatment processes

1. Raising the concentration of useful microorganisms in the reactor
2. Improving the removal of effluent water quality (BOD, COD)
3. Improving the efficiency of nitrification and denitrification
4. Improving biological removal of phosphorus
5. Improving the decomposition of nondegradable organic substances
6. Promotion of flocculation
7. Control of bulking
8. Growth control of noxious microorganisms
9. Stabilization and improvement of anaerobic treatment process
10. Growth promotion of microanimal
11. Improving the efficiency at low temperature
12. Reuse of sludge

Because of these shortcomings, a lot of other technologies concerning biological treatment have been developed to apply to full scale or pilot plant experiments. These methods can be summarized as:

(1) submerged filter process; (2) rotating biological contactor process; (3) anaerobic filter process; (4) sequencing batch activated sludge process; (5) anaerobic-aerobic activated sludge process; (6) fluidized bed process; (7) biological filter process; (8) immobilized microorganisms process; (9) UASB (upflow anaerobic sludge blanket) process; and (10) fixed bed anaerobic digestion; (11) expanded bed granular activated carbon (GAC) process; (12) microorganism-attached activated carbon fluidized bed process

Of all of these methods, they have at least one characteristic like 1) letting biofilm attached on the supporting media; 2) using anaerobic microorganisms; 3) cyclic use of the anaerobic and aerobic reactors. First characteristic plays an important role in keeping high density of useful microorganisms in the reactor, second one save the energy consumption for the decomposition of organic matters, the other one supplies the requirement condition for the removal of nitrogen and phosphorus. How to keep the high concentration of useful microorganisms, and how to control the anaerobic or facultative bacteria in some part of processes are the key points for the development of these methods. Table 9 shows the concrete technological subjects expecting to be solved in biological treatment processes.

As for the first key point, the mixed culture system is more useful in wastewater treatment than pure culture system. For instance the pure culture using the genetically engineered microorganisms (GEMs), is possible to make a strong microorganism, but is not easy to treat with the domestic wastewater which concentration is low and the compositions are diverse. It is clear to find that the removal efficiency in mixed culture system is quite high, through examining the treated water by activated sludge process. That is because that the functions like mutualism, competition, predation and so forth are carried out in mixed culture system, while it is impossible in pure culture system. The process utilized a complex ecosystem composed of bacteria, fungi, protozoa and small metazoa. Bacteria degrade polluting organic materials to carbon dioxide and other small molecules, protozoa and small metazoa prey on the bacteria and, in turn, become prey for high species. Therefore, it is important to use these interactions in biological treatment processes. Although there are many merits in mixed culture system, the operation and control of microbial interactions have been still difficult by now. If the control of these coactions becomes possible, this will mean a great development in biological treatment process. Further endeavors are needed to develop these processes.

In general, the operating conditions to control the phase of microorganisms in the reactor are as follows:

1) the concentrations and loadings of nutrients;

2) water temperature, pH and dissolved oxygen;

3) hydraulic and sludge retention time;

4) the habitat of microorganisms;

5) aeration, mixing and optical conditions;

6) the combination or separation of reactors.

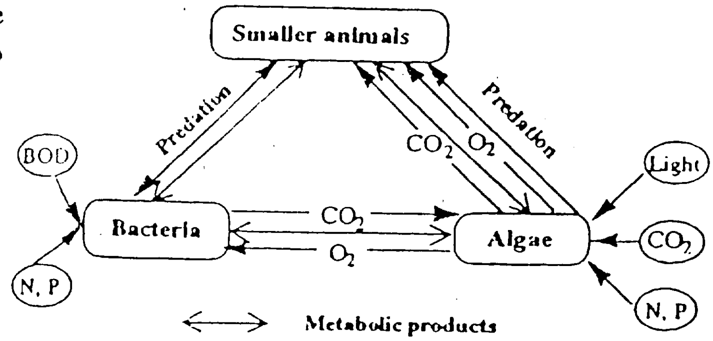

Figure 3 Interactions between bacteria, algae and smaller animals

In activated sludge process, some of the operating conditions are controlled by experiences. It is difficulty to hold specific microorganism artificially in the process.

It is well known that protozoa and micro-metazoa are useful in aerobic treatment process. Figure 3 shows the interactions between bacteria, algae and smaller animals. To improve the treatment efficiency, it is necessary to know the factors affecting the growth of protozoa and micro-metazoa.

The environmental conditions and results for the growth of protozoa and micro-metazoa such as *Vorticella microstoma, Philodina erythrophthaloma, Nais* sp., *Aeolosoma hemprichi* isolated from activated sludge process are shown in Table 10. It is clear that water temperature and pH are important factors for these microorganisms. The proper ranges for water temperature and pH are 20-30°C and 5.6-7.7, respectively. Beside them, physical and chemical conditions like mixing strength, salt concentration are quite important for the growth and domination of specific microorganisms. The operating conditions such as (1) Sludge retention time (SRT); (2) Temperature; (3) pH; (4) Continuous inoculation and excess of microorganisms in the reactor; (5) Preventing the growth of noxious microorganisms are very important for the wastewater treatment process.

Table 10 The effect of environmental conditions on the growth of microorganisms

	Rotatoria	Oligochaeta				Protozoa
Items	*P. erythrophthalma*	*A. hemprichi*	*Pristina* sp.	*Nais* sp.	*Dero* sp.	*V. microstoma*
Water temp.(°C)	30	33	30	25	-	25
pH	6.7-7.7	6.0-7.7	6.0-7.7	6.0-7.7	-	6.6-7.5
Phosphate buffer solution (M)	<1/50	<1/375	<1/150	<1/375	<1/7,500	2/75-1/150
Intensity of mixing	strong	medium	weak	weak	weak	strong
Maximum growth rate (day $^{-1}$)	0.69	0.42	-	0.12	-	2.2
Food habit	wide	narrow	wide	wide	-	narrow

4. New technologies for Wastewater and Polluted Water Treatment

The development studies of new technologies and treatment methods in Japan (in our laboratory) may be summarized as follows.

1) Anaerobic and anoxic-oxic wastewater treatment technology

The treatment efficiency of the conventional activated sludge process is quite low if the wastewater contains low organic concentration. However, new developed anaerobic wastewater treatment process can be both used for high and low organic wastewater, through returning the sludge to aeration tank and keeping high concentration of microorganisms in the process. Additionally, an equipment was set for removing the bubble attaching on the flocs from the solids-liquid separation, and the development of the anaerobic sludge filter was also made to raise the concentration of microorganisms. The sludge concentration can be raised more than 20,000mg · l^{-1} by this technology.

In UASB reactor, the feed wastewater is introduced in the bottom part of the reactor and moves upward through an active bed of biomass. The UASB technology was developed initially by Lettinga (1980), and was used primarily for the treatment of carbohydrate-rich wastewater in Netherlands. The UASB reactors are now successfully used all over the world to treat wastewaters from the food, beverage, and pulp and paper industries. The major advantage of the UASB design is the ability to obtain a high concentration of aggregating microorganisms (granules), which in turn are responsible for the high volumetric productivity. An important improvement of the original UASB design is the anaerobic hybrid reactor. In this design, the upper 20 to 30% of the reactor is filled with a floating material which maintains the biomass in the reactor. This material can be polyurethane (PU) foam, polymer balls, or randomized plastic rings. As the retained biomass participates actively in the biological process, the hybrid design is more productive and reliable compared to the standard UASB process. Other anaerobic filter processes are also being developed by using the biofilm attached on support media in the reactor, and raising the concentration of microorganisms.

To improve the removal of nitrogen, UASB-aerobic biological filter filled with ceramic media recirculation process was developed in our laboratory (Figure 4). Denitrification efficiency was improved by nitrification in aerobic biological filter combined. This process removes 98% and 70% of BOD and nitrogen respectively. This process was applied to treatment facility of beer company in Japan.

There are still a lot of problems to be solve to apply anaerobic filter process to wastewater treatment, such as HRT, BOD loading, the flow pattern of wastewater, the effect of temperature, the shape and packed ratio of media, the collection of gases, the scale of the facilities, and the drawing of sludge.

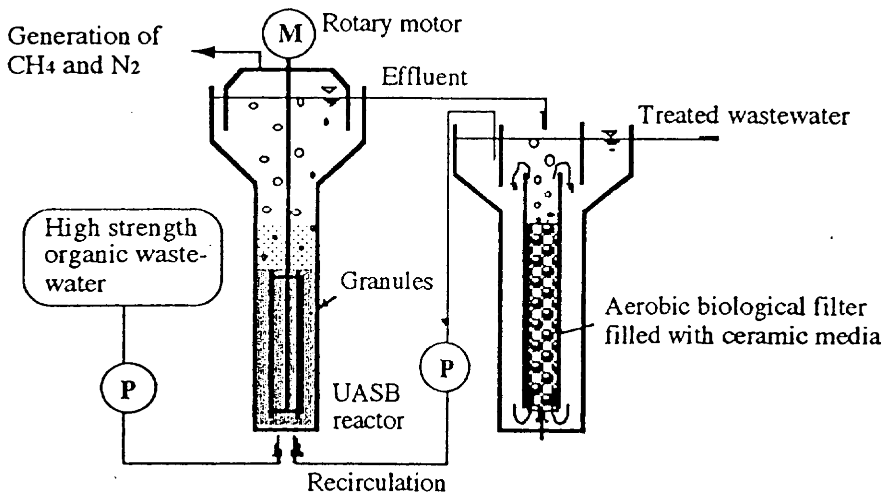

Figure 4 UASB-aerobic biological filter filled with ceramic media recirculation process which removes high strength organic substances and nitrogen

2) Processes for biological removal of nitrogen

On-site domestic wastewater treatment facilities called "Johkaso" is one of the effective processes to remove nitrogen biologically, and privately owned wastewater treatment system in Japan (Figure 5). Johkaso is different from septic tank in view point of treating domestic wastewater effectively using anaerobic and aerobic micro-organisms, and is required to achieve an effluent quality less than 10mg · L^{-1} both in BOD and T-N in advanced type. It is used in "individual treatment" intended for individual households and "collective treatment" intended for a community. Laws have made it mandatory for individual households or communities in an area where no sewerage system is in service but flush toilets are used, to install Johkaso to get night soil (black water) purified before being discharged into water systems. Among various domestic wastewater treatment facilities, the Johkaso should be designed to have any capacity to suit a specific need from small household use to large housing complex-like community use according to the number of peop le involved. This flexibility in designing makes i t advantageous over other wastewater treatment systems.

There are two types of Johkaso : "night soil treat ment Johkaso" (N-type) that treats night soil onl y (untreated gray water directly discharged into water systems), and "domestic wastewater treat ment Johkaso" (D-type) that treats both night soi l and gray water from kitchen, bath and so on. T he Johkaso originally has been installed in a part of flush toilets at places where there was no sew erage system. Therefore, most of them installed so far are N-type. The number of registered Johk aso by size and type are shown that 6,899,391 (9 5.0%) are N-type out of 7,261,752 Johkasoes. D-type is 5.0% only in 1992. However, the ratio of D-type is growing rapidly as the total number of Johkasoes is increasing slowly. As untreated gray water poses a serious pollution problem in water systems, the spread of D-type and the inhibition of the install of N-type has become an urgent issue to keep clean water environment.

