BSPE 95591-00-1089-7

우리나라 반폐쇄성 해역의 부영양화에 대한 대책방안 연구

Managing Coastal Eutrophication in Korea

1997. 4

한국해양연구소

제 출 문

한국해양연구소장 귀하

본 보고서를 "우리나라 반폐쇄성 해역의 부영양화에 대한 대책 방안 연구"과제의 최종보고서로 제출합니다.

1997년 4월

연구책임자 : 권 문 상
이 원 갑
연 구 원 : 이 지 현
남 정 호
이 미 진
연구조원 : 조 회 정
이 연 정

요 약 문

I. 제목

우리나라 반폐쇄성 해역의 부영양화에 대한 대책방안 연구

II. 연구의 목적 및 중요성

본 연구는 우리나라 생태계의 건강성을 위협하고 연안 이용 행위의 쾌적성을 저하시키고 있는 '부영양화' 현안에 효과적으로 대처할 수 있는 관리전략 도출을 주 목적으로 한다. 연안 부영양화를 저감하기 위해서는 부영양화 원인물질인 육상기인 영양염의 해양으로의 유입을 줄이기 위한 총체적인 대책이 중앙정부, 지방자치단체, 시민, 전문가 등 이해당사자들의 통합된 노력을 통해 실행되어야 한다. 이에 본 연구는 연안육역과 해역에 대한 통합적 접근개념에 기반하여 비점오염원의 관리, 지역사회 중심의 관리전략 수립, 및 자료의 질관리 프로그램 운영 등에 중점을 두고 있다.

III. 연구의 내용 및 범위

이 연구는 총 5개의 장으로 이루어졌다. 제1장 서론에서는 연안 부영양화에 대한 정의, 부영양화 관리의 중요성, 부영양화에 대한 기존 연구의 검토 등으로 구성되어 있다. 제2장에서는 연안부영양화의 원인

규명을 위해 부영양화에 직접적인 영향을 미치는 다양한 인문사회적 지표의 변화양상 및 수질환경의 현황 등이 분석되었다. 이 연구보고서의 제3장은 연안부영양화를 비롯한 연안오염방지를 위한 정부의 관리체계에 대한 소개 및 분석으로 구성되었으며, 본 연구의 목적인 부영양화 방지를 위한 대안도출 및 활용에 대한 건의는 제4장과 제5장에서 각각 논의되었다.

IV. 결론 및 제언

해양환경에서 부영양화 관리를 위한 중앙정부의 중·장기 계획과 정책은 해양수산부를 비롯한 6개 부처가 공동으로 입안한 '해양오염방지를 위한 5개년 계획'으로 구체화되었다. 해양오염방지를 위한 정부의 다각적인 노력이 부영양화 오염저감에 많은 기여를 하였음에도 불구하고, 현행 관리체제는 관리대상의 부적절한 설정, 이해당사자간의 협조체계 미흡, 육상과 해양의 통합관리체제 미비, 적절한 관리를 위한 자료의 질관리 부재 등 많은 한계를 안고 있다. 따라서 적조의 대규모 발생 및 무산소층 형성의 원인자인 부영양화를 방지하기 위해서는 다음과 같은 노력이 경주되어야 한다.

첫째, 현행 법체계상에서 명문화되어 있는 질소와 인에 대한 규제가 실효성을 가질 수 있도록 해야한다. 둘째, 연안 부영양화의 주 원인인 비점오염원을 관리하기 위하여 오염원의 현황파악을 위한 연구 및 소규모 수계에 대한 관리방안을 새로이 수립해야 한다. 또한 오염원 배출을 효과적으로 억제할 수 있도록 하기 위하여 현재 아원화 되어 있는 경제적 유인제도(economic incentive system)를 배출부과금을 강

화하는 방향으로 정비하여야 한다. 이는 환경시설의 설립을 위해 마련된 환경개선분담금의 경우 배출원인자들의 자발적인 억제를 유도하거나 배출량을 억제하는 많은 한계를 안고 있기 때문이다. 넷째, 연안부영양화 방지계획을 적절하게 실행하기 위해서는 과학적인 조사와 자료의 질관리가 절대적으로 필요하다. 질 높은 자료의 확보 및 관리는 자연과학적 접근 및 인문사회과학적 접근을 통해서 획득한 자료에 대해 공히 적용되어야 한다. 질관리를 위한 제도적 장치의 마련은 과학적인 환경오염 관리체계 수립의 전제이다. 다섯째, 연안부영양화를 통해 발생하는 피해에 대해서 중앙정부보다 직접적인 이해관계를 가지고 있는 지방자치단체의 역할과 관리역량을 제고해야 한다. 또한, 지방자치단체의 역량강화와 함께 지역주민에 대한 지속적인 교육과 참여를 제도적으로 보장하여 안정적인 관리체계를 구축할 수 있도록 해야 한다. 지방정부의 역량강화와 관리체제에 주민 참여는 연안환경에 대한 책임주체를 명확히 함으로써 연안환경개선의 주체정립을 공고히 하는데 기여할 것이다. 지역사회를 기반으로한 관리체제의 구축(community-based management system)은 장기적으로 비용의 절감 및 저변역량의 재생산구조 구축이라는 효과를 가져다 줄 것으로 기대된다.

SUMMARY

I. Title

Managing Coastal Eutrophication in Korea

II. Goals and Significance

The goals of this research project are to identify coastal eutrophication problems in Korea and to develop an effective management system on the eutrophication often caused by the land-based nutrients. Establishment of comprehensive countermeasures is emphasized to reduce input of land-based pollutants by involved parties at various levels, including both national and sub-national government agencies, and public sector. This study is focused on integrated approaches between coastal land and water. Special attention is given to the importance of nonpoint pollution management, data quality assurance program, and community-based management strategy.

III. Contents and Scope

This report is divided into five sections. The introduction is considered in section I which includes definition of coastal eutrophication, significance of eutrophication management, previous studies on the coastal pollution, and objectives of the study. Assessment of coastal water quality is dealt in section II, reporting demographic indicators and riverine water quality which are heavily associated with the eutrophication. In section III, analysis of current marine environment management system is made to establish an improved management strategies on coastal eutrophication.

Section IV and V consist of recommendations for the effective countermeasures to manage coastal eutrophication, point to the hurdles to be overcome in dealing with the problem, and assess the prospects for the future coastal environment.

IV. Conclusion and Suggestions

National eutrophication management system in marine environment is represented by the 'Five Year Plan for Prevention of Marine Pollution'. The plan is composed of three main parts of preventative, responsive, non-regulatory actions. Curreot management system, despite of much contribution to prevention of the pollution, has some deficiencies such as inadequate designation of management factors, lack of enforcement in cooperation between involved parties, negligence in obtaining accurate investigation data, and lack of integrated management system between land and marine environments. Thus, strategies to be reinforced to improve coastal environment and manage eutrophication problems are recommended as follows.

First, to prevent and manage eutrophication in coastal waters, a direct regulation on the sources of nitrogen and phosphorous (main limiting factors for the red-tide) should be carried out. Second, to manage nonpoint sources , major cause of eutrophication problem in coastal area, should be performed through basic studies on the source conditions and management on small watersheds. Third, to implement the incentive system. an effective industrial pollution management tool, effluent charge system rather than environment improvement charge system should be applied. The environment improvement charge system, functioning as a financial source for constructing environmental facilities, is not considered to be a right tool that could lead to self-regulation of the pollution by the industry. Fourth, to realize coastal eutrophication prevention plan, detailed scientific surveys and data quality management are required. Hence, QA/QC should also be adopted in reconstructing and collecting demographic data as well as basic scientific data. Fifth, because sub-national government is more familiar with the direct impact of the eutrophication, development of national strategy to efficiently preventing coastal pollution such as eutrophication should be concentrated on the intensification of management capacity of regional governments. Lastly, citizen together with sub-national governments, especially at local level, can be a major player in solving environmental problems through synergistic cooperation with national government agencies. Thus, current centrally based management system should be replaced by community-based management system.

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I. INTRODUCTION

The coastal water represents a unique, highly productive and economically important ecosystem. It also supports a diverse array of living resources, providing feeding, breeding, nesting and nursery areas for various animal and plant life including many economically important species. This productivity that benefits human beings is what interests most of humanity. The productivity of the coastal area to support people is dependent on the quality of its water (Ray, 1988). Coastal water pollution could affect public health, recreation, commercial fishing, mariculture, other related economically important industries, and aesthetics (UNEP, 1995). However, 'preserving and protecting' the water quality is a difficult problem and requires special urgency when faced with environment already in the advanced stage of deterioration. Many coastal environments in Korea have such urgency.

One of the main causes of harm resulted from human activity to the coastal water's resources (water pollution) is eutrophication, often followed by red-tide and hypoxia. Water pollution sources (point and non point sources) which may cause eutrophication can be generalized as follows; various treated or untreated municipal sewage, domestic waste discharge by water-craft and industry; animal wastes, sediment, the runoff of inorganic fertilizers and pesticides; land runoff; atmospheric pollution; discharge of water used in industrial plants such as cooling and processing (e.g., pulp and paper industry); power utilities; production, transport and use of oil, etc. (Kupchella and Hyland, 1986).