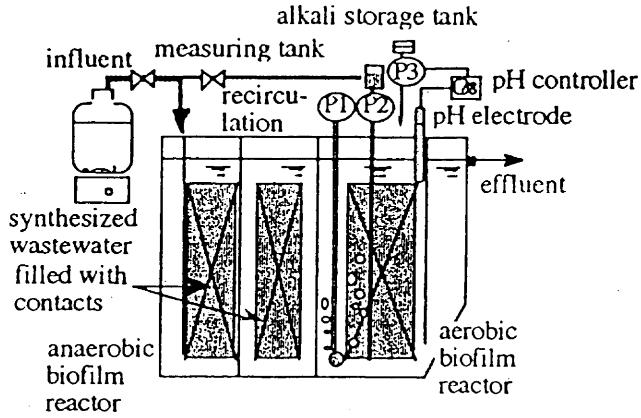

Figure 5 Experimental apparatus of Johkaso

P1 air pump for aeration
P2 air pump for recirculation
P3 perista pump

Nowadays, what is important particularly from the viewpoint of eutrophication control is the devel opment of D-type, especially small-scale one (less than 20 persons). In many installed small-scale D-type, it w as impossible to achieve stable nitrification, much less denitrification. It was reported that the spread of conv entional D-type caused more serious pollution in Lake Kasumigaura.

That is to say, it is greatly important to install an advan ced D-type (A-type) which can treat both BOD and nit rogen effectively. It is needless to say that paying atten tion to regional characteristics is essential.

Anaerobic-aerobic recirculation biofilm process in D-t ype which can circulate treated water with nitrification from an aerobic tank to an anaerobic tank is drawing much attention as a promising biological nitrogen rem oval process. There are some advanced D-type to achi eve the removal rate of 70% and less than 10mg · l^{-1} i n total nitrogen. In some regions, D-type added soil tre nch (Figure 6) is applicable to remove nitrogen and p hosphorus. Figure 7 shows purification mechanisms of soil trench.

There is another problem. Gases; CO_2, CH_4 and N_2O ar e emitted through the wastewater treatment process. T hese gases are called greenhouse effect gas and could give rise to global warming. It is considered that the gr eenhouse effect per one molecule of CH_4 is 20-30 time s, and that of N_2O is 200-300 times, as large as that of CO_2. Therefore, to develop the technology that can su ppress especially N_2O emission through the wastewate r treatment process is regarded as important.

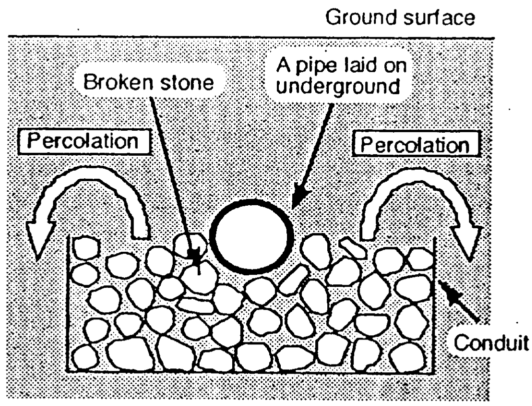

Figure 6 Soil trench system

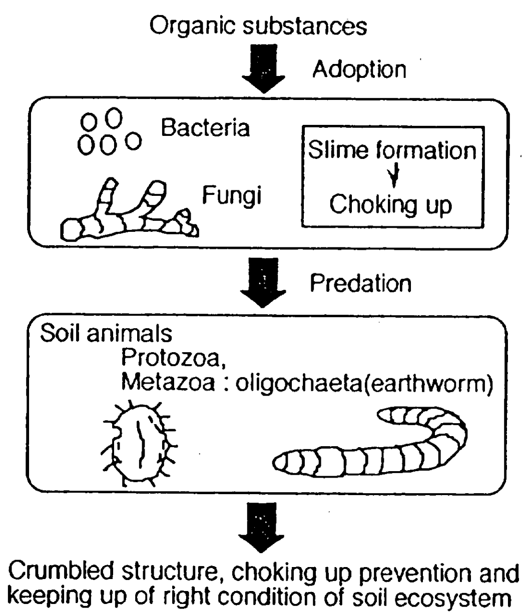

Figure 7 Purification mechanism of soil trench treatment process

Biological nitrogen removal process consists of nitrification and denitrification. Nitrification makes progress under aerobic condition for instance when aeration is done, while denitrification makes progress under anaerobic condition. N_2O is emitted through both of them, in case that treatment doesn't progress successfully. N_2O emission from nitrification-denitrification process is shown in Figure 8. However, the mechanism of it and the amount of N_2O emitted from wastewater treatment facilities are not clarified enough. In our institute, laboratory and full scale plant experiments are conducted so as to examine the factors involved in N_2O emission through the nitrification-denitrification process.

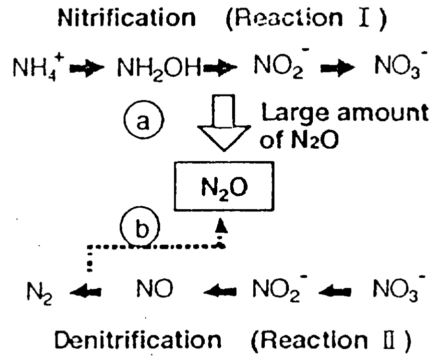

Figure 8 N_2O emission through biological nitrification-denitrification process (ⓐ≫ⓑ)

If the nitrification-denitrification (Reaction I → Reaction II) process is operated appropriately, N_2O emission from nitrification process can be controlled.

Through our studies, it was clarified as follows: applying anaerobic condition such as intermittent aeration or anaerobic tank to wastewater treatment process was very effective way to suppress the N_2O emission as well as to remove organic matters and nutrients from wastewater. Nitrification and denitrification make progress effectively under suitable combination of aerobic and anaerobic condition.

From reasons mentioned above, countermeasures for eutrophication caused by domestic wastewater must be executed with spread of advanced system such as A-type Johkaso which can remove BOD and nitrogen simultaneously in black and grey water making use of Japanese historical reflection.

3) Processes for biological removal of phosphorus

The processes for biological removal of phosphorus are divided into Anaerobic/Oxic (A/O) process which is a process for the removal of phosphorus only; and Anaerobic/Anoxic/Oxic (A2/O) process which is used for simultaneous removal of nitrogen and phosphorus. A2/O process is practically used in U.S., Europe and South Africa. A few of such process have been installed for full scale plants in Japan. In order to remove nitrogen and phosphorus simultaneously, following operations are needed:

(1) return of water from aerobic tank to anaerobic (anoxic) tank;

(2) keeping influent BOD more than $100mg \cdot l^{-1}$;

(3) preparing enough capacity of aerobic tank for proper nitrification at low temperature.

In case of domestic wastewater treated by this process, the value of the nitrogen and phosphorus at effluent can be obtained less than $10mg \cdot l^{-1}$ and $1\ mg \cdot l^{-1}$, respectively.

4) Sequencing batch activated sludge process

This process is developed for the problem of bulking in small scale wastewater system. The principle of this system is to use the combination of aerobic and anaerobic (anoxic) cycle for simultaneous removal of nitrogen and phosphorus. It may be composed of one or more tanks. The single tank system is applicable for noncontinuous flow situations, especially for small rural towns where smaller wastewater flows occurs. Minimum operator input is required for satisfactory performance of the single tank system. The operation of multiple tank systems can be either simple with a minimum of operator input or complex, depending on flow and load variations and degree of treatment required.

5) The technology for the treatment of polluted water sources by the biofilm process

The pollution of water resources in Japan was considered a pressing social problem, and the problem has caused difficulty in drawing raw water for water s upply by conventional water treatment methods in water works plant. Therefore, biological treatment process and biological a ctivated carbon treatment process have been introduced in wate r supply engineering as a pretreatment process. As an example (Sudo et al 1990), honeycomb biological treatment process has been practically used in Kasumigaura purification plant since 1985. The HRT of this process is only 2-3 hours, but the remov als of algae, odor concentration and musty odorous compounds are as high as 55-93%, 50-81% and 50-60%, respectively. It is clear that this process is effective to algae and musty odorous c ompounds removal. However, the removal is changeable for di fferent algae as shown in Table 11. Additionally, the removal o f THM (trihalomethane) precursor is found to be 70 %. Massiv e growth of water blooms is frequently observed in Lake Kasu migaura, and the treated water had musty odor before introduci ng this pretreatment process. Since the pretreatment process wa s used, the musty odor complain from the residents was disappe ared. There are still a lot of problems to be solved concerning t he removal mechanism of algae and musty odor, the relationshi p among the species of algae, musty odor, water quality. Table 12 shows the dominant species of microanimal in biofilm. It is necessary to make clearly the operational conditions like the flo w type, DO concentration in the reactor, the shape of the suppo rting media, the timing and frequency of backwash, the amount of sludge in the reactor. And the development of the more convenient and easier technologies to remove toxic algae and musty odor is also required.

Table 11 Removal of algae by submerged filter

Algae	Removal (%)
Synedra sp.	63-83
Melosira sp.	45-52
Oscillatoria sp.	40-78
Anabaena sp.	62-100
Myxosarcia sp.	38-51
Phormidium sp.	47-74
Aphanizomenon sp.	40-50
Microcystis sp.	35-100

Table 12 Dominant species of microanimal in biofilms

Ciliata	*Vorticella campanula*
	Vorticella convallaria
	Espistylis sp.
	Carchesium polypinum
	Zoothamnium aselli
	Trithigmostoma cucullulus
	Chilodonella fluviatilis
	Stentor igneus
	Coleps hirtus
	Didinium nasutum
Sarcodina	*Euglypha* sp.
	Difflugia sp.
Rotatoria	*Cephalodella* sp.
	Philodina sp.
Turbellaria	*Stenostomum* sp.
Oligochaeta	*Aeolosoma hemprichi*
	Nais sp.
Gastrotricha	*Chaetonotus* sp.
Tardigrada	*Macrobiotus macronyx*
Crustacea	*Paracyclops* sp.

6)Advanced water treatment technology using fluidized bed process with biological activated carbon (BAC)

This technology was developed to treat the polluted lake water by enhancing the biological activity of microorganisms attached on the surface of activated carbon. Real eutrophicated lake water was purified with pilot plant (working volume:110L) under HRT 1hr. This pilot plant removed 50% and 40% of TOC and SS respectively. It was found that there are many microorganisms , micro animals, protozoa and metazoa in BAC biofilms. These biofilms played an important role in removing polluted organic matters (TOC), THM, musty odors (Figure 9). Beside the physical and chemical reaction of activated carbon, the fluidized bed process with BAC built up an effective biological process, and improved the treatment efficiency. There are many water purification processes combined with BAC (Figure 10). Results of our study indicated that this process should

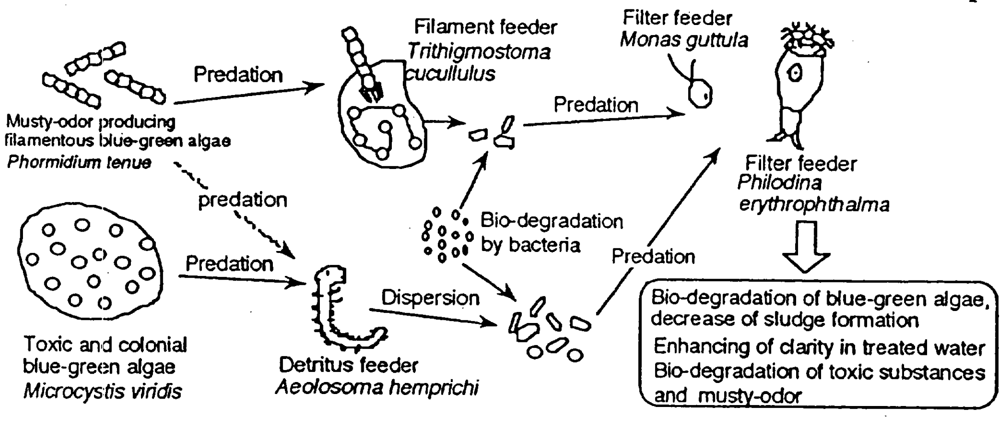

Figure 9 Role of microorganisms in biological treatment of polluted lake water

be an effective pretreatment process for advanced water treatment in water supply.