Eutrophication can be defined simply as a process where an aquatic system becomes rich in plant nutrient, minerals and organisms which often results in oxygen deficient water environment especially during the warmer season (The New Encyclopedia Britannica, 1981; Encyclopedia of Science & Technology, 1982; Guralnik, 1986). Certain chemicals in the right concentrations can distort and disrupt the balance of aquatic ecosystems by overfeeding certain components of such system. Overfeeding (i.e., eutrophication) can occur in two ways, primarily through two kinds of chemical pollutants. One way is through the addition of inorganic nutrients that are normally limiting for plants, and another way is through the addition of organic chemicals that serve as food for decomposers (Kupchella and Hyland,1986).

Dissolved organic matter increases the activities of decomposers to the point depleting available oxygen as they utilize the organic matter. Typical response of aquatic organisms to low oxygen ranges from reduced abundance and growth, physiological stress, behavior alteration, increased vulnerability to predation and mortality, and sometimes decimation of a whole cohort of certain species in critical stages. In extreme cases, even among the decomposers have changes in species composition to anaerobic species. This in turn leads to the production of foul-smelling toxic end products of anaerobic respiration. Inadequately treated municipal sewage constitutes one of the largest source of this contaminant. Body wastes of farm animals also contribute to eutrophication via organic pollution (The New Encyclopedia Britannica, 1981; Kupchella and Hyland, 1986).

Addition of inorganic matter, primarily phosphates and especially nitrates, can also overenrich and thus pollute coastal water ecosystem. Detergents, fertilizers used in agriculture and wastewater discharge are major sources of these contaminants. When phosphorous or nitrogen is added to water, it triggers a rapid growth of plants. While this plant growth initially results in an increase in oxygenation, plant respiration, decomposition of dead plant material, and prevention of the light penetration and oxygen absorption necessary for underwater life due to algal blooms or blooms of other microscopic organisms create a problem similar to the organic pollution of water aforementioned. Nitrogen in organic or inorganic forms of ammonia, nitrite, and nitrate is the major limiting nutrient for the algal growth in coastal water environment. Inorganic forms of nitrogen are preferentially used by phytoplankton to support their growth. Hence, regulation of carbon (organic matter) and nitrogen (inorganic form) input is the major task in controlling coastal water eutrophication (The New Encyclopedia Britannica, 1981; Kupchella and Hyland, 1986; National Research Council, 1993).

Worldwide seriousness of regulating coastal water pollution is confirmed by World Resources Institute (WRI) report (1995) showing that current improvement on coastal environment is far from the goal to maintain sustainable level of coastal resources. Urgency to implement plans to deal with coastal water eutrophication was intensified when 'Intergovernmental Conference to Adopt a Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP)' was held in October, 1995. UNEP provided guidelines as to the actions (targets and timetables) that should be considered at national, regional and global level in accordance with each nation's capacities, priorities and available resources. To combat eutrophication by nutrient input due to human activities which is usually confined to the vicinity of coastal discharges, several objectives were proposed by UNEP. They were (1) identify marine areas of nutrient inputs likely to cause pollution, (2) reduce nutrient inputs from areas identified, (3) reduce the number of marine areas where eutrophication is evident, and (4) protect and restore areas of natural denitrification (UNEP, 1995, see Appendix 1). Main mission for the Korean government to reduce eutrophication should be to adapt the second objective suggested by UNEP which is to deal with activities related to municipal sewage treatment and control, and industrial waste regulation and management.

In Korea, studies on eutrophication have been mainly focused on the identification of red-tides and hypoxia utilizing standard scientific approaches. Since Park and Kim (1967) first reported outbreak of red-tides in Chinhae Bay, researches on red-tides in marine ecosystem has been carried out by many scientists (Park, 1975; Cho and Kim, 1977; KORDI 1980, 1981, and 1982; Lee *et al*., 1981; Yang and Hong, 1982; KORDI, 1990). They asserted that eutrophication in marine waters is the main cause of red-tides and hypoxia, and is strongly associated with nutrients input of nutrients from land activities. And, studies concluded that the improvement of marine environment can be achieved through regulating land-based pollutants (Park, 1994; Park *et al*., 1996). As red-tides following eutrophication heavily damaged marine environment, related agencies such as MOE (Ministry of Environment) and MOMAF (Ministry of Maritime Affairs and Fisheries) have concentrated on integrated management of land and marine environments. Notwithstanding much effort and investment by various groups, coastal environment did not improved. It is considered that actual prevention of eutrophication would need new management framework including re-organization of existing institutional systems and establishment of better integrated countermeasures. This study includes conditions of various demographic and environmental indicators, existing countermeasures by involved agencies, and several recommendations for improving coastal environment. Focal points of this study will be given to nonpoint sources, quality assurance program and community-based management system. Some suggestions have been already addressed in other studies, including establishment of environmental facilities, enforcement of legal control system, expansion of special control areas, and development of new technologies for reducing nutrient loadings. The status of eutrophication, i.e., caused by nutrient (N, P) overload, which is one of the main problem of coastal destruction in Korea is also assessed. To minimize further deterioration and to improve coastal ecosystem, management alternatives are identified and recommended.

II. ASSESSMENT OF COASTAL WATER QUALITY IN KOREA

1. Demographic and social indicators

It is a well accepted fact that coastal eutrophication, usually the result of by-product of wastewater discharge, is strongly associated with the increase in population, cities, industrial factories, and energy consumption. Intensive emission of nitrogen and phosphorous, i.e., oversupply of nutrients, is a side effect of expansion of cities, centralization of population, and increased demand/supply of energy and water consumption. According to National Statistical Office of Korea (1996), population, GNP per capita, and total quantity of oil consumption show a steady increase since 1950's (Table 1). By-products of increases in aforementioned demographic indicators such as discharged pollutants are endangering not only populated coastal areas, but also relatively undisturbed areas. Contrast to such expansion, increases in investment on environmentally beneficial or friendly facilities (e.g. wastewater treatment facilities) have not been observed.

Among different demographic indicators, variation in population is considered to be the most important and convenient tool in estimating pollution potentials. Increase in population has a strong link with increase in wastewater effluent (Fig. 1; NSO, 1996). The NSO (1996) study showed that the effluent per capita has increased 78% while population has an increase of 20.6% over the same period (1980 to 1994).

In addition to the population increase, centralization of population also greatly influences the pollution loadings and has a close association with coastal eutrophication. It was reported that 33.4% of total population of Korea live in coastal zone in 1996[1] (CSKDI, 1996). Table 1 shows increases in population between 1960 and 1995 and relevant parameters which may have detrimental effects on coastal environments (NSO, 1996). Population, a variable positively related to production of nitrogen and phosphorous, has increased 1.8 fold over 35 years. Also, total quantity of oil consumption over last 25 years increased *ca.* 10 fold, which is associated with growth of industrial activities and improvement in quality of life.

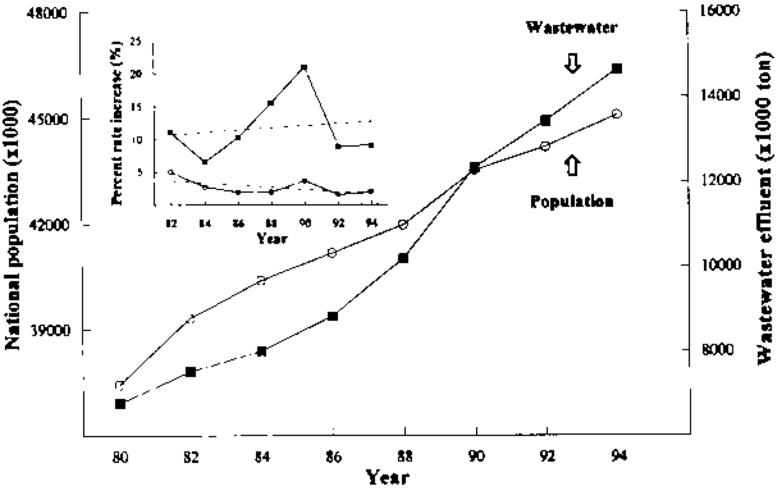


Figure 1. Yearly variation in population and wastewater (Source; NSO, 1996).
The inset shows change in percent rate of population and wastewater. The dotted lines (inset) indicate data-fitted trends over the years.

[1] Reported total national population was 45,829,852 in which 15,291,731 lives in coastal area.

Table 1. Survey of major demographic indicators

Classification	Unit	1960	1970	1980	1990	1995
Population	thousand	25,102	32,241	38,124	42,869	45,248
GNP per capita	US $	79	253	1,587	5,883	10,076
Oil consumption	thousand Bbl	-	62,702	182,105	356,349	676,982
Water supply per capita daily	liter	99	158	256	369	408
Distribution of waterworks	%	16.8	32 3	54.6	78.4	82.1

(Source: NSO, 1996)

2. Water quality of major rivers

Ministry of Environment (MOE) has conducted monthly monitoring of water qualities at 1,379 sites in watershed around the country and presented monitoring data through Environmental Statistics Yearbook. According to MOE (1996a), Han River, Nakdong River, Kum River, and Yongsan River showed indication of degradation in water qualities with each year. For example, biochemical oxygen demand (BOD), one of the parameters monitored, recorded highest value of 7.3 mg /l in Nakdong River (Fig. 2). Based on the water quality standards of riverine water (Appendix 2), aforementioned rivers either belong to Class 2 or Class 3.

According to MOE report in April 1997, water quality data from March 1997 showed rivers were deteriorated more rapidly within a year (1994 to 1995), compared with past several years (Table 2). Especially BOD, one of the variable associated nutrient overload, of Han and Yongsan Rivers suggested that two rivers were highly stressed. The water qualities at

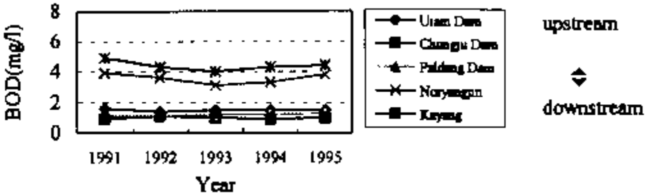
Chungju and Naju Lakes were classified into Classs 2 and Class 5, respectively, suggesting freshwater lakes are also contaminated by the water pollution. Class 1 water quality was only assigned to Andong site in Nakdong River among twenty sites within 4 major rivers. Study was not conducted to directly link these deteriorated riverine and lake conditions with outbreaks of eutrophication in the coastal waters of Korea, however, every indication points to their strong influences in initiating coastal water eutrophication (see MOE, 1996a). As coastal eutrophication is affected mainly by nitrogen and phosphorous from land-based activities, it is necessary to monitor and treat the sources which causes coastal eutrophication for the purpose of preventing the oversupply of phosphorous and especially nitrogen.

Table 2. BOD in Han River and Yongsan river

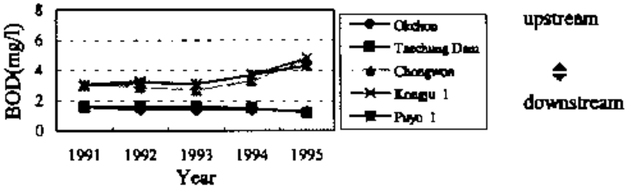
(Unit : mg/l)

		March 1997	March 1996	Remarks
Han River	Uiam Dam	1.3	1.5	upstream ↑ ↓ downstream
	Chungju Dam	0.8	1.2	
	Paldang Dam	1.4	1.6	
	Noryangjin	4.3	5.7	
	Kayang	6.2	6.9	
Yong san River	Tamyang	2.5	1.7	upstream ↑ ↓ downstream
	Woochi	2.7	3.0	
	Kwangju	6.9	5.6	
	Naju	6.9	8.7	
	Muan	2.7	2.2	

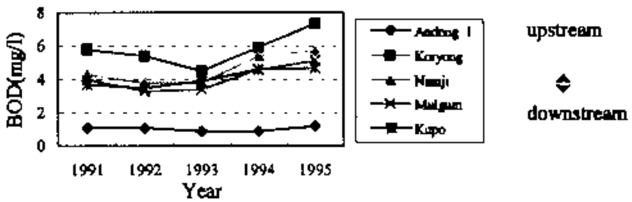
(Source : MOE report on Hangyeore, 1997. 4. 30)



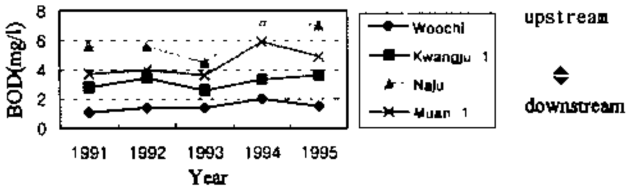
(a) Han River



(b) Kum River



(c) Nakdong River



(d) Yongsan River

Figure 2. Yearly variation of BOD in the major rivers of Korea (Source: MOE, 1996a)

3. Water quality of coastal waters

Occurrences of eutrophication in coastal waters are strongly associated with effluent rate and concentration of nitrogen and phosphorous coming into coastal ecosystem. Balance in nutrient concentrations to support healthy population of marine organisms has been affected by effluents containing high concentration of nutrients. Oversupply of phosphorus and mostly nitrogen frequently becomes a base for the red-tide in coastal waters (MOE, 1996b; Park *et al.*, 1996). Especially shore waters adjacent to industrial and highly populated cities have been suffered heavily from oversupply of nutrients. In addition, eastern coastal sea of Korea known to have relatively 'clean' water, is not free from the eutrophication. Marine observation data from MOE suggested that the eutrophication in coastal water has now become ubiquitous in Korean coastal waters and in critical level. Abatement procedures to minimize the coastal water eutrophication are of urgent issues to be solved by national and sub-national government agencies.

National government has conducted water quality monitoring system on 251 sites of 62 inshore and 40 sites of 7 offshore waters. Twenty one parameters are monitored including for water quality measurement including nutrients and heavy metals. Coastal waters are then certified into three water quality classes by comparing water quality standards (Appendix 3, 4).

1) Water quality indicators

MOE and other researchers (Park, 1975; Lee *et al.*, 1986; Lee, 1996) have suggested that land based marine pollution endangers health of coastal ecosystem. *For example, chemical oxygen demand in* Masan bay where industrial factories has been constructed since 70's, was recorded to be high 3.8 ppm (MOE, 1996a). Despite of intensive efforts by the government such as dredging and construction of wastewater treatment facilities, water quality in this bay did not improve. The coastal waters with the highest COD level among 22 coastal areas are categorized into water for industrial and port uses (MOE report in April 1997, Appendix 5).

Concentrations of COD, used as a quick indicator of water quality, did not show any substantial difference in most coastal areas except the coastal waters of Masan (Appendix 5). According to marine-water quality standards, the aforementioned areas can be categorized into either Class III[2] which is not suitable for fishing and recreation or Class II. COD in some areas such as Mokpo and Pusan showed drastic increases, which indicates red-tide outbreak a very probable event. In 1995 and 1996, however, frequent red-tide episodes were observed in all coastal waters of South Sea and East Sea, and each occurrence persisted longer duration than previous years[3] (NFRDI, 1997). These red-tide outbreaks were unwarranted if only COD was considered which showed no substantial increases in the COD value. This suggests that COD value cannot be used as an exclusive indicator of coastal eutrophication. Since it is known that COD could not represent levels of eutrophication accurately, the focus have to be given to total nitrogen and phosphorous concentrations directly related to occurrence of eutrophication (i.e., an exponential increase in red-tide species).

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[2] Class II category water is suitable for bathing, tourism, and recreation, and Class III category water is suitable only for indusrial cooling water and anchoring

[3] Red-tide broke out mainly in summer with high water temperature in early 1990's, but in recent years. It was often observed from February to October.

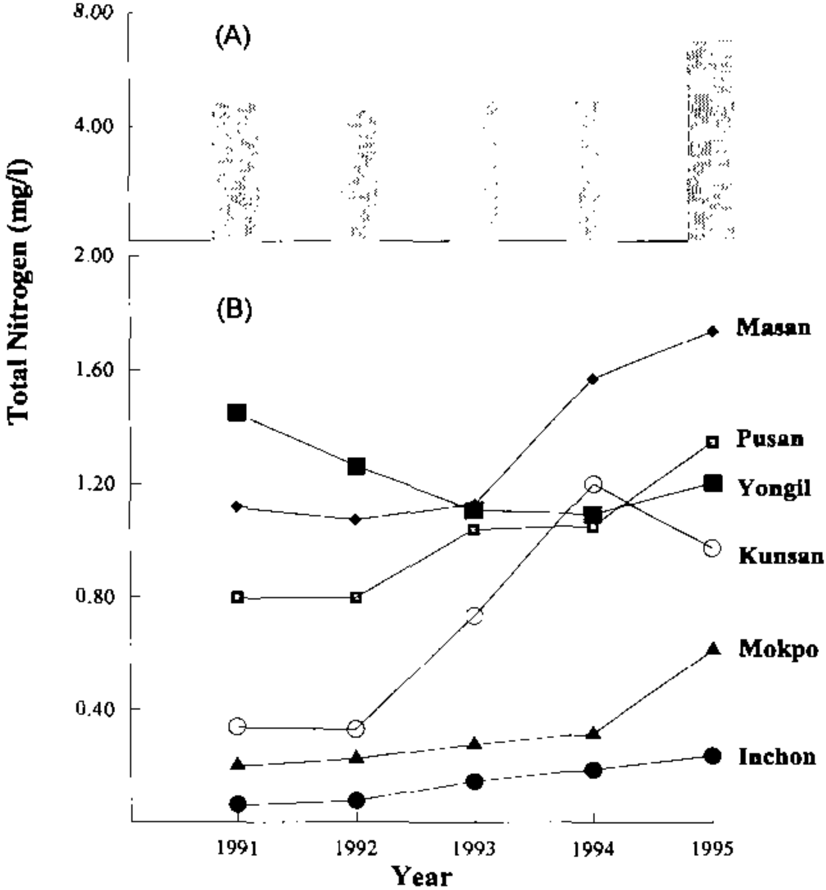

Figure 3. Yearly variation of total nitrogen concentration in major coastal waters (source: MOE. 1996a). (A) Sum of total nitrogen concentrations from six coastal cities, Inchon, Kunsan, Mokpo, Masan, Pusan, and Yongil. (B) Total nitrogen concentrations of six individual cities.

For example red-tides that broke out along eastern coast of Korea in September 1995, was reported to be associated with concentration of eutrophication sources (i.e., nutrients) rather than COD[4] (NFRKDI, 1997). Figure 3 represents averaged yearly fluctuation of nitrogen concentration. Gradual increase of red-tides occurrence, showing 27, 39, 29, and 65 in 1991 to 1995 respectively, is considered to be correspond to increase of nitrogen concentrations. General increase of nitrogen concentrations at high level suggests that countermeasures on eutrophication and related pollution events should be implemented urgently (refer to Appendix 4).