7)Treatment of landfill leachate using biotechnology

Most municipal and industrial wastes including sewage sludge are disposed in landfills. Leachate

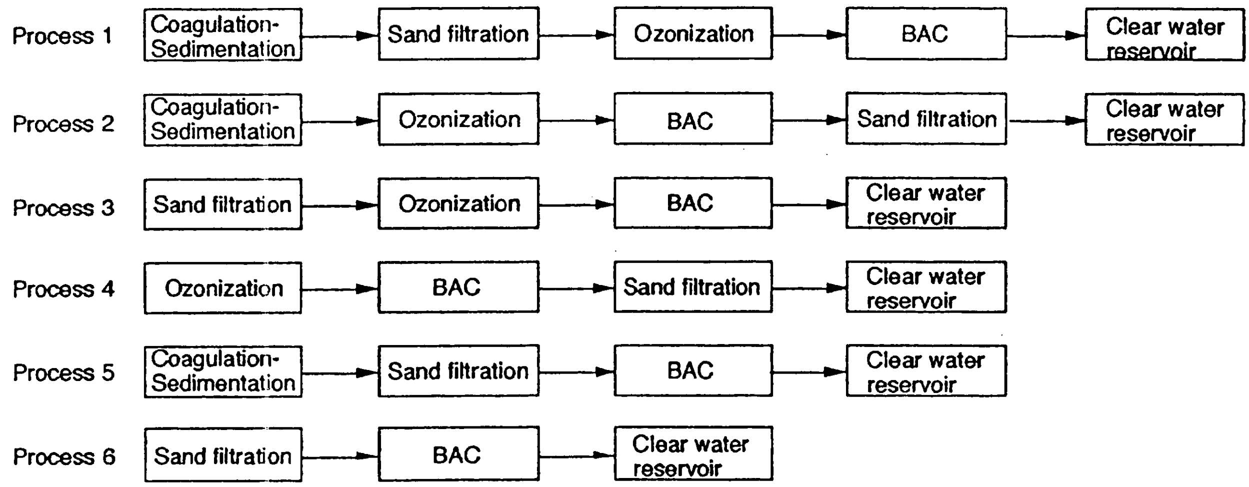

Figure 10 Water purification processes combined with BAC

from landfill of old age usually contain high concentrations of refractory organics and ammonium nitrogen which are potentially a major environmental hazard as surface and groundwater contamination. The landfill leachates exhibit a significantly low ratio of BOD to COD, indicating a low biodegradability. With increasing stringent requirement for the landfill leachate pollution control, it is necessary to treat the landfill leachate effectively and economically.Therefore the biological activated carbon fluidized bed (BACFB) process (Figure 11) was applied to treat the landfill leachate. The BACFB process removed about 60% and 70% of refractory organics and nitrogen, respectively, from the landfill leachate simultaneously and steadily over a more than 700 days of operation period without exchange of activated carbon. A mass balance on organics around the BACFB process revealed that more than 90% of the removed organics may be biodegraded. It was suggested that the BACFB process should be highly effective in biodegrading the refractory organics in the landfill leachate.

Beside above mentioned technologies, a lot of new developed technologies such as immobilized microorganisms process; expanded bed granular activated carbon (GAC) process; microorganism-attached activated carbon fluidized bed process; advanced water treatment process (Membrane filtration technology; Ozonization technique etc.) are being developed in Japan. Oxidation ditch and intermittent aeration process are also useful for small scale wastewater treatment. As for the improvements of nitrification, immobilized microorganisms treatment process with packed nitrifying bacteria are also practical.

The immobilized or adsorbed cell systems are used in certain traditional processes such as the production of vinegar. With the use of reactors containing immobilized cells, e.g., for the continuous production of alcohol, amino acids are already known. Compared to the immobilized enzymes, the im-

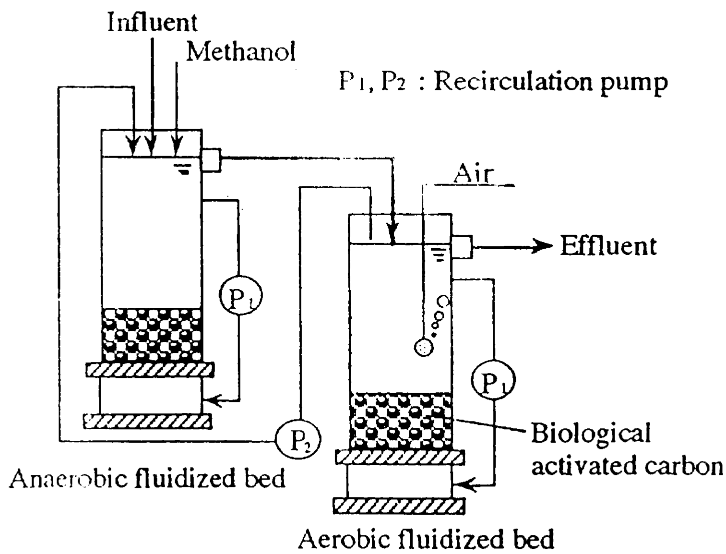

Figure 11 Schematic diagram of biological activated carbon fluidized bed process

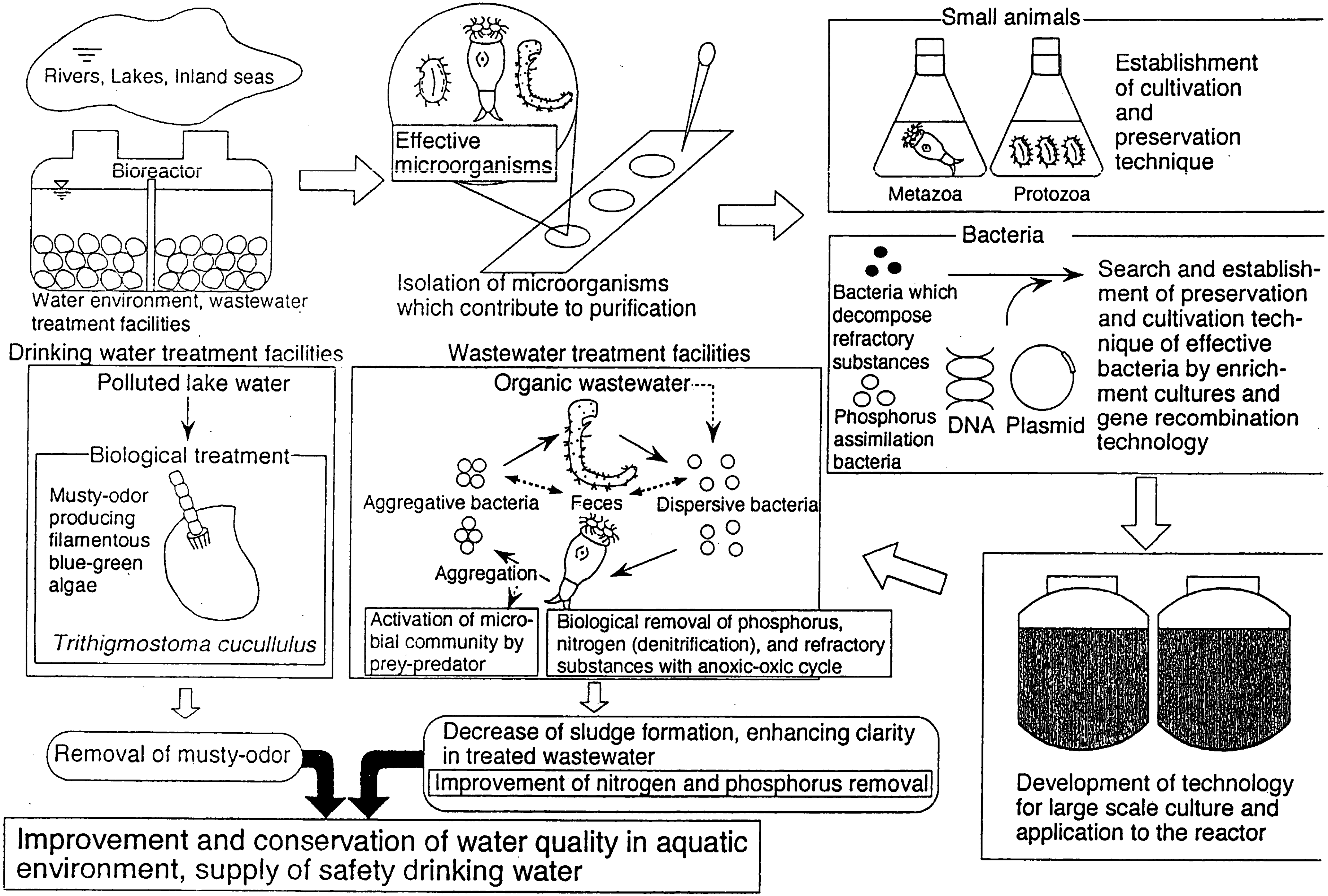

Figure 12 Application of effective microorganisms to restoration of water environment

mobilized cells present an advantage of the improved stability of the multienzymatic systems, added to the fact that no additional step of extraction and purification is needed. Immobilized cell anaerobic reactor, due to their capacity to retain biomass, are favored in terms of volume, microbial activity, and performance. Although most new reactors installed today use immobilized cell technology, numerous suspended biomass reactors are still in operation. However, the percentage of immobilized cell systems treating industrial wastewaters is continuously increasing.

The steps to the purification of water environment using effective microorganisms are indicated in Figure 12.

5. Estimation of Environmental Effects of GEMs

Originally, genetically engineered microorganisms (GEMs) were envisioned to be useful in the medical and industrial disciplines where GEM would be used to produce a specified chemical product which would then be isolated and used in a purified form (Ford 1993). Recently, the great potential of biotechnology for use in agriculture and for environmental applications has been realized. Genetically modified microbes are being developed to enhance waste-treatment technologies, bioremediate environmental pollutants, to serve as biological pest control agents and fertilizers, for use in regulating corrosion and biofouling in cooling systems and other liquid transport and delivery systems, and for other environmental applications (Ford 1993). GEMs are currently also being used to develop organisms capable of performing specific commercially desired tasks, including those of potential use in ecological engineering. GEMs will have such diverse ecotechnological applications as fixing nitrogen, ore leaching, and degrading hazardous wastes. If the introduction of useful microorganisms to wastewater treatment by GEMs becomes successful, it will be possible to get a more smaller reactor and lower cost wastewater treatment process. For example, the substances like PCB and trichloroethylene are difficult to decomposed, if the microorganisms which can decompose such substances are able to be created by GEMs, this will mean a great development in wastewater treatment field. However, despite this potential usefulness, there is a lack of development of adequate risk assessment methodologies for those GEMs that are deliberately introduced into the environment. Therefore, the Japanese Environment Agency has appealed that it is necessary to make a legal regulation for GEMs in the use at open systems since 1990. But the legal regulation is still under consideration. Although the guideline was determined in each Ministry, there is no concrete assessment method for the environmental effect of GEMs. It is still unable to use this technology in open system in Japan.

As the limitations of conventional ground water and soil cleanup technologies become more apparent, research into alternative cleanup technologies will intensify. Bioremediation is an especially attractive alternative because it is potentially less costly than conventional cleanup methods, it shows promise for reaching cleanup goals more quickly than pump and treat methods, and it results in less transfer of contaminants to other media. The most important principle of bioremediation is that micro-organisms (mainly bacteria) can be used to destroy hazardous contaminants or transfer them to less harmful forms. The goal in bioremediation is to stimulate microorganisms with nutrients and other chemicals that will enable them to destroy the contaminants. The bioremediation systems in operation rely on microorganisms native to the contaminated sites, encouraging them to work by supplying them with the optimum levels of nutrients and other chemicals essential for their metabolism. Thus

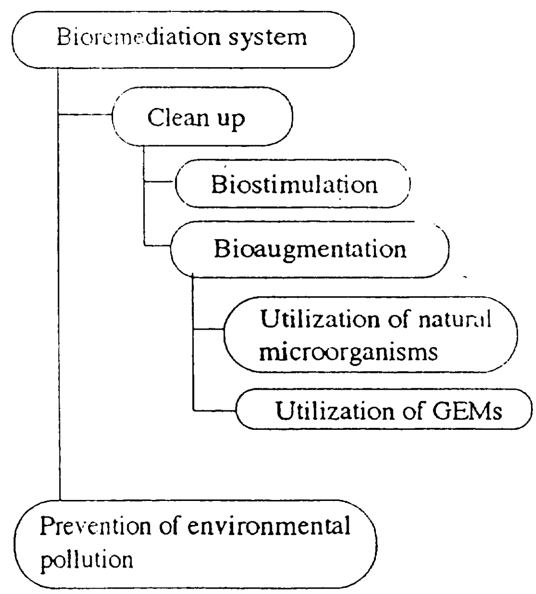

Figure 13 The concept of bioremediation systems

, today's bioremediation systems are limited by the capabilities of the native microbes. However, researches are currently investigating ways to augment contaminated sites with nonnative microbes including GEMs specially suited to degrading the contaminants of concern at particular sites. It is possible that this process, known as bioaugmentation, could expand the range of possibilities for future bioremediation systems (Wood et al 1993). The basic concept for bioremediation system is shown in Figure 13.

To prevent environmental damage from GEM release, future testing procedures must have a broad scope to ascertain realistically the probability of some damages before environmental or economical damage is incurred by either private or public factions. Ecological engineering studies, using microcosm, greenhouse, and field data, will generate basic ecological information concerning the fate of GEMs and their recombinant DNA in nature. Ecotechnological assessment such as microcosms and mesocosms, can be designed to evaluate adequately the potential for adverse effects prior to the actual release of the GEM. Microcosm-based tests examining critical functional attributes of ecosystem compartments will have general applicability to a variety of ecosystems.

Ecological microcosms are small ecosystems held in containers. Starting originally as a way to bring the beauty and complexity of nature into schoolrooms and living rooms the world over, these small "worlds" have become a major research tool. They are useful for studying the way ecosystems work and for the very practical purpose of determining what happens to toxic substances in ecosystems. Microcosms are important because they are a way to study whole, simplified ecosystems, and because they can be replicated for experimental studies at reasonable cost. There are aquaria, terraria, circulating streams, long tubes to represent deep waters, and microcosms large enough to include people. Ecological microcosms can be as small as a few milliliters or as large as an armory (Beyers et al, 1993).

Inamori et al (1990, 1991) examined the env

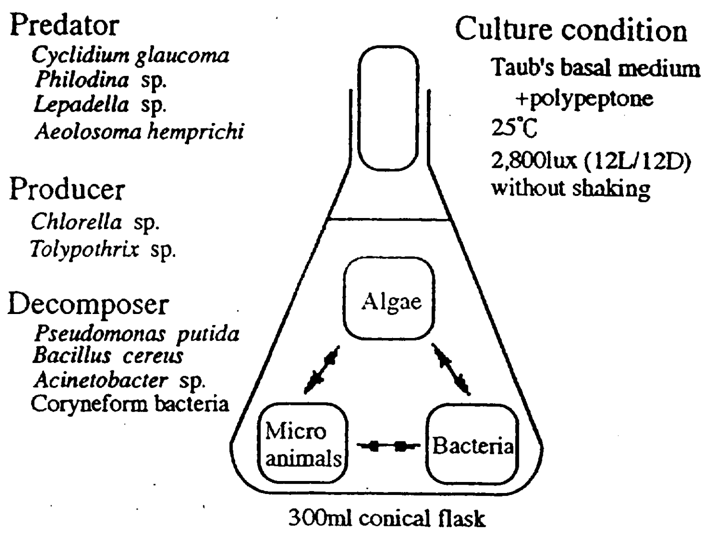

Figure 14 Outline of microcosm test used

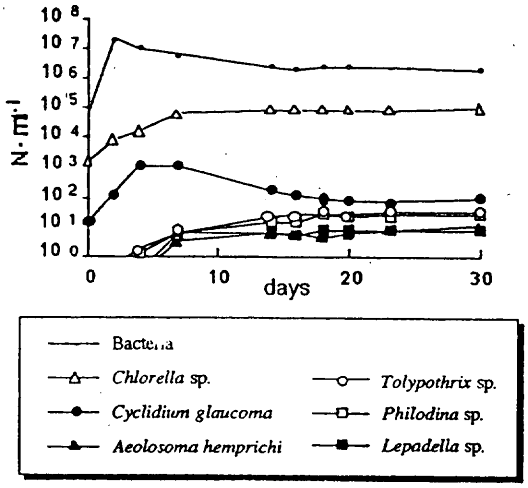

Figure 15 Growth curves of microorganisms in microcosm system

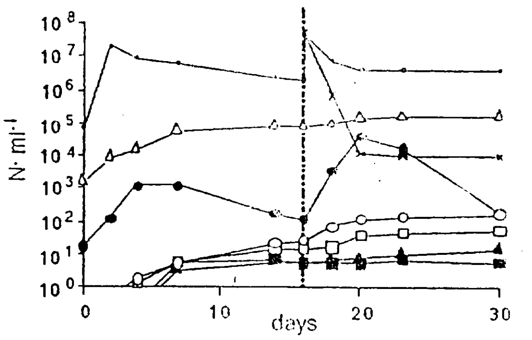

Figure 16 Growth curves of microorganisms in microcosm system inoculated with GEMs

ironmental effects of GEMs by using originally developed microcosm system(Figure 14). Figure 15 shows the phase of various microorganisms in the microcosm system. Stable ecosystem was consisted by bacteria, protozoa, algae, rotatoria, oligochaeta in this microcosm. The GEMs was incubated and inoculated to this microcosm (Figure 16). If the GEMs in microcosm system decreases remarkably or disappears, then it means no environmental effect of GEMs. The results showed that GEMs decreased transitory, and kept even density, the survival potential was quite low. Therefore, it may be concluded that advanced wastewater treatment processes using GEMs are expected in the near future. Further study is needed for ecological and environmental effect of recombinant DNA.

The process of environmental assessment of gene recombination microorganisms using microcosm is shown in Figure 17.

6. Summary

(1)The current state and effective application of ecotechnology and biotechnology to the restoration of water environment, and the prospect of the new technologies for biological water and wastewater treatment in Japan have been presented.

(2)As a cost-effective, energy-saving and less technique intensive innovation/alternative, ecotechnology and biotechnology may be more important and useful to water environmental conservation.

(3)Wetland system, aquatic plant system, land treatment system, stream purification system, and some biological wastewater treatment systems will be established in the near future.

(4)The technical development for the removal of nitrogen and phosphorus by using the combination of ecotechnology and biotechnology, and the efficiency promoting for the biological water and wastewater treatment must be carried out to prevent eutrophication.

(5)The genetically engineered microorganisms (GEMs) and bioremediation are expected to be used in the restoration of water environment in near future, although it is still not practical due to having the possibility to influence the ecosystems.

(6)Many studies, both science and engineering, are needed to develop an effective treatment system which provides suitable habitats of aquatic livings.

(7)Furthermore, the importance of international cooperative studies has been increased because the water pollution of international rivers and oceans become more serious problems and it is recognized that emission of green house effect gases from deteriorated water environment and wastewater treatment may cause global environmental problems.

To create and conserve the sound water environment, developed countries including Japan have a great responsibility to developing countries, and we believe that international cooperations among these countries would save our environment.

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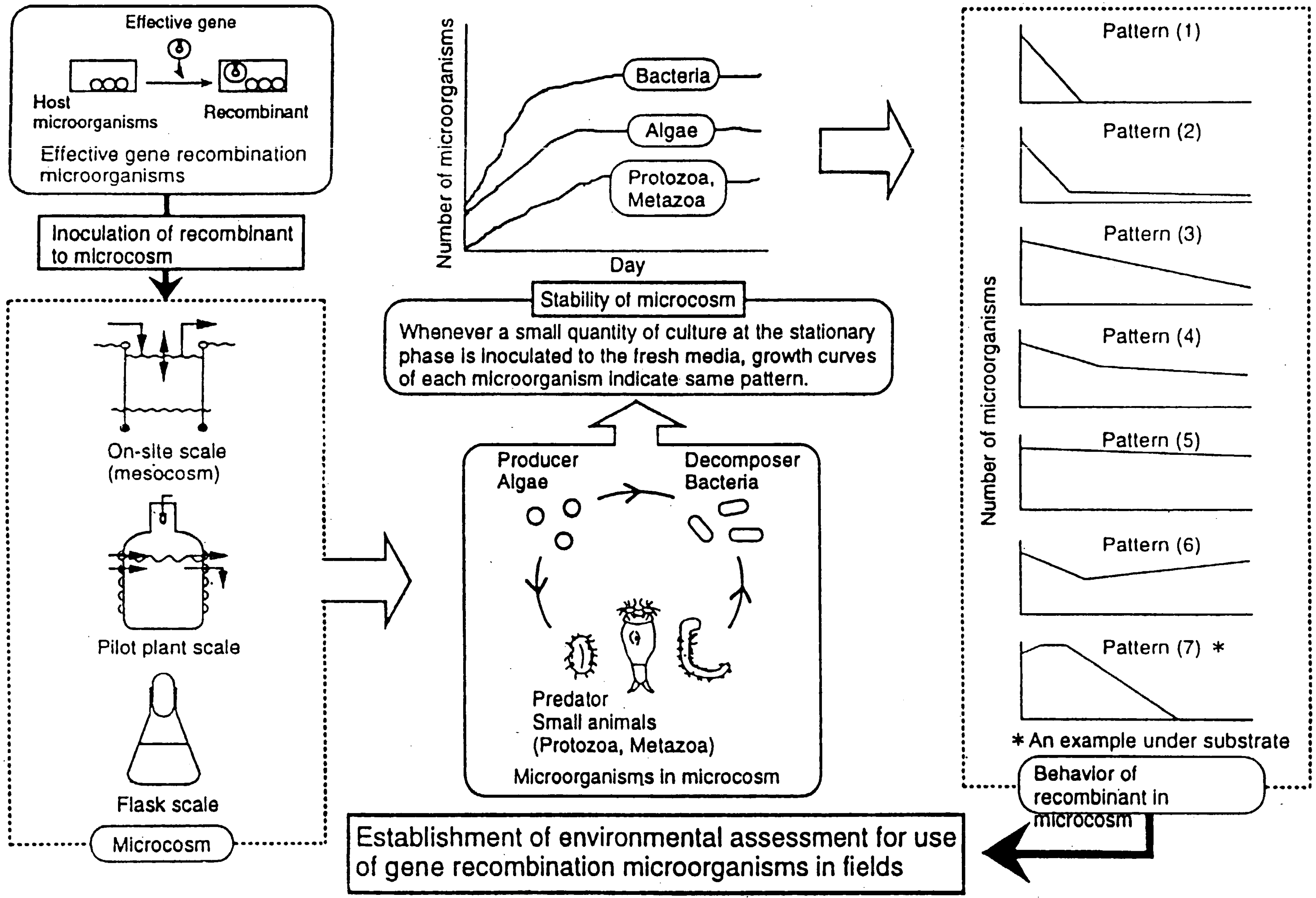

Figure 17 Environmental assessment of gene recombinanation microorganisms using microcosm

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All-Russian Research Institute for Nature Protection

9th Northeast Asian Conference on Environmental Cooperation
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Ulaanbaatar, Mongolia

WATER POLLUTION CONTROL IN THE RUSSIAN FEDERATION

The presentation overviews activities on environmental control in the Russian Federation: it briefly describes the present trends in changing quality of surface water. The author cites the basic data on control technologies and procedures focusing on introducing into practice the newly elaborated economic approaches, and also puts forward proposals on organizing control of surface water quality within the international ecomonitoring network.