2) Red-tides

Coastal eutrophication via land-based nutrients is usually associated with red or brown tide. The events are named in such way due to the color of water reflecting chlorophyll of the dominating species of blooming autotrophs. There were three observed outbreaks in 1980, forty in 1990 and sixty five in 1995 when unparalleled large-scale red-tides broke out, severely damaging sensitive fishing industry (NFRDI, 1997). Diatoms such as *Skeletonema costatum, Chaetoceros curvisetus,* and *Nitzschia pungens* were dominant species of red-tide till 1980's, however, dinofalgellates that release

[4] Square correlation coefficients between COD and eutrophication sources were represented by 0.200 (COD and total nitrogen) and 0.266 (COD and total phosphorous) from 1991 to 1995. Thus, it is considered that management of coastal eutrophication should be made considering the distribution of total nitrogen and inorganic phosphorous. Concentrations of eutrophication sources in east coast were higher than those in western coast in 1995. COD can be used as a preliminary test or a supporting measurement, however, confirmative or more reliable measurements are needed to accurately monitor coastal pollution to optimize the utilization of collected data and to minimize the damage rendered by red-tide.

toxic materials, including *Cochlodinium polykrikoides*, *Gymnodinium mikimotoi*, *Heterosigmo akashiwo* and *Procentrum micans*, replaced diatoms in the early 90's. In the earlier years, occurrence of red-tides were restricted to southern coastal areas in the earlier years, however, more recently, it has expanded to east coast which was considered to be relatively clean water. Hence, all the reports gathered indicate red-tide events become longer in duration, larger in scale, more toxic, more frequent and more ubiquitous (Kim *et al.*, 1993).

III. MANAGING COASTAL EUTROPHICATION IN KOREA

Many countermeasures, developed and established by the central government agencies, have been applied to improve water quality of fresh and salt water environments. Some of the general approaches implemented by the central government for marine pollution prevention are based on the following principles;

- Setting clear policy direction
- Identifying current situation and anticipating future marine pollution
- Applying preventive measures
- Promoting technical development
- Enhancing international cooperation

On the basis of the these guidelines, responsible agencies were to establish and implement the management approach for preserving marine environment, and strive for interagency cooperation to attain the goals. Consolidated countermeasures to prevent coastal eutrophication are represented by 'Five Year Plan for Prevention of Marine Pollution', which also includes countermeasures for various other marine pollution such as red-tides and oil spills. As the plan can help go forward in improving deteriorated coastal environments and draw interests of related-agencies to cooperatively solve marine pollution problems, it is hoped that coastal eutrophication would be controlled and managed in future. The fact that sources of eutrophication are from land encourages that a tight relationship is needed not only among agencies, but also between local inland and coastal city governments.

To manage the pollution problems more efficiently and effectively, national government classified riverine and lake waters into five classes, and marine waters into three classes based on water quality standards[5] with each classes. Monitoring system[6] in marine water is operated by national agencies, whereas the system for freshwater monitoring is managed cooperatively by national and regional agencies. Periodically, observed data are scrutinized in improving and re-establishing environmental conservation policy such as intensification of water quality standards, planning of wastewater treatment facility construction, and implementation and development of institutional system to accomplish such management.

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[5] Basic Environmental Policy Act ordain matter on establishment of environmental standards for the purpose of protecting the health of citizens and creating comfortable environment.

[6] Due to newly established Ministry of Maritime Affairs and Fisheries, number of monitoring sites is expected to be changed

1. Preventative action

1) Designation of special management area for controlling coastal pollution

Central government, based on Article 4 paragraph 4[7] of the Sea Pollution Prevention Act, designates specified contiguous areas to the coastal land which is deemed to have any effect on the pollution as special control areas. Special control areas include Ulsan, Pusan, Chinhae coastal areas, and Kwangyang Bay total equivalent area of 934 km^2 in 1982, and will have included 11 more areas[8] added incrementally by 1999 (Table 3, MOE *et al.*, 1996). Management policy on the special control areas will be implemented on the basis of guidelines as follows;

- consideration of heavily polluted areas and major fishing grounds
- change of designation principles (bay-based management from wide area-based management)
- establishment of integrated management including the land area contiguous to coastal sea, and
- establishment of parallel management with environmental assessment of coastal zone development, and construction of environmentally friendly facilities (e.g. wastewater treatment facilities).

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[7] "Article 4 paragraph 4 (Designation, etc. of special control sea area) (1) The Minister of Environment may designate and notify publicly as special control sea areas in which it is difficult to maintain the water quality standards by sea area as prescribed in Article 4-2 (1), and there is or might be any remarkable impediment in the preservation of the sea environment (including the land having any direct impact on the sea pollution), after consulting with the heads of related administrative agencies and the sea area management authorities, and establish any special measures for preserving the environment in ....".

[8] Jaran Bay in Kosung, Kangjin Bay in Namhae, and Kamak Bay in Yosu are additionally designated as special control areas in 1996. These areas has increased level of pollution, due to unregulated outpouring land-based pollution sources

In accordance with assessment of drawbacks and advantages, previous land-oriented environment management had problems in managing marine pollution. Designated special control locations were areas primarily with large-scaled pollution problems such as coastal cities, ports, and coastal industrial complexes. Thus, preservation of high-valued sustainable fishery resources and major fishing grounds was not included, and countermeasures on potential negative impacts were not incorporated. Second problem was in the process of a wide area-based designation which had difficulties in carrying out eutrophication management; ambiguity in the scope of responsibility, absence of area-specific management, etc. Another major problem was insufficient monitoring and incomplete assessment on land-based pollutant loadings which accounted 80% of marine pollution (MOE *et al.*, 1996; Park *et al.*, 1996). For effective abatement of land-based pollutants, comprehensive countermeasures including establishment of basic environmental facilities, implementation of integrated coastal management system, and identification of area-specific countermeasures are recommended.

Table 3. The designation plan of special control area

	Total number of designated areas	'95	'96	'97	'98	'99
Total number	15	4	4	5	1	1
Heavily polluted area	7	4 (Kwangyang Bay, Chinhae Bay, Pusan, Ulsan)	-	1 (Inchon)	1 (Kunsan)	1 (Mokpo)
Major fishing grounds	8		4 (Kamak Bay, Kangjin Bay, Kosung Bay, Jaran Bay)	4 (Yoja Bay, Hansan Bay Doim Bay, Deukryang Bay)	-	-

(Source : MOE *et al.*, 1996)

2) Wastewater treatment facilities

The existing water treatment facilities were surveyed by MOE. It was concluded that the facilities are not suitable for treating and purifying ever increasing amount of wastewater (MOE, 1994; recited in Jeong and Lee, 1995). It was reported that 95 (27%) of total 355 facilities have problems in efficiently operating the facility in their full capability, such as capacity shortage (37 facilities), insolvency of collection chamber (32 facilities), and superannuated treatment system (26 facilities). In 1994, it was found that the discharged wastewater from 69 facilities did uot meet the satisfactory discharged-water quality standards (Table 4). Also, 73 facilities (20.5%) were understaffed and were operating with insufficient maintenance cost (10%).

Table 4. Conditions of wastewater treatment effluent

	Total number of treatment facilities	Measurement		Not measured or not operating at the time of the survey
		below standards	above standards	
Total facilities	355	205	69 (19.4%)	81
Sewer	43	33	8 (19.0%)	2
Night soil	189	80	51 (27.0%)	58
Industrial wastewater	17	11	2 (12.0%)	4
Agriculture and industry wastewater	65	54	5 (8.0%)	6
Simple sewage	20	19	-	1
Simple livestock	19	7	3 (16.05)	9
Livestock	2	1	-	1

(Source : MOE, 1994. recited in Jeong and Lee, 1995)

To minimize and possibly prevent eutrophication of coastal waters, serious countermeasures including the treatment facilities expansion are needed in coastal area. Currently wastewater treatment facilities under operation in the coastal area show lower treatment efficiency (23%) than national average (42%) which is already in the status of low efficiency (MOE *et al.*, 1996). In order to improve the management of wastewater treatment, national government has revised an existing plan to expand the treatment facilities around the country. Appendix 6 shows a yearly construction plan of new sewage treatment facilities to upgrade the existing facilities and to increase the level of the treatment systems of coastal areas to 63% efficiency (percent treatment from total incoming wastewater). The coastal wastewater treatment system for managing night soil, livestock and industrial wastewater will be equipped through large-scaled financial investment, equivalent to 102.7, 55.8, and 188.9 billion won, respectively (MOE *et al.*, 1996).

2. Responsive action

1) Dredging the polluted bottom sediment

Semi-enclosed coastal areas or bays including Chongcho Lake, Kwangyang Bay, and Masan Bay, are some of the examples where the water is heavily polluted by strong sedimentation, decomposition of pollutants, weak water circulation and slow exchange with offshore water. Dredging accumulated pollutants have to be performed in conjunction with establishment of basic environmental facilities in order to improve water quality of these areas. Heavily polluted areas such as previous mentioned semi-enclosed areas are in urgent need of dredging (MOE *et al.*, 1996). A nationwide dredging is scheduled to begin in seven areas where wastewater treatment systems are already established (Table 5).