1. STATE-OF-ART OF SURFACE WATER CONTROL IN THE RUSSIAN FEDERATION

The Russian government policy in the field of water protection is guided by the main principles of the «Lawon protecting the natural environment and «Water code of the Russian Federations It is implemented by coordinated efforts of several agencies State Committee for Environment Protection, Ministry of Natural Resources, State Committee for Hydrometeorology and Ministry of Health of.

The main objectives of the government ecological control of water bodies are detecting pollution sources, setting up standards for pollutants discharge with due account for total anthropogenic loads, supervising standards observance, and ecomonitoring.

Control Systems

Environmental observations in the Russian Federation are carried out by the State Ecomonitoring Service (SES) based on the units of the Russian State Committee for Environment Monitoring (Roscomhydromet).

To evaluate the present state, forecast changes in the environment pollution level in regions located at a distance over 100 km from sources of anthropogenic pollution (baseline regions) a system of integrated baseline monitoring has been created. Today it has over ten stations in biosphere reserves, four of which are located in the Asian Russia.

The results of observation of basic parameters of surface water and pollutants concentrations analyzed by atomic absorption spectroscopy, etc. have been disseminated in monthly and annual publications since 1973.

Alongside the federal, the regional ecological control systems are operating in Russia.

The Russian Federation State Committee for Environment Protection whose affiliation is the All-Russian Institute of Environment Protection (VNIIPriroda), control of surface water quality is carried out by a network of specialized inspections of State Ecological Control and Analysis (SIGEKA) operating in 89 subjects of the Federation. A network of specialized inspections is intended to perform the necessary and sufficient control of indicators of state-of-art of anthropogenic and technogenic pollution of air, water and soil.

Affiliated to the Republic (district and territory) committees (ministries) for environment protection are 244 analytical centers (SIGEKA) with about 2,000 employees including 1,600 chemists-analysts.

The total number of objects controlled by specialized inspections is 17,650 sources of water pollution.

The list of pollutants controlled by the system of State Committee for Environment Protection comprises 227 items including 64 pesticides.

Control over sources of the anthropogenic pollution of water bodies is carried out along 17-60 parameters.

The recent years have witnessed an improvement in the logistics of the analytical laboratories. Photocolorimetric and titrimetric methods are replaced by high production and more sensitive techniques, e.g. chromatography, atomic absorption, mass spectrometry, etc. Broadly used are modern instruments for fluorescent assay «Ftuorat» («Lumex» firm, St. Petersburg), atomic absorption spectrophotometers «Quant-AFA» («Kortek» firm, Moscow), portable analyzers for dissolved oxygen, petroleum products analyzers KN-2 (Novosibirsk), and solid electrode polarographers («AVA», St.Petersburg, «IVA», Tomsk), etc.

In 1997 several laboratories of the State Committee for Environment Protection located in the Asian Russia (Magadan, Irkutsk, Kemerovo, Tyumen, etc.) have received several million dollars worth of modern analytical equipment supplied within the framework of Gore-Chernomyrdin Commission under the Program for Import of Energy-Saving Technologies and Environmental Equipment. It will allow radically increasing the number and quality of assays, controlling a larger number of water pollution indicators, and creating a system for global ecomonitoring upon supplying the equipment for data processing and delivery.

The VNIIPriroda and Moscow Region Committee for Environment Protection of the State Committee for Environment Protection serve as a basis for the Federal Environmental Analytical Center that is being currently organized. It is capable of carrying out studies and control of all the presently known pollutants using the analytical equipment supplied within the framework of Gore-Chernomyrdin Commission under the Program for Import of Energy-Saving Technologies and Environmental Equipment (PIESTEE).

Methodological Support

Special attention is paid to standardizing the methods for water assay to ensure compatibility of results of laboratories affiliated to different organizations and agencies. For this purpose the authorized government bodies of water protection have signed an Agreement on creating a unified system of standards and methodologies for analytical control stipulating harmonized techniques for natural and waste water assay. These techniques have been certified by the metrological expertise of the State Committee for Standards. The Government Register of water assay techniques supervised by the State Committee for Environment Protection comprises 120 methods for evaluating with adequate precision and sensitivity the content in water of major mineral and organic pollutants.

Ecomonitoring of water basins is also in the focus of attention.

The R & D in analytical techniques are based on various optical methods:

- Laser fluorescent method offering a variety of sample preparation options to evaluate toxicants in the air, bottom sediments and water with the threshold level equal MAC and below;
- Nuclear absorption method with laser atomization of samples to evaluate heavy metals in soil and bottom sediments;
- Refractometric methods to control technological processes and water purity.

The developed methods and equipment are used on three levels of ecological control:

1. Automatic unmanned, relatively simple in operation and inexpensive testing instruments for continuous automatic control of the state of environment in selected points;
2. Mobile analytical equipment for operational detailed analysis of the emerged and progressing environmental pollution,
3. Laboratory instrumental and methodological complexes for in-depth analytical studies of pollution.

The degree of finalizing the above-mentioned R & D varies from working out methods to creating a prototype analytical instrument. Currently the scientists have elaborated the isotope spectral methods and designed equipment to control environmental impacts of nitrogen fertilizers use in agriculture (nitrites accumulation in agricultural products, natural and communal waste water pollution by nitrogen compounds), and to assay waste water from livestock breeding and industrial (pulp and paper) complexes.

The above-mentioned methods are intended for arbitration analysis of sophisticated samples and metrological certification of rapid assay sensor techniques.

A prototype isotope analyzer «Azot-15» has been prepared for laboratory tests at agrochemical stations. The threshold for nitrate detection is 4 mkg/kg in agricultural products and 0.1 mkg/ml in water.

A prototype automated refractometer has been prepared for continuous quality control of natural and waste water. Its operation is based on the principle of violation of total internal refraction. The analytical signal is related to the intensity of light passing along light guide. A refractometer can be mounted on both open water surface and pipelines. Measurements are taken continuously in an automated mode evaluating the concentration water-soluble substances affecting the medium refraction index. The range of detection is 0.01....70 mass%.

In view of a large variety of environmentally dangerous objects, and consequently a large number of characteristic spectral bands, variable size and remoteness of objects, it is practically impossible to design a universal optical observation instrument capable of detecting and reliably identifying a multitude of indications.

One should bear in mind that most environmentally dangerous objects should be continuously monitored in extreme climatic and temperature conditions. It was decided to work out a basic unitized design that could be adapted to solving any environmental mission on a short notice. The unit should be hermetically sealed and be capable of operating within a broad temperature range.

The prototype was based on the scheme and design on an optical communication receiver. Such communication system was developed, manufactured, tested and submitted to the customer. The device was adapted to meet the requirements for an optical observation system. An optomechanical unit comprises several functional components that could be modified, compute scaled and assembled on four Invar rods to meet the customer's demands.

The functional components are: input window (hermetic sealing, light separation wedge, meniscus or light filter are optional), meniscus unit, large mirror unit, small window unit, output optical unit, photo receiver unit, mounting, focusing and protection units. Today the basic design of all functional components has been finalized, except for input optics and photo receiver. These units are responsible for picture quality correction and spectral selection. The parameters depend of the customer's requirements, hence the design and optics are adjusted to the specification.

The optical scheme of a TV channel comprises a vertical sealed window, meniscus, large spherical mirror, small spherical mirror, correcting system of lenses, and photo receiver.

The lens is designed so that the cells of basic optical components (large mirror, small mirror and meniscus) responsible for picture quality and stability, are mounted on four Invar rods with calibrated spacers. The large mirror unit is unadjusted and incorporates shutoff devices. The meniscus units is also unadjusted. The precision of the units mutual installation is ensured technologically. The small mirror unit has independent adjusting shifts along and across the optical axis, and a gradient around the center of curvature. The main unit is covered by a sealed cover with a sealed window and output optical unit at the front side. The sealed cover has a mounting device and an input for dry nitrogen filling. As mentioned above, the main optical unit consists of mirrors that are not modified depending on the spectral band or purpose of the device. Modified are the scheme and design of the optical output unit by using the appropriate materials selectively reflecting or transmitting holographic or absorption elements.

Specification

Entrance pupil diameter, mm	210
Field of view, grad	3
Diffusion disk diameter, mm	50
Relative aperture	1/3

The blueprints of the developed units are being input in the computer with the purpose of modifying the design to solve a specific task.

It can be stated that theoretical, designing and technological problems of creating optical observational systems for various ecological purposes both with and without spectral selection have been in principal solved. We hope that publication of these materials would help establish business contacts with the organizations interested in developing or supplying multipurpose optical instruments with spectral selection.

Biotesting methods are being broadly introduced in various Russian regions to timely and effectively evaluate the general toxicity of waters based on the reaction of test organisms without carrying out a full chemical analysis of water.

Mobile hydrochemical laboratories with rapid assay techniques are used for preliminary studies of water objects (screening).

Legal Support

The legal support of environment protection and human health against pollutants is regulated by legal acts on various levels. The most important are the Constitution of the Russian Federation, Fundamentals of the Russian Federation legislation on protecting population health (1993), RF Law «On the sanitary and epidemiological well-being of the population» (1991), RF Law «On protecting consumers' rights» (1992), RF Law «On protecting the natural environment (1991), RF Law «On ecological expertise» (1995), RF Law «On basic principles of town planning in the Russian Federation» (1992), Water Code of the Russian Federation (1995), RSFSR

Law «On protecting the atmospheric air» (1982). Certain aspects of environment protection and human health are reflected in the federal laws «Basic principles of forest legislation of the Russian federation^ «On the animal world», «On especially protected natural areas», «On continental shoal», etc.
The Administrative Code of the Russian Federation envisages administrative liability for various violations in the field of environment protection: exceeding the Maximum Allowable Concentrations (MAC) or provisionally agreed discharges of pollutants in the atmosphere; exceeding the standards of, maximum allowable negative physical impacts on the atmospheric air, discharge of pollutants into the atmosphere without permission by especially authorized government bodies.
The Criminal Code of the Russian Federation (1996) envisages criminal responsibility for environmental crimes.
The Constitution of the Russian Federation states that «universally acknowledged principles and standards of the international law and international agreements of the Russian Federation are part of its legal system. In the event an international agreement signed by the Russian Federation envisages the rules different from those stipulated by the law, the norms of the international agreement should be applied».
Among the most important international agreements ratified by Russia are the Convention on Long-Range Transboundary Pollution (1979) and Basel Convention on Control of Transboundary Transport of Hazardous Wastes and their Disposal (1989).
The basic regulatory and methodological documents on protecting the environment and population health against potentially hazardous chemicals are adopted by the USSR Ministry of Health and contain specific standards limiting the content of hazardous substances in natural objects, production and food raw materials, foodstuffs and industrial wastes.
In accordance with the RF Law «On protecting the natural environment the principal economic methods regulating environment protection are: cadasters of natural resources, ecological programs, payments for environment pollution, licensing and economic incentives. The above-mentioned methods constitute the economic mechanism of nature use and have a different degree of practical implementation. The most elaborated and operational since 1991 is the system of payments for environmental pollution. However with the changes taking place in the legislation on industrial relations it also requires improvement.
In accordance with the Constitution of the Russian Federation the issues of nature use, environment protection and ensuring ecological safety are jointly supervised by the Russian Federation and subjects of the Russian Federation. It implies that the subjects of the Russian Federation have a right to adopt lows and other regulatory and legal acts in the field th t should not contradict the federal ones.

2. POLLUTION OF WATER OBJECTS IN THE RUSSIAN FEDERATION

Today only 1% of the surface water in Russia correspond to the first quality class. Over a half of drinking water supply networks should be renovated because they are sources of secondary pollution of drinking water. A growing number of control tests leaves no doubt that the problem of water quality control hardly be solved by traditional methods.
Anthropogenic pollution of Russian water bodies - oceans, seas and large lakes, takes places via several routes.

1. Pollutants enter water bodies directly from a source located on the water body, e.g. off-shore oil extracting platform or a shore-based factory.
2. Pollutants are transported in a large water body by waterways from the continent both from point and diffusion sources.
3. Atmospheric pollutants from home sources enter a water object via its surface.
4. Transboundary transport of atmospheric discharges induces additional pollution that in some cases exceeds the home pollution.
5. Prolonged pollution from bottom sediments should not be ignored that under favorable conditions in a water body could be not only long-term but also quite significant, e.g. pesticides.

Therefore, a control system should take into account all the above-mentioned routes of noxious substances entry in water bodies. One should also realize that atmospheric pollutants comprise not only sulphur and nitrogen oxides but heavy metals compounds. This is particularly vivid in regions with unauthorized combustion and processing of oil (e.g. Checehn Republic), and use of coal and crude oil as a fuel of technologically obsolete boilers. Hence evaluating air pollution by sulphur and nitrogen compounds one should take into account heavy metals as well.

Calculations by a meteorological synthesizing center «Vostok» under EMEP program (Moscow) carried out in 1995 on a semispheric model (on the Northern Hemisphere scale) of sulphur and nitrogen oxides, ammonia nitrogen fallouts during five years show that a major inflow of pollutants is directed from the European countries. An exchange between the European Russia and European countries is 1:10, while the Asian Russia is subject to a lesser impact.

In Western Siberia 76% of pollution sources are local ones due to the world's most powerful source of sulphur dioxide discharge - the Norilsk mining and metallurgic works.

A third part of sulphur oxide fallout in Eastern Siberia are due to foreign discharges. A considerable contribution is made by China (15%). The European countries account for 8%, Kazakhstan and Central Asia - 7%. The remaining 2.% is contributed by Mongolia, Southern and Northern Korea and Japan.

The rate of nitrogen oxide fallout in East Siberia from foreign sources is not significant. Ammonia nitrogen fallout from Asian countries in Eastern Siberia is about 70% with China contributed 64%.

Water pollution is far from limited by waste water that is being monitored and taken into account. An increasingly important role is played by dry and wet pollutant fallout from the atmosphere. The density of sulphur fallout in Russia varies from over 2.0 to 0.25 t/sq.km per annum. With the water bodies area of about 0.5 mln sq.km the sulphur fallout on their surface is estimated at 500 thou. tons per annum. But sulphur precipitates on catchment areas and also on snow cover, and is transported to water bodies by snow welt and rain water. The same is true of other pollutants precipitated from the atmosphere.

The density of ammonia nitrogen fallout from the atmosphere is 0.3 t/sq.km or 5.5 mln.t for Russia. Out of this amount 150 thou.t is precipitated directly on water bodies surface, and the rest on catchment areas. At the same time ammonia nitrogen discharges in Russian water bodies are estimated at 186 thou.t Hence the dry and

wet precipitation from the atmosphere on water bodies surface are almost equal the ammonia discharge with waste water.
Dry and wet precipitation could be referred to as area fallout (unlike point discharges with waste water) that play an increasingly important role in water pollution. Apart from atmospheric fallout it comprises fertilizers and pesticides transported from farm lands by snow melt and rain water. According to the available estimates the runoff is estimated from 30 to 50% of the total amount of fertilizers and pesticides. Thirdly, the focal points of water area pollution are formed at landfills and dumping sites of waste from livestock breeding farms.
An important factor of pollution of natural water bodies are artificial water reservoirs with large amount of organic matter and vegetation buried during their construction. Besides, water stagnation results in eutrophication and modification of water passing through reservoirs.
In the last years water quality has sharply deteriorated in the Ladoga and Onega lakes, the largest lakes in Europe. The main reason is that all large water bodies in the European Russia have become accumulators of pollutants precipitating from the atmosphere. About 25 thou.t of sulphur and 15 thou.t of ammonia nitrogen fall out on the Ladoga lake surface annually. The basins of the Ladoga and Onrga lakes are subject to regular impacts by acid rains. The Ladoga lake water is polluted by copper and manganese salts, phenols and organic compounds at concentrations above the allowable standards. Pesticides are common here. The Onega lake is polluted mostly by organic compounds and petroleum products.
The global unique nature of Lake Baikal is well-known. Despite the Government decisions its pollution continues, forests are cut in the water catchment area, industries grow on the rivers flowing in the lake. The surrounding industrial zones contribute to precipitation on the lake surface of 15 thou.t of sulphur and 5 thou.t of ammonia nitrogen per year. Particularly significant is the pollution of the southern part of the lake with concentration of major industries polluting the air and discharging waste water in the lake and in-flowing rivers.
Drastic changes of water quality have been reported on the Sea of Azov that used to be a valuable fishing area. Due to large removal of water from the Don and Kuban rivers the fresh water inflow has reduced by about 1/4, and the salt content in the sea water is growing. A considerable amount of pollutants is transported by river water. The Don and Kuban rivers carry 13 cub. km of waste water a year, 60% of water treatment plants are ineffective. A large portion of 250 thou.t of fertilizers and chemicals used in the Kuban river basin are washed in the Sea of Azov. Large asphixiation and hydrogen sulphide areas appear in the sea in summer.
The cities and resorts in the Krasnodar territory discharge about 160 mln.cub.m of waste water in the Black Sea. Areas covered [illegible] an oil film are frequently reported here. In the last years showers wash down in the coastal zone large amounts of garbage and pollutants , organic and suspended matter increasing the *Escherichia coli* content in sea water. Pesticides have been detected in the Black Sea water, and mercury along the whole extent of the Krasnodar coast.
Main pollutants of the Arctic seas are oil, petroleum products, detergents, pesticides and heavy metals discharged by companies engaged in prospecting and exploitation of natural gas deposits, marine and river ships, depots of combustible and lubricant materials, cities, sea ports and villages located on the Arctic coast. Significant amount

of pollutants is transported by the North European Russian rivers and the Ob river in Western Siberia.

Biohydrochemical data show that surface water in the European Russia are subject to eutrophication and pollution by heavy metals, e.g. copper, zink, nickel, and also by pesicides and petroleum products.

Waterways in the Asian Russia are polluted mostly in industrial concentration sites, e.g. Rudnaya in the Maritime Territory, and densely populated areas.

Permanent pollution exceeding the allowable standards is reported in cities and villages located on the Pacific coast. The main reason is that most human settlements, including large cities Vladivostok, Magadan, Petropavlovsk Kamchatsky have practically no waste water treatment facilities.

Coastal marine zones accumulate pollutants precipitated from the atmosphere.

However, the issue of pollutants transport by large rives, e.g. the Amur with a large catchment area shared by several countries is important in the context of each country's contribution to the total pollution. It implies not only controlled discharges but also atmospheric fallout in each country. It is easier to evaluate the pollution by rives crossing the countries borders, e.g. Razdolnaya (called Sui Firr .He in China). Particular attention should be paid to the Selenga river with the catchment area beyond the Russian borders and pollutants flowing in Lake Baikal - an internationally protected object.

The best solution of controlling pollution of transbounddary waterways would be creating a protected area in the water catchment area, e.g. the Tumannya river (called Tumangan in China and Democratic Republic of Korea).

3. PROSPECTS OF IMPROVING THE SYSTEM OF SURFACE WATER QUALITY IN THE RUSSIAN FEDERATION

The most actual problem in the near future would be working out indicator means for rapid assay of drinking water quality and sources of industrial and drinking water supply with a system of indicator and evaluation scales. In this context the analytical methods will be used for arbitration purposes upon detecting toxic properties by biotesting methods.

Recently the world has witnessed a rapid development of the state of environment indication methods based on various biotest systems highly sensitive either to numerous toxicant classes (indicators of general toxicity of water operating in real time at water intake or discharge points) or selective sensitivity to individual chemicals (indicators of the presence of a specific substance or class of substances in a mixture).

Analysis of the recently published «Methodological recommendations on applying biotesting methods to evaluate water quality in industrial and drinking water systems' most recommended techniques are based on the visual count of cells or organisms exhibiting different reaction to an impact. These methods are labor and time consuming, and cannot be automated, i.e. not fully satisfying the requirements to be met by toxicity indicators, namely the timely indication of toxic properties in a water source or discharge.

The most prospective in terms of pollution indication are the methods based on registration of parameters of physical processes, since it allows automating the

technique, making it operational and objective. One of these methods is measuring the luminescence of living objects.
The ability of plants to luminescence under direct light impacts is well-known. In the recent years the plant luminescence was used for biotesting. The tests are noncontact, low-damage and allow diagnosing changes in the physiological status of plants under the impact of various factors. At the same time their use is complicated by objective difficulties in interpreting the results due to extremely sophisticated and variable luminescence mechanisms.
The sphere of application of this biotesting technique is limited to pollutants negatively affecting photosynthesis, particularly herbicides, heavy metals, unbalance concentrations of biogenic elements, UV, heat, etc.
Under a growing diversity of toxic substances we face a growing importance of searching for and developing new analytical test-systems for detecting environmental substances hazardous for human health (anthropotoxicants). Among them are biological analytical test-systems offering an integral assessment of the environmental situation. Unlike analytical chemical methods they are aimed at qualitative detection of specific substances, and allow characterizing the environmental pollution as a whole.
The present attempts to evaluate the state of environmental pollution, e.g. analyze air, water, soil for toxicants by differential methods of analytical chemistry, are expensive and time consuming, not coping with the rapidly changing environmental situation. Obviously, modern equipment for detecting pollutants should be capable of rapid integrated assessment of the state of environment, and be cost-effective. Such rapid assay should precede but not exclude chemical and analytical expertise to identify the chemical nature of a toxicant. Therefore integrated biotesting methods should be classified as initial, bearing the main load of preliminary investigations of environment objects. A spectrum of test-objects for modern biotesting is extremely broad. It comprises one-celled (microorganisms, yeast, protozoa) and multicellular organisms (fish, insects, mollusks), sub-cellular particles (mitochondria, chloroplasts) and, finally, bioplymers (ferments and polyferment systems). Extremely diverse are the analyzed functions used as indicators of toxic impacts of air, water and soil samples, e.g. vital activity, respiration, photosynthesis, contractibility, etc.
A detailed analysis has allowed formulating the basic requirements to a hypothetical test-system for biotesting pollutants and anthropotoxic components of the environment, namely:

1. A measuring technique for registering the test-system function should be based on a highly sensitive method capable of analyzing substances in nano- or microgram range of pollutants concentration;
2. The selected system should ensure a maximum broad and integral evaluation of a multitude of toxicants in the studied medium;
3. A test object should maintain functional activity for a long time,
4. The registered function used for characterization of a pollutant or medium toxicity should be suitable for qualitative evaluation of the environmental situation;
5. A technique for measuring toxicity should be simple in operation, rapid and replicable;

6. A measuring cycle should be performed at a specialized measuring instrument adapted for ecological expertise;
7. Components of a measuring systems (chemical reagents and instruments) should be inexpensive and easy-to-access.