The water quality in Masan Bay improved immediately after the intensive dredging over 5 years (1990 to1994) (refer to MOE(1996a)). Water quality in this bay, however, became deteriorated to previous level before dredging (MOE report in April 1997). A thorough environmental impact study is always needed to answer if dredging is an efficient method in reducing pollution level at a particular site, even if the work could immediately remove pollutants from polluted area. Masan dredging project gave a important lesson to interested parties that dredging of polluted sediments should not be implemented without sufficient establishment of a treatment system for managing pollution sources, and consideration on future development plan. Notwithstanding of weakness on Masan project, dredging is regarded as an efficient tool for removing contaminants from many polluted coastal locations .

Table 5. Yearly dredging plan on heavily polluted semi-enclosed areas

	Sum	Dredging performed (up to 1995)	Yearly plan					
			Sub-sum	'96	'97	'98	'99	2000
Area	8	Masan bay	7	Chongcho Lake, Chuksan Port	Chumun -jin Port	Yongil Bay	Ulsan Bay	Kwangyang Bay, Sunso coastal area
Dredged quantity ($1000\ m^3$)	8,362	2,111	6,251	827	330	579	805	3,710

(Source : MOE *et al.*, 1996)

2) Cleaning up mariculture ground

One of the major sources causing eutrophication is from the feed used in mariculture industry. The main components of coastal water deterioration due to such industry are oversupply of the feed and crowded animal husbandry around island coasts. Coastal waters by the mariculture grounds show steady decline in water quality especially due to the lack of general investigation and enforcement of environment improvement procedures by the regulatory agencies (MOE *et al.*, 1996). For example, it is the industry manager's duty that the mariculture ground be cleaned every 3 years. However, this regulation is not at all implemented and the ground is heavily contaminated by the accumulation of organic debris (e.g., feed residue, farm animal fecal matters, dead and decaying animal, etc.) high in nutrients which contributing to the problem of coastal eutrophication.

In order to reduce pollution and improve the environment. 108.5 billion won will be spent by year 2000 (Table 6) to help clean up the mariculture farming grounds. Government designated nine areas with frequent red-tide events as special management area and has already begun conducting overall cleaning of affected mariculture ground, organizing the ground facilities, and regulating illegal farmiug.

Table 6. Yearly plan of the mariculture ground purification

(Unit ; billion won)

Classification	Sum	1995	Yearly plan					
			'96	'97	'98	'99	2000	sub-sum
Sum	108.5	18.3	15.6	17.6	18	19	20	90.2
Special grounds	64.4	-	5.9	13.6	14	15	16	64.4
General grounds	44.1	18.3	9.8	4	4	4	4	25.8

(Source : MOE *et al.*, 1996)

3. Non-regulatory action : economic incentive system

It is well known that a monetary surcharge method of 'effluent charge system' is a practical way of reducing water pollution. Water resource consumption by industrial enterprises of Brazil decreased by 40-60% over 2 years since institutionalization of charge system. The consumption in the Netherlands was lowered to 30% during 1970 to 1976 by adopting incentive system (Kim, 1995). Economic incentive system of Korea is also based on the polluter pay principle similar to other countries (e.g. USA, Japan) (Kim, 1995), and is accomplished by 'water environment improvement expenses[9]' and 'effluent charge'. The effluent charge system is based on principle that polluters should bear the expenses for the prevention of environmental damages and recovery of damaged environment[10]. The water environmental improvement charge system is differentiated from the effluent charge in that the former has a primary goal of meeting fund for constructing wastewater treatment facilities. Hence, the improvement charge does not function as a fundamental tool in controlling and regulating wastewater effluent from various pollution sources. The scope of the improvement charge system is prescribed by the Presidential Decree, which is based upon consumption-circulation facilities, such as buildings area over 1000 m^2, restaurants over 160 m^2, commercial accommodation facilities (e.g. hotels, motels) over 240 m^2, retail stores over 270 m^2, medical centers over 380 m^2, and public baths

[9] The purpose of the decree ' Liability for Environment Improvement Expenses Act', as referred to Article 1, is to contribute the formation of a comfortable environment which is the foundation of the continuous development of State, by driving forward comprehensively and systematically measures for improving the environment and promoting the environmental improvement through raising reasonably investment resources incidental to it.

[10] Article 19 of the Water Environment Preservation Act

over 410 m^2 in total floor space.

In the case of the surcharge method, the basic goal of environmental preservation is expected to be fulfilled when it is fully implemented. The system, based on polluter pay principle[11], functions as policy tools to minimize national or community cost by controlling effluent quantity by the offender. The system includes characteristics of economic incentives and administrative regulations (Kim, 1995). Newly amended 'Water Environment Preservation Act' (December, 1995) made the discharged water quality standards to be more demanding and strict than before and incorporated total nitrogen and phosphorous into the water quality standards (Appendix 7). As permissible discharged both industrial and domestic wastewater standards become stringent, independent control by concerned industries or persons will be considered to be a sufficient tool in reducing water pollution.

[11] Article 7 of the Basic Environmental Policy Act describes the principle as follows, (Liability of person causing pollution for expenses) Any person who causes environmental pollution due to his act or business activities, shall in principle bear the expenses for the prevention of such pollution, recovery of the contaminated environment and relief of damages

IV. STRATEGIES FOR IMPROVING EUTROPHICATION MANAGEMENT

1. Controlling nutrients by total quantity

Current regulation on discharged wastewater is based on concentrations of each pollutant measured at the wastewater outfalls. Permissible wastewater discharge standards is divided into two categories, a total quantity under 2000 m^3 and over 2000 m^3 per day (Appendix 8). However, the standards are still based on concentration determined at the outfall, and are not sufficient in managing wastewater pollution. Concentration-based control standard, i.e., current regulation, has a substantial shortfall in that discharged pollutants with below standard pollutant concentrations at the outfall might exceed carrying capacity of environment in sum of the total volume discharged. Recognizing the problem, the government incorporated regulation of total quantity into the Water Environment Preservation Act[12], amended in December 29, 1995. However, the policy for water preservation by controlling total quantity of pollutant discharged is not implemented in freshwater where most of coastal contaminations are originated. Also, the scope of the law is limited only to heavily polluted area. Incorporation of the management of nitrogen and phosphorous into pollution regulation policy is highly recommended to focus on the establishment of environmental standards (i.e., total concentration and volume of pollutants allowable in the

[12] The Act provides control of total quantity in Article 9, that is 'of any zone or special countermeasure area where the water pollution state exceeds the environmental standards as prescribed in Article 10 of the Basic Environmental Policy Act and it might thereby bring any severe danger and injury the health and property of residents or breeding and growth of animals and plants, in case of a zone where business places are located closely together, the Minister of Environment may regulate discharged pollutants in total quantity for business places in such zone'.

wastewater output) and examination of water quality. Various pre-conditions including organization of institutional system and funding have to be satisfied in order to carry out the pollution management policies.

Some of the recommendations in accomplishing the regulatory procedures for controlling total output of nitrogen and phosphorous are (1) estimation of watersheds' carrying capacity, (2) appointment of regulated pollutants, (3) sufficient research on pollution mechanism, (4) survey on demographic and social conditions, (5) study on availability and cost-effectiveness of treatment technology, (6) establishment of continuous monitoring system, and (7) analysis on socio-economic cost for the related institutional implementation. Fulfillment of the above premises should also be concurrently followed by institutional system, such as tradable permit system (Kim, 1995; Ahn, 1996). For instance, Japan takes a measure which government allots permissible discharge quantity to each effluent source after determining total permissible discharge quantity. Also in the United States, even among various institutional systems, the tradable permit system is utilized.

Regulation on the total pollutant-quantity output in Korea did not produce acceptable result. Preliminary investigations on Nakdong River carried out by Park (1994) and Kim (1995) suggest that the regulation on water pollution could be implemented in 2006 with preparation period between 2001and 2005. Kim (1995) also reported that increase of sewage treatment efficiency, laying a basic foundation for nitrogen and phosphorous treatment system, and practical establishment of effluent charge system should also be accomplished in this preparation period.

The studies on Nakdong River showed many practical guidelines. First, the regulation of total quantity as well as point concentrations will improve polluted water environment. Second, development of treatment technology, expansion of wastewater treatment facilities, scientific research on demographic and social conditions, and optimal application of incentive economic system are effective enforcement to accomplish basic goals of the regulation. Third, assuring fund is essential in completing the regulation successfully. The fund is expected to be satisfied by collection of permissible effluent charge based on the newly established regulations.

Execution of the regulation of total pollutant output has a preferential application for heavily polluted areas, focusing on a comprehensive management of large-scaled, polluted area (Kim, 1995). Associated with wide area-based management, Park (1994) concluded that primary targets of the regulation authority should be placed on provincial governments which could establish a control system on affiliated local governments. Each provincial government should provide practical policy and management technique to local governments. In addition to administrative support, national government will have a fundamental role in improving financial systems of sub-national governments. Without any progressive financial and technical assistant programs, hasty full-scale implementation of the national scale will lead the project into an ineffective program due to under-experienced regulatory agencies or local governments and shortage of fund.