Studies by the Research Institute of Physiology in St. Petersburg have shown that the closest to the ideal are bioanalytical test-systems based on such natural objects as leucocites of human peripheral blood or ferments of oxidaze-peroxidaze cycles. Such test-systems induce bio- and chemoluminescation that significantly decrease in the presence of various pollutants: heavy metal ions, products of incomplete combustion or oxidation, organic compounds, petroleum products, etc. Measuring luminescence by a luminometer allows qualitative assessment of environmental pollution.

Application of high-effective luminescent method is known in the ecological expertise practice. For example, reaction of luminescent microorganism to toxic agents by turning of their own luminescence was used in a commercial technology by the MICROBIX firm, USA. However the capabilities of the method are limited by the nature of a test-object that cannot be used to evaluate environmental pollution in a selected nano- and microgram range. The cell nature of the test-object selected by the firm significantly reduces high sensitivity of the luminometric method. By a joint effort a number of St. Petersburg research institutes have improved the ferment analytical biotesting system and created the EXPRESS-ECO-TEST instrument. The ferment ecotest technology more fully meets the above-mentioned demands. The test sensitivity in the nanogram range is ensured by a luminometric measuring technique. Evaluating a pollutant content in a studied sample is carried out both integrally and qualitatively. The instrument is simple in operation and characterized by rapid measurement (several minutes), long-term functional activity of test-objects, and easy-to-access raw materials to produce reagents.

Modem methods for studies and control of water pollution will be further improved and put into environmental control practice in the Russian Federation.

The existing set of control indicators cannot cover all the pollutants that have standard values in the Russian Federation. To increase the control system efficacy both the number of indicators and observation stations should be increased. Today it is complicated by economic constraints. To reduce expenses and improve the data quality Russia proposes an integrated use of bioassay, bioindication (for integrated assessment of water environment and biota capacity to neutralize pollutants), and also biosensor techniques for identifying nano-toxicants alongside absorption and spectroscopy methods. A network of observation stations should be based on a basin principle.

4. PROPOSALS ON ORGANIZING AN INTEGOVERNMENTAL NETWORK OF REGIONAL CONTROL AND MONITORING

To carry out a higher quality control of acidification and pollution of the environment in the existing conditions, the Russian part considers it expedient to organize a network of intergovernmental ecomonitoring. Recent studies have shown a correlation between human health and pollution of the air, water, soil and vegetation by heavy metals and organic toxicants. It has been stated that combustion of liquid and solid fuel at technologically imperfect installations results in environment pollution by heavy metals. Such interrelations are clearly traced at water catchment areas during an integrated analysis of pollution of different media and biota reaction. In this context the following aspects are of special importance:

- Creating a shared database on the existing observations of water, air and soil pollution in North East Asian countires,
- Intercalibration of analytical equipment and methods;
- Creating a unified coordinated observation system using the monitoring networks operating in each country;
- Working out proposals on regional standards for environment quality;
- Setting up observation stations at borders between the countries;
- Creating an intergovernmental Commission on monitoring in North East Asia;
- Working out an acceptable for all North East Asian countries liability for transboundary air and water pollution;
- Evaluating environment pollution and human health in small river basins being a major landscape and territorial unit;

Setting up the first station of integovernmental monitoring network at the Tumannya river basin shared by Russia, China and Democratic Republic of Korea. It is a concentration or the animal species listed in the Red Data Book, protected by three conventions and falling under the jurisdiction of two more nature conservation conventions.

FOR THE 9th NORTH EAST ASIAN CONFERENCE ON THE ENVIRONMENTAL COOPERATION

THE CURRENT SITUATION OF WATER CONTAMINATION AND PURIFICATION IN MONGOIIA

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1. THE COUNTRY

The territory of Mongolia occupies 1.56 million km^2 in central Asia at an average elevation of 1,600 m above sea level, the highest point reaching an altitude of 4,653 m, and the lowest being 553 m above sea level. The climate is continental, with sharp contrasts and abrupt fluctuations in temperature. Precipitation is low. Sixty-five per cent of annual precipitation occurs in the summer; very little snow falls in the winter; spring is extremely dry and windy.

2. WATER RECOURSES

Some 1,200 lakes and 6,900 springs can be found in the country. The annual volume of water resources is estimated at 34.6 billion m^3, of which 28 consist in run-off water. Surface water resources are 22.0 km^3 and the ground water resources are 6.8 km^3. The territory of Mongolia divided into three large watersheds in the central and eastern Asia, namely:

- Northern Arctic Ocean Basin (AOB) (51 per cent of the precipitation and 20.5 per cent of the territory)

- Pacific Ocean Basin (POB) (37 per cent of the precipitation and 67 per cent of the territory)

- Central Asian Internal Drainage Basin (ADB) (12 per cent of the precipitation and 12.5 per cent of the territory)

The demand for water is increasing due to expanding industrial activity, and the problems of scarcity and contamination are becoming one of the environmental problems. Water resources in Mongolia unevenly distribute in space and time. The water resources of the northern territory are sufficient for all water users. But in the Gobi and desert areas, where are no large or medium rivers, perennial lakes and oases, the most serious water deficit problems are occur. Water resources are amounting on the yearly basis to 24,000 cubic meters per capita and 19,000 per km^2. However, in semi-desert areas these figures decrease to 4,000 and 1,500 respectively.

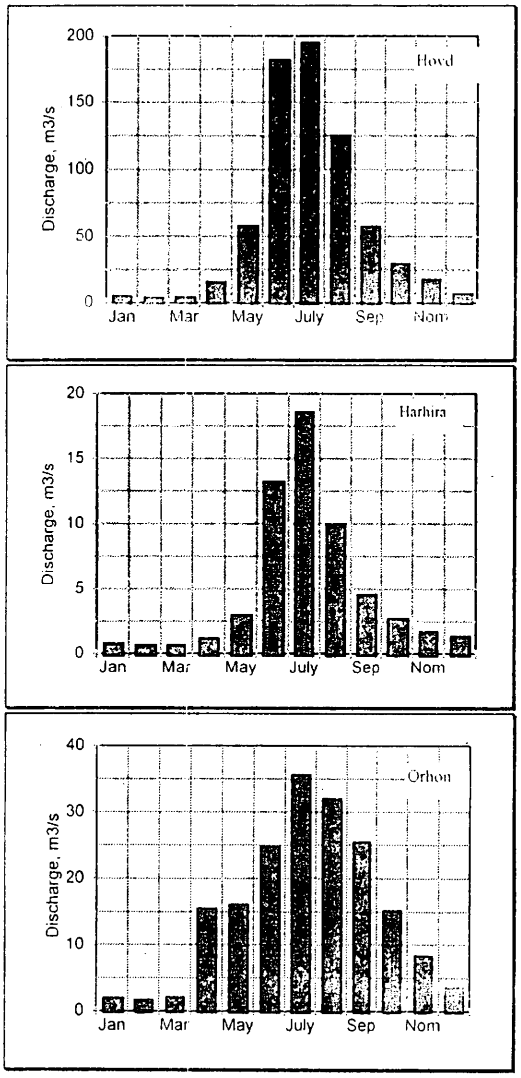

Figure 1. Annual variation of selected river in the different basins

The annual precipitation in Mongolia is 361 km^3 or 230 mm, and roughly 90 per cent of it lost to evapotranspiration, about 6 per cent is surface run-off. Most (95 per cent) of this surface run-off flows out of the country's territory.

There are four main climatic water regimes observed in the rivers of Mongolia. These are:
1. Winter low flow period which lasts approximately from December to April;
2. Spring runoff period due to snow melting which lasts approximately from April to June;
3. Summer runoff period due to rain, which lasts approximately from June to September
4. Warm season low water period, which follows after rainy season and lasts to the winter low flow period. However, this includes the short periods between floods due to rain.

3. WATER QUALITY

Water quality monitoring network

The systematic investigation of the quality of national surface waters was begun in 1946 by the National Hydrometeorological Board in Ulaanbaatar (recently Agency for Hydrometeorology and Environment Monitoring) and intended to provide baseline data on water quality in Mongolia. From then, until the end of 1970, although the number of sampling stations were increased from year to year, only a limited number of variables, such as dissolved salts, major ions, pH and hardness were carried out.

At the end of 1970, there was a shift in interest in water quality monitoring from major ions to nutrients, organic and inorganic pollutants. Also, a number of stations were established in order to monitor the degree of water pollution in rivers flowing through provincial centers and industrial areas.

At present, surface water quality monitoring is carried out in laboratories on samples taken manually. The manual monitoring network comprises approximately 110 stations distributed throughout the national hydrological network. The main objectives of the monitoring are to gather information about the present state of the rivers or lakes and to control the quality of the surface waters. Particular attention has been paid on the parameters, which to be analyzed and the sampling frequency. For example, in settlement areas, the frequency of sampling is once a month and all possible parameters are analyzed. The rural area is monitored every two months, with selected parameters.

Any discharges of pollutants into natural waters (rivers, lakes, reservoirs, etc.) in excess of their self-purification capacities, qualifies as water pollution. When this occurs, the water can no longer be used for activities like drinking, swimming, etc. The principle source of water pollution in Mongolia can be classified as domestic sewage, industrial wastewater, agricultural and livestock wastewater. Industrial wastewater, which is generated by a variety of production activities, contains hazardous substances such as heavy metals. Unlike household effluents, the heavy metal concentrations in industrial wastewater are high, posing serious threats to the environment.

Mineralization of water depends on the level of the particular bed from sea level. Rivers of Altai, Hangai, Hentii Mountains are less mineralized which are around 50-100mg/l. The lower riverbed rivers are more mineralized because of the differing composition and quality of the land surface and minerals, lower rain and snowfall, and higher vaporization. The mineralization can be as high as 200-300 mg/l and during the dry season it can be even higher.

It was estimated that 31 percent of the population used piped water with an average consumption of 96 lpcd. 18 percent of the urban population using surface water, which is below standard and 45 percent of the water sources are below standards. In terms of mineral content about 80 percent of sources were acceptable according to local quality standards.

The river water quality

It is important to illustrate status of the river water's chemical composition and condition of quality through interpreting the row data of the river water's chemistry and quality to make them accessible to the users. By chemical monitoring, the river water quality is carried out such parameters as ammonium, nitrite, nitrate, phosphate, pH, oxidability or permanganate value, dissolved oxygen, BOD and some metals like iron, manganese, chromium and others in addition to basic chemical compositions.

As has been studied (P.Batima, 1997) the concentrations of water quality parameters in the rivers in Mongolia compared to the Maximum Acceptable Concentrations (MAC).

there was not observed any remarkable pollution. Nevertheless, ammonium concentrations are among the highest of the nutrients. There was not found a strong seasonality of water quality parameters in the river water. This allows us to make a conclusion that most of the rivers not yet affected by human activities. It not means that we are not polluting the rivers, but it is because only of the river's self-purification rate is higher due to their mountain origin.

The rivers are classified on the base of The Water Quality Index which evaluates the quality of water by parameters as ammonium, nitrate, phosphate, permanganate value and TSS (P.Batima, 1996).

The rivers in Arctic Ocean Basin are classified as acceptable. The quality of the river water is much better in Internal Drainage Basin, particularly rivers more than 50% of this area are 'clean'. The rivers in the Pacific Ocean Basin are mostly classified as acceptable; the quality is much less than the rivers in other two basins. It was also considered that the downstream of the provincial centers, river's water quality went down by 1 or 2 score points.

River water self-purification

Rivers are the natural collectors of rain runoff from drainage areas and sometimes receive direct or indirect discharges from industrial and domestic sources. Rivers are less sensitive receivers compared to lakes, as stratification does not exist, waters are aerated through their perpetual motion. Traditionally rivers in Mongolia have been the principal supplies of fresh water to population, agriculture, and industry. The presence of dissolved oxygen in river water is essential element for the aquatic life. Organic materials entering the river consume oxygen as they decompose.

In order to evaluate the self-purification of river the Streeter-Phelps model is used.

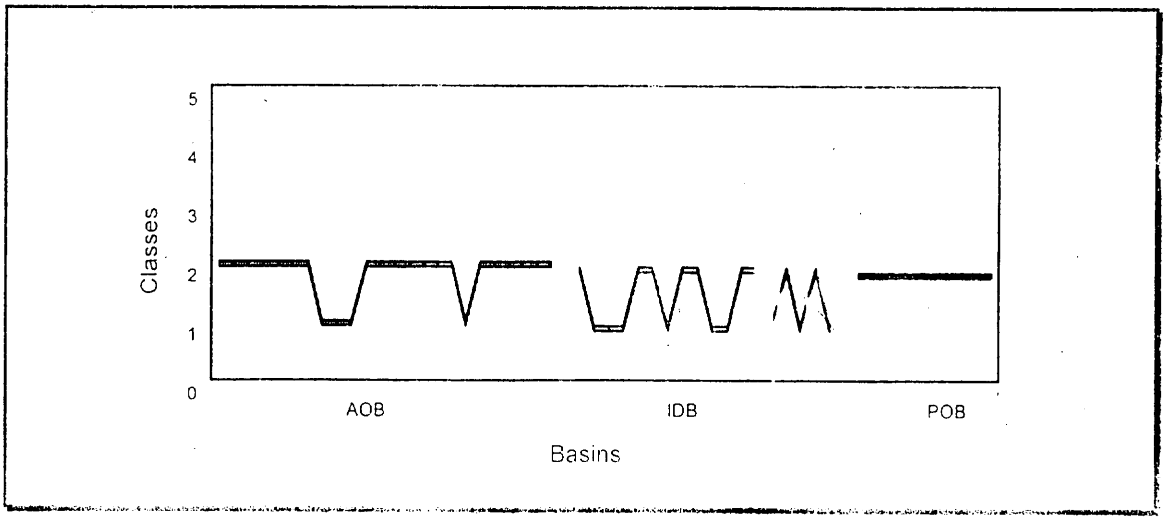

Figure 2. Graphical representation of water quality classes of the rivers in different basins

The result of self-purification some of the rivers running through province centers is given in the Table 1. It is clear that the distance of mixing and time conservation pollutants in the river are similar in those rivers. However the maximum possible concentrations of the BOD which can be discharged into the river are not quite same e.g. they differ from each other by tens of mg/l.

Table 1. Self-purification parameters of selected rivers.

River	BOD, mg/l	BOD load, kg/hr	Conservation time, day	Mixing distance, km
Selenge	65.1	5274	20	20
Ider	94.5	7573	15	10
Muren	73.5	1238	15	10
Orhon	14.1	2145	15	5
Haraa	46.6	5639	10	10
Eree	84.5	2415	15	10
Herlen	53.6	1671	15	10
Hovd	110.5	1651	15	10

From the result of this model it can be concluded that as the rivers in Mongolia takes their origin of mountainous, water of the rivers is cool and clear. Most of the rivers, especially in rural areas are not yet affected by human activities and we could suggest that the rivers have high carrying capacity or good self-purification rate.

4. WASTE WATER TREATMENT

The discharge of untreated or inadequately treated waste water into the environment is the basic type of pollution, deteriorating water quality. As the end of 1999, the nation's sewage treatment facilities were able to handle 39.8 % of all daily sewage generated nationwide. However as only 64.2 % of the country is served by sewage pipes and as treatment facilities are still using antiquated equipment, much sewage flows directly into rivers.

There are 120 wastewater treatment plants throughout Mongolia. There are difficulties with maintenance of worn equipment, high cost of maintenance and repairs.

According to 1995 statistics, the total discharge of waste water was 126.4 million cubic meters, of which 42 per cent come from sewage, 46 per cent from industry, and 12 per cent from rural areas. 65.6 per cent of total wastewater treated and about 43 million cubic meter wastewater discharged into the environment without any treatment, mostly into the surface water sources.

Water [illegible] in the [illegible] reser[illegible] [illegible] and because they are located in the [illegible] [illegible] areas located [illegible] middle or lower parts of river, which account for about 67 % of all potable water, constantly receive wastewater from nearby cities or production facilities.

Only 32.4 percent of water sources have protective sanitation zones. 70 cities were subject to potential industrial pollution, and at least 47 of these had no realistic prospect of relief from pollution.

Many settlement areas don't have sewage treatment facilities, and in some of them WWTP either doesn't work at all or are working much below their capacity.

Due to factors such as rapid population growth, urbanization and industrialization, the quality of both surface and ground water resources are deteriorating, especially around settlement areas. The principal sources of water pollution in Mongolia are industrial discharges, domestic effluents, run-off water of urban areas and run-of from agriculture areas.

The major cities and most aimag centers are served by sewerage systems. Associated sewage treatment plants provide mechanical and biological treatment in larger systems and primary settlement or pond systems in smaller ones. Most industrial wastewater is discharged to the public sewerage system. USAG (Ulaanbaatar water supply company) has an industrial pretreatment plant, but it does not function efficiently. USAG's treatment capacity was designed for 21,000 m^3 per day but today the plant treats only 13,000 m^3 a day. The leakage of the water supply network is real threat to the groundwater of this area and the Tuul River, one of the important rivers in Mongolia. USAG has no standby power generation, so that in the event of a power failure the entire raw domestic and industrial wastewater flows are diverted directly to the Tuul River. [illegible]

5. LEGISLATIVE FRAMEWORK

The Government policy on ecologically sustainable social and economic conditions is to be implemented through legislative documents, long-term programs, planing of activities, coordination and projects. During 1990-[illegible] the Parliament enacted package of laws and concepts regarding coordinating development with natural environment.

Institutions

Modern water management history in Mongolia goes back more than 60 years. Due to economic reforms and structural changes, Ministry of Water Management was abolished in 1986. Most of the functions performed that ministry, were transferred to the Ministry of Nature and Environment. Since the end of [illegible]87, the ministry of Nature and the Environment has [illegible] charge of water [illegible] management policy [illegible] before the [illegible] Water [illegible] and Mine [illegible] and more environment aimed at improvement of the level of proper use of water resources and wastewater treatment activities.

The NWPP defines the basic strategic trends on water sector and has three phases of its implementation (I phase up to 2000, II phase 2001 - 2005, III 2006 - 2010). Within the program the Cabinet established the National Water Committee, which in charge of organization, regulation and monitoring on the program implementation. National Water Committee has local coordinating sub-committees in each aimag (administrative unit).

International cooperation (implemented and ongoing projects in this field)

Since 1990 in Mongolia implemented (or ongoing) following projects, aimed to improve water service and purification activities:

Provincial towns basic urban services project
Rehabilitation of water supply facilities in Ulaanbaatar city
Ulaanbaatar service development project
Development of National water, sanitation and hygiene education programm for the 21st century
Improvement of water treatment equipment. And the quality and safety of water supply in the settlement areas are improving.

6. MAIN CHALLENGES EXISTING IN MONGOLIA

According to the Mongolian Environmental Action Plan, actions to improve water quality have the highest priority, because over half of the population of Mongolia is at immediate risk from water pollution. The primary cause is the poorly controlled disposal of wastewater from common treatment facilities and from industrial plants (such as those engaged in meat processing, pig farming, and wool and leather processing).

During last years, government spent limited fund for water sector, especially for wastewater abatement activities. However, there is very important to introduce market-oriented approaches for combating wastewater pollution. Main concept is implementation of the fee system on wastewater, and the revenue will be used much effectively for wastewater purification activities. Only by improving resource utilization efficiency, reduction of pollution emission and prevention from deterioration of the water resources we could achieve the environmental sustainable development.

Another source of pollution is solid waste, and it is one of the environmental problems face capital city Ulaanbaatar. According to the Ministry of NE 1996, approximately 900 000 m3 of solid waste are generated each year. There are three waste disposal sites located within 20-30 km of Ulaanbaatar that are polluting the land of city's and river than 20 follow up Regulations on water management were initiated by the Ministry of Nature and Environment.

According to the Water law adopted in 1995, administrative authorities of all levels, from Parliament itself down to the local level, are given responsibilities and obligations in respect of water management.

Existing Standards

There are two types of water quality standards – Standard for classifying the degree of purity of surface water and its potential usage for different purposes, for specifying the quality of water to be used for a specific beneficial use and waste water standard.

1/ Government Resolution No.143/a/352 of 1989 presents "classification and surface water purity" where a surface water is classified into the following five purity grades:

Grade I	Highly Pure
Grade II	Pure
Grade III	Slightly Polluted
Grade IV	Polluted
Grade V	Severely Polluted

These purity grades are determined by several indices for oxygen condition, mineral composition, organic pollution, biological indices, toxic substances, and physical/sense. In addition, this standard also establishes water quality norms and requirements for water to be used for specific purposes, such as a community water supply, use in the food industry, recreational uses, and fish breeding.

2/ The Standard has two type of permissible maximum amount of pollution substances and its limit. Main purpose of this Standard is to set up permissible maximum amount of pollution substances and limits of wastewater discharge to the surface water and soil infiltration.

The wastewater discharge Standard parameters are identified by the water quality requirements of the rivers. In the Standard the total pollutant loads discharged from pollution sources should be controlled in concerning of the dilution capacity of the rivers and permissible contamination of discharge loads where determined.

The National Water Policy Program, 1999

This Program reflects overall related issues on water management activities including water resource, water quality, water uses and protection from deterioration and pollution of the water resources. The Program defined main and priority objectives as implementation of multi-stage activities on preventing from negative impacts on health of population by improving of water supply and quality, creation a economic and legislative

Tuul. In 1995, only 40% of the total solid waste in Ulaanbaatar, was properly disposed of; the rest was just dumped and is becoming a major source of soil and water pollution.

7. CONCLUSION

Water scarcity, the gap between human demand for and the availability of water in the required quantity and qualities, is the fundamental issue of the water supply in Mongolia.

Many users and communities are dependent on groundwater, the flow and availability of which are inherently more stable than of surface water.

At the present time water pollution is serious problem in Mongolia, especially in urban areas. Over half of the population of Mongolia at an immediate risk from urban air and water pollution and actions for reducing water pollution must include following issues: improving sewage and waste removal, improving and expanding wastewater treatment facilities including mitigation measures of most polluted rivers, and improving water quality monitoring.

The quality of water is concerning issue. Every group of users requires water of different quality, and total demand is increasing. There is very important to separate users by group: high quality drinking water must not used for industry and agriculture needs or for this reason there was not unnecessary treatment of water for purposes which do not require it.

Water quality degradation is an increasingly important issue. Water quality in Central and Northern part of Mongolia is heavily degraded, because of high population density, urbanization, comparatively high industrialization, and the general lack of pollution control facilities.

Based on the present data the most rivers in Mongolia are classified as "*clean*' and "*acceptable*".