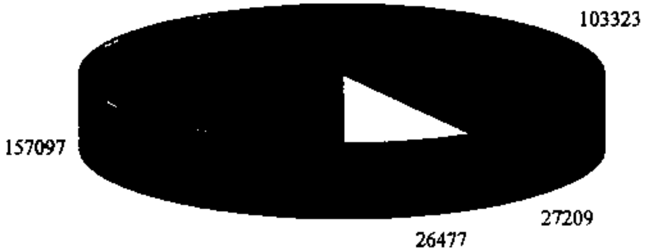
2. Controlling non-point source pollution

1) Eutrophication potentials by nonpoint nutrients

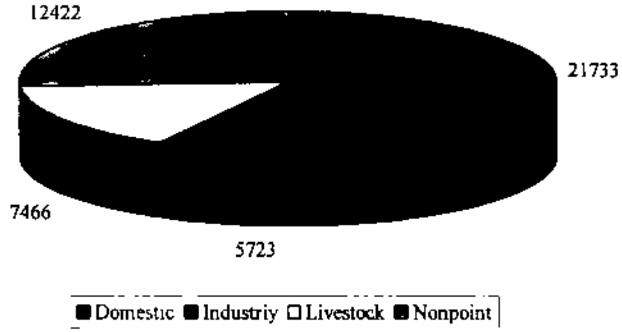
Environmental Protection Agency (EPA) of United States (1991) proposed through the joint EPA/NOAA document of America that nonpoint source pollution has become the largest single factor preventing the attainment of water quality standards. EPA included erosion from construction sites; runoff from urban areas; erosion from agricultural lands, stream beds, and roadways; runoff from livestock production areas; and atmospheric deposition as part of nonpoint source. Coastal environment is especially susceptible to storm water or heavy rainfall when mixed with aforementioned runoffs and erosions. This is called sewer overflow (CSO)[13]. National Research Council (NRC, 1993) suggested that nonpoint source control options include a range of activities to limit urban and agricultural runoff and atmospheric deposition into water that in turn degrade the coastal environment. Notwithstanding recent recognition that nonpoint source pollution is detrimental for coastal environment, investment and researches on the source were not improved in the United States. Since US had implemented Nationwide Urban Runoff Program (NURP) through EPA from 1978 to 1983 and, established the Water Quality Act in 1987 to effectively manage nonpoint source, a national database system on nonpoint source was established. In US, total national spending on nonpoint source pollution controls reached only six percent of the total amount spent on point source pollution (EPA, 1990).

Studies on nonpoint sources in Korea were first carried out in 1980 to estimate effluent quantity during an average rainfall, and a discharge model on nonpoint sources was developed in 1990's (see Appendix 9 for comparison with conditions of US). According to MOE (1995), nutrients from nonpoint sources such as total nitrogen and phosphorous contributed 50.4% (157,097 ton/year), and 26.2% (12,422 ton/year) respectively to whole nutrient pollutants in 1994 (Fig. 4 and 5).

[13] NRC(1993) defined the combined sewer overflow as follows; during rain events, the discharged mixture is called a combined sewer overflow when quantity of the mixture is beyond a capacity of the treatment plants so that tributaries, rivers, and coastal waters receive the mixture over carrying capacity.



(a) Total nitrogen (unit : ton)



(b) Total phosphorous (unit : ton)

Figure 4. Total discharge quantity of nitrogen and phosphorous sources (Source : MOE, 1995).

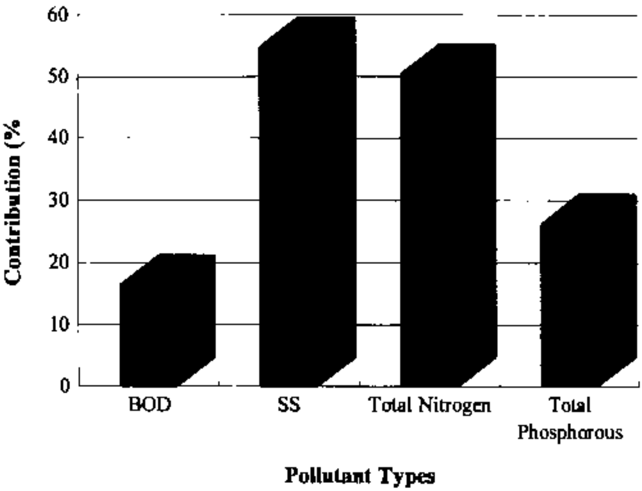


Figure 5. Contribution by nonpoint sources to whole pollution sources
(Source : MOE, 1995)

The nonpoint nutrients pollution flow into coastal areas without treatment (Appendix 10). Discharge of nonpoint-source nitrogen into Nakdong and Yongsan River watersheds, directly flowing into South Sea where frequent red-tides are observed and many semi-enclosed areas exist, showed no substantial variation to Han and Kum watersheds. This means that nonpoint sources could have a significant affect on semi-enclosed coastal area even without point sources. It is considered that in future, pollution contribution by nonpoint sources would increase if development of treatment technologies and facilities of dealing with nonpoint sources are not implemented immediately. Thus, comprehensive and scientific countermeasures are needed to be established for preventing further damage to coastal environment as well as inland water. To develop a comprehensive pollution management system, continuous assessment and monitoring on conditions of nonpoint sources have to be achieved. In addition, management agency should be built in as a part of the Ministry of Environment or MOMAF similar to organization arrangement in US. In Korea, most of the nitrogen measurements originated from nonpoint sources are strongly related to coastal blooming, and the nitrogen from nonpoint sources is not being managed and treated properly by agencies responsible.

2) Improving urban sewer system

Another focus should be placed on extensive construction of sewage pipe lines and treatment facilities. This is based on the fact that nitrogen and phosphorous via nonpoint sources from urban cities have a more direct influence on coastal water environment. The pollution from nonpoint sources will be reduced efficiently through construction of the sewage treatment system (Appendix 11). The problem can become more serious among larger urban cities (Appendix 12). The discharge and maximum treatable quantities of sewage at current efficiency were 13,972 (12,544 from cities) and 9,653 thousand ton/day[14] respectively. Leakage prevention by replacement of antiquated sewer lines and increase of collection efficiency by expansion of the lines are needed to reduce pollution by nonpoint sources.

Construction cost of new and improved pipe lines and facilities should be supported through an increase in sewer usage fee which is lower than other utility charges[15]. Although Jeong and Lee (1995) suggested the contrivance of a time-limited-object tax from a city planning or a public facility tax, it is

[14] The treatment efficiency of sewage, total treatment capacity of 9653 thousand ton/day was *ca* 50% in 1995 (NSO, 1996).

[15] The public services payment distribution is as follows; electric, 100%; water, 32.5%; sewer, 21.5%, and garbage service, 30-40%(estimation)(Jeong, 1995)

likely that increase of sewer usage fee which is lowest amongst all utility charges, could accomplish dual purposes of establishing fund and controlling water consumption. However, the time-limited-object tax can only function as a financial tool for constructing environmental facilities. Current sewage system is a rainfall-based and most of the system is consisted of combined sewer system (Table 7; Appendix 13).

Table 7. Condition of sewage pipe system in Korea

(Unit: m)

Classification		Planned	Current	Distribution (%)
Total pipe lines		85,741,550	52,784,301	61.6
Combined sewer pipe lines		33,098,799	35,799,874	108.0
Separate pipe lines	Sewer	23,942,790	7,154,611	29.9
	Rainfall	28,699,961	9,869,816	34.4

(Sources : MOE, 1996)

Combined sewer system which occupies 67.8% of sewer system, can not effectively manage all the pollutants (including nonpoint sources). This is a pivotal problem which needs to be improved and incorporated into comprehensive nonpoint source pollution management policy. Rainfall itself is less polluted than sewage, however, a lot of rainfall even with the low pollutant causes sewage treatment facilities to reduce treatment efficiency and overburden the facilities. Thus, to discharge rainfall from cities directly into rivers or other tributaries[16] and improve treatment efficiency of sewage in the facilities. the construction plan of sewage pipe in populated areas should be focused on 'separate sewer type' pipe system. Deficiency of sewage pipes and treatment facilities in coastal areas is especially serious. MOE (1996) reported that sewage pipe system in Kyongnam and Chunnam provinces which have long coast lines and also heavily polluted coastal areas, is not well developed, representing distribution rate of 19.4% and 2.1%, respectively (national average of 45%) (Appendix 14).

3) Applying small watershed management measures

Management activities on inland water quality are currently centered on major rivers. Government classified national watersheds into four main and eleven intermediate watershed areas[17] (Appendix 15), and formed committees for environment management in accordance with each designated area. Management policy for main watershed area has slowed development of nationwide environmental improvement. Figure 6 shows that effluent quantity of small rivers with discharge of under 1,000 m^3/day, just 46.1% of total effluent from land which is equivalent to 2,375,000 m^3/day (major rivers[18], 53.9%). This means that large portion of untreated water is flowing

[16] There is a report that discharge quantity of nonpoint nitrogen and phosphorous in June to August contributes over 60% of yearly nonpoint discharge (MOE, 1995).

[17] The Article 28 of the Water Environment Preservation Act defines 'control over environment by influence sphere in water system' as '(1) Minister of Environment shall control the water in such manner that he grasps the situation of the water pollution by influence sphere in the water system, consider any proper preventive measures, etc., under the conditions as prescribed by the Presidential Decree (2) The Minister of Environment shall determine and announce publicly the influence area in the water system to control the water by influence sphere in the water system as referred to in Paragraph (1)'.

[18] Those include Han River, Nakdong River, Kum River, Yongsan River, Mankyong River, Somjin River, Tongjin River, Taewha River, Hyongsan River, Tamjin River, Hoeya River, Ansong Stream, Sampkyo Stream, Samchok Osipchon, Kangnung Namdaechon, Yongdok

into coastal seas. Some of the small streams are difficult to manage directly by the central government. Most of the streams must be under the control and management of local governments to increase management efficiency and local awareness. The management guidelines and policies are responsibility of and provided by the central government.

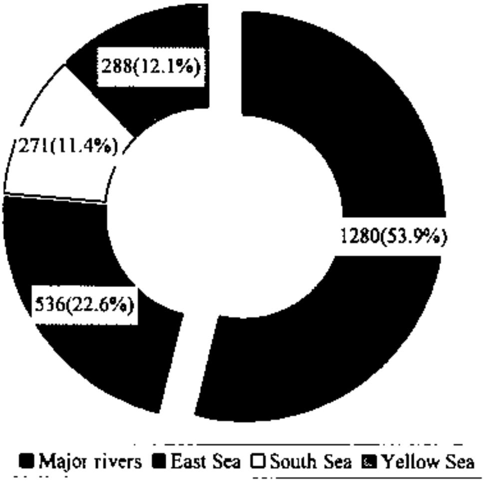


Figure 6. Percent wastewater effluent from various watersheds (unit : 1,000 m^3/day). Each 'Sea' means small rivers, i.e. minor watersheds, connected to three Seas around Korean Peninsula, and 'major rivers' includes rivers that discharge over 1000 m^3/day (revised from MOE, 1996a).

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3. Developing incentive-based system

Studies on incentive-based system in other developed countries showed that it has been performing well as expected and has been efficiently executed in minimizing water pollution (Boland, 1989; EPA, 1991). Current incentive systems in Korea are classified into three categories, environment improvement charge, effluent charge, and deposit-refund charge system[19] (Table 8).

Table 8. Conditions for incentive-based system in Korea and OECD countries

Korea	OECD
Environment improvement charge Effluent charge Deposit-refund charge	Effluent charge Deposit-refund charge Product charge User charge

The implemented charge systems particularly for water environment protection are the water environment improvement charge and effluent charge system. Since the improvement charge is levied periodically, independent of permissible wastewater discharge standards, the environment improvement charge system is an economic system known as a stabilized revenue source in constructing environmental facilities (Kim, 1995). However, the improvement charge system has problems in estimating regional

[19] The deposit-refund system is utilized on recyclable products such as plastic or glass bottles

coefficients[20], and causes a conflict with local sewer tax system. The coefficient of natural environment preservation is set up as low as 0.67[21]. This low value does not contribute to preservation of non-polluted areas and pollution abatement. The coefficients related to environment improvement expense is based on assumption that all facilities have pollution prevention system, independent of facilities with or without the prevention system. The improvement charge system does not provide any motive to polluters to operate or to establish pollution prevention system. It has also been pointed out that the improvement charge does not have any direct role on pollution prevention fund for constructing water quality improvement facilities. Hence, the improvement charge should be incorporated into the effluent charge system that has stronger control function in prevention of environmental pollution. This recommendation is based upon the fact that consumption-circulation facilities, with low investigation cost, are regarded as point sources. Nonpoint sources which generates complex information cost should be regulated by increase of sewer tax (Kim, 1995). The results of an increase of sewer tax are twofold; local governments will have stronger responsibilities and execution capacities through intensification of financial self-support. To introduce and establish more efficient and practical systems to pollution prevention policy, an unbiased scientific investigation on effectiveness of implementation requirements are needed. Also, present regulation-based system should be incrementally replaced with self-control system by polluters.

In Korea, it has not been well studied whether the economic incentive

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[20] The Coefficient, one of variables used in estimating the charge, represents pollution level of regions and population. Thus high coefficient is attributed to extremely populated areas in order to control water pollution.

[21] Metropolitan city, 1; Special city, 2.07; city with a province hall, 0.69; , and tour-recreation area and city, 0.67

system alone could curtail coastal water pollution, reduce damage by the pollution, or be a cost-effective tool in controlling wastewater discharge. Not even a pilot or demonstration research on influence of incentive system is realized. The effectiveness of such system can be inferred from the experiences of other countries with similar policy. For example, the Robbins Company, a metal finishing and plating operation in Attleboro, Massachusetts (USA), was notorious as a polluter of the Ten Mile River that connects to Narragansett Bay. Intensification of discharge limits by federal and the state governments compelled the company to choose one of four options, 'do nothing', 'upgrade present system', 'build a full wastewater treatment plant', and 'modify the process and build a closed-loop system' (Berube and Nash, 1991; recited in NRC, 1993). After taking them into serious considerations, the company concluded that an environment-friendly approach, i.e. a close-loop system, was a best choice for the company. The choice made by the company, environment-friendly action, was cost saving for the company, and also an efficient regulatory measures in long run for the company (Appendix 16).

4. Developing data quality assurance program

Water quality monitoring is a useful mechanism in establishing and implementing policies pertaining to water quality preservation and preventive pollution management. Monitoring and testing of sewage treatment facilities and industrial outfalls are the fundamental tools in assessing long term regulation and management of the water pollution of both industrial and domestic origin. Agencies concerned such as MOE and Ministry of Maritime Affairs and Fisheries (MOMAF)[22], periodically investigate water

[22] MOMAF was integration of Marine Police of Korea, National Fisheries Research and

quality of fresh and marine water[23]. Results from the regularly monitored data will immediately indicate the conditions of water quality, especially the areas of unacceptable conditions[24]. Hence precision and accuracy of observation and data analysis are essential for effective water environment management and pollution prevention.

To achieve successful ongoing accomplishment of such endeavor (e.g., reducing water pollution), appropriate quality assurance and quality control (QA/QC) must be implemented as a indispensable part of the whole program (see Appendix 17). Data analysts must have confidence in the representativeness, consistency, and accuracy of data collected by various agencies. Without such confidence, there would be no significance to the data, and decision-makers will have no foundation to determine any long term policies. Effective QA/QC procedures and a clear division of QA/QC responsibilities are therefore fundamental key to ensure the usability of environmental monitoring data, and must be implemented. QA is the whole system of activities that is accomplished to provide analysts with data that meet defined standards of quality with a predetermined level of confidence. QA system includes the coordinated activities of quality control and assessment. It involves management's review and oversight at the every stages of an environmental data collection activity that assures that results provided to data users are of the quality needed and claimed (USEPA, 1990). QC refers to any activities performed during environmental data collection to produce data of desired quality to document that quality. This involves

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Development Institute, National Fisheries Office, and etc

[23] Monitoring executed by some agencies will be integrated into Ministry of Maritime Affairs and Fishery.

[24] Government established special measures for prevention of the events when red-tide damaged coastal fishing and mariculture grounds in 1995

determining the 'precision (human error) and accuracy (instrumental or procedural error)' of the numbers. It involves planning regulatory procedures to ensure that the analysis stay 'in control' and that data of known quality are produced. It is also recommended that continuing evaluation of the performance of the people collecting and analyzing the data called 'quality assessment' should be implemented. To calibrate each agencies conducting data collection, technicians and laboratory chemists (especially from government laboratories and laboratories under governmental supervisions), will undergo periodic inspections to check their performance and consistency (USEPA, 1990).

Aforementioned efforts to implement data quality management will have a substantial role in achieving the objectives of comprehensive pollution prevention and abatement programs. This will be particularly important when the successful coastal eutrophication prevention agenda are implemented including practical 'total quantity' control on nitrogen and phosphorous. The regulation of 'total quantity' on pollutants from wastewater outfalls could never be an effective and suitable tool to control eutrophication without accurate and precise diagnosis and analysis of water quality conditions. It could be envisaged that long-term and reliable analysis supported by QA/QC can attest to establishment of necessary conditions set forth to control the total quantity of pollutants from point sources (see Kim(1995)).

5. Enhancing the role of sub-national government

Contemporary environmental policy on coastal management in Korea has been implemented on land and sea separately, which resulted in a minimal interaction of policy between two geographic sects. The separate policy has led unmanaged deterioration of coastal pollution bringing about frequent occurrence of red-tide. However, concerned agencies of marine pollution recently established management strategies which integrate both land and coastal environment treating them as interdependent entities through the 'Five Year Plan' to reduce and prevent marine pollution (MOE *et al.*, 1996). Despite of establishment of the new plan, however, the management strategies are yet to be improved. Eutrophication and red-tide are observed more often and more pervasively.

Actual implementation of the whole management strategy will be paralleled with the enactment of Coastal Management Law. Before executing a nationwide integrated coastal management policy, however, it is necessary to plan and complete a pilot or preparatory program to minimize procedural errors before incorporating it fully into legal system, such as planning of sub-national coastal environment management policy. Sub-national (provincial and local) governments of coastal area should be the major player in planning coastal zone management policy. For example, eutrophication and occurrence of red-tides are felt more deeply by the immediate coastal residents and such problem can be best handled by sub-national governments than national government. However, local and provincial governments as they are today, have a little management capacity to design strategies and achieve management objectives.

UNCED asserted in Agenda 21 that capacity and the role of sub-national governments should be strengthened to realize sustainable development of coastal area through preservation of environment and prevention of pollution such as coastal eutrophication (refer to Johnson, 1993). There are some encouraging reports on strengthening coordination between national government and various sub-national governments in Korea (Jeong and Lee, 1995; Jeong, 1995; KORDI, 1996). According to Jeong (1995), the current system of environmental management by sub-national governments only includes minimal delegated works or simple execution of detailed plans by national government. This results in attenuation of self-supporting capacity of sub-national government and results in increased dependence on national government. Jeong (1995) also pointed out that current financial support system to sub-national governments by the Korean government does not agree with the principle of integrated environmental management, the system strongly rooted from a long history of accepting specific grants and relying on central government for most of everything (Table 9).

Table 9. Types of monetary support system by national government on environmental affairs (Jeong, 1995)

National Affairs	Specific Grants Affairs	Supplementary Grants Affairs
• Industrial waste water treatment facilities	• Livestock treatment facilities (70%)	• Sewage treatment facilities (50 to 70%) • Nightsoil treatment facilities (70 to 100%) • River purification (30 to 70%)

Note : % indicates percent contribution by national government.

Responsibilities for establishment and operation of treatment facilities are basically attributed to sub-national governments. However, actual rights on designing and execution are reverted to national government in Korea. Thus, disharmonious and inappropriate sharing of roles between governments at various levels are developed, preventing effective accomplishment of coastal eutrophication management. To overcome such a discord between governmental agencies, several suggestions can be made;

- turning over governing authorities to sub-national to intensify their responsibilities on its environmental management (handing over delegated authority should be through analysis on scale and characteristics of each sub-national government);

- increasing technical and financial support to strengthen the capacities of sub-national governments for the environmental management, and decreasing jurisdiction authority by national government; and
- intensifying cooperation and coordination between sub-national governments and branches of national agencies.

Also, roles between branches of national agencies and sub-national governments should be clearly separated. MOGA (1994) reported that environmental organizations under sub-national governments occupied only 32.2% of total available responsibilities. Specific and professional fields such as development of environmental technology, large-scaled investigation, assessment and testing on various environmental factors should be under the control and responsibility of national branches. The planning and implementation of environmental management have to be incorporated into sub-national authority. Some responsibilities are to be shared between national and sub-national governments. An accurate investigation[25] on demographic and natural environments, administration capacities, financial sources and other activities by sub-national governments should be studied before the governments can take over their new responsibilities. Then, each coastal zone can be classified into some regions, and development and preservation strategy suitable for each coastal region should be put into regional framework by their governments. It is feasible that sub-national governments would be under stronger administration by national government if the jurisdiction capability of national governmental enforcement is not settled. When delicate balance of power sharing and

[25] Hotta (1995) suggested that in planning ocean utilization, various unique characteristics should be taken into full consideration, including socio-economic factors such as structure of hinterland of coastal waters. According to Horta (1988; recited in Hotta, 1995), 'ocean space' was classified into three types; coastal seas and enclosed ocean space; inner bay and semi-closed ocean space; and open ocean space

responsibility are established, collecting baseline data of coastal eutrophication problem can begin as a first step toward the successful coastal environmental management.

6. Promoting public participation and education

Other countermeasures have also been addressed to manage or, if possible, to prevent coastal eutrophication in Korea. They include encouragement of public participation on environment protection (MOI, 1994; Yoo, 1994; Cho, 1996; KORDI, 1996), enforcement of education to officials and related persons of industries (MOE, 1996; KORDI, 1996), and establishment of regional characteristic-oriented environmental protection guidelines (Jeong, 1994; KORDI, 1996).

KORDI (1996) suggested that public participation always strongly coincide with a capability of regional governments to enforce any management policy. Two factors of environmental management, public participation and governmental enforcement, constitute main elements of sustainable society. It is considered that public participation would have a fundamental role in encouraging capabilities of environmental management administration of sub-national governments. Especially the participation increase through active interaction with education.

Also, the target of education should not be limited to average citizens. It should include public officials and employees of other related industries (MOE, 1996). Public and administration participation in educational programs will increase awareness of coastal problems and encourage better management of pollution such as coastal eutrophication. Especially the residents of coastal areas will benefit from the program, and play an important part in coastal environment management, and increase cooperation with provincial and local government. From the awareness program, officials and related employees will assume stronger responsibility and professional ability in carrying out their tasks. Lastly, sub-national guideline on eutrophication management needs to be developed. Current pollution prevention system in Korea has no usable eutrophication guidelines which is supported by scientific investigation. Jaworske (1981) suggested "permissible" limits of nutrient input so as to protect shallow (4m to 9m) temperate zone estuaries from eutrophication, i.e. below 24 mmol P m^{-2} yr^{-1} and 380 mmol N m^{-2} yr^{-1}(40 to 95 mmol m^{-3} yr^{-1}) (recited in NRC, 1993). Establishment of area-specific eutrophication criteria is considered to be a useful tool in regulating land-based pollutants through precise assessment of pollution carrying capacity.

V. Conclusions and Suggestions

Progress has been made in improving the quality of coastal waters, however, it has been a slow and frustrating advancement. The health of coastal waters is still very much at risk. Since first reported red-tide broke out in Chinhae Bay in 1967, eutrophication in coastal area are observed in increasing frequency with passing year (NFRDI, 1997). Red-tide, following eutrophication of water, is devastating to mariculture and fishing industries, as well as local tourism industry. The coastal zone-based development policy, such as construction of large-scaled sea ports and airports for logistics, development of industrial complexes, and expansion of nuclear power plants, encourages centralization of population and intensification of various human activities. As pollution prevention and environment preservation policies did not include aforementioned developments, coastal water quality adjacent to the developments has been gradually deteriorated. Eutrophication is one of the result of coastal water pollution, and is just a small part in the whole array of coastal pollution problem. To manage eutrophication, the whole array of water pollution problem must be dealt within the integrated management policy.

In 1996, recognizing the seriousness of coastal pollution problems, governmental agencies developed and established cooperative plan, the Five Year Plan for Prevention of Maine Pollution, to help reduce and better manage coastal pollution problems (MOE *et al.*, 1996). The comprehensive countermeasures for red-tide (i.e., eutrophication) in the 'Five Year Plan for Prevention of Marine Pollution' is considered to be a first major indication of properly managing coastal eutrophication. Moreover, this is an actual evidence that administrative authorities are taking preserving environment as an important task and are serious in implementing integrated coastal management. The national government has also executed various countermeasures to improve water quality of Korean coastal environment including management and designation of special control area, expansion of wastewater treatment facilities, dredging of polluted sediment, reconsideration of economic incentive system, and enactment of coastal zone management law.

Some of the fundamental tools in pollntion prevention and management system are introduction of institutional system, construction of environmentally friendly facilities, establishment of scientific data set on coastal zone, and financial and technical supports to sub-national governments. Other strategies to be reinforced to improve coastal environment, specifically management of eutrophication problems, are summarized as follow. First, to prevent and manage eutrophication of coastal water, a direct regulation on the sources of nitrogen and phosphorous (main limiting factors for the red-tide) pollution should be accomplished. The successful execution of regulation system is yet to be implemented despite of incorporation into current legal system. The implementation should be based on the establishment of environmental data set, analysis of carrying capacity of coastal zone, and construction of treatment facilities. Second, management of nonpoint sources which is another major cause of eutrophication problem in coastal area, should be carried out through basic study on the source conditions and management on small watersheds. In order to increase management efficiency, current sewer system needs to be reformed; turning combined sewer system into separate sewer system and expanding of sewer pipe lines. Third, the incentive system, an effective management tool on industrial pollution, should be developed focusing on effluent charge system rather than environment improvement charge system. The environment improvement charge, functioning as financial source for constructing environmental facilities, is not considered to be a right tool that could lead to self-control of the pollution by the industry.

Fourth, to implement coastal eutrophication prevention plan, detailed scientific surveys and data quality management are required. Inaccurate data will lead related agencies to implement environment policy that may have negative impact. Thus, quality control of data collection is considered to be a necessary precondition to implement sustainable coastal management policy. QA/QC should also be adopted in reconstructing and collecting demographic data as well as basic scientific data. Fifth, because sub-national government is more familiar with the direct impact of the eutrophication, development of national strategy to efficiently preventing coastal pollution should be focused on the intensification of management capacity of regional governments. It is based on the belief that local residents could develop and manage better area-specific and detailed policies. Enacting environmental ordinances in sub-national governments, e.g. Inchon and Pusan metropolitan cities, is regarded as encouraging news for strengthening sub-national capacities. In addition, public participation also needs to be incorporated into environmental policy and implementation of the policy on coastal environment management process. Agenda 21 of 1992 UNCED asserted that citizen as well as local governments could have a substantial role in establishment of sustainable society by environment preservation and pollution prevention. Citizen together with sub-national governments, especially at local level, can carry out a key role in solving environmental problems through synergistic cooperation. Thus, current central government-based management system should be replaced by community-based management system (see KORDI, 1996). Community-based includes a principle that the establishment of the plan and decision-making for all development activities should be based on consensus and cooperation between related parties, such as local governments, local assembly, industries, citizen, and specialists on the area. Examples of successful community-based management system were shown in the Sarasota Bay National Estuary Program (1992) and Santa Monica Bay Restoration Project (1994) in the United States. Based on these programs, citizen-involvement approaches for management of the coastal areas increase the management capacities of local governments and promote participation of public into the projects. For example, forming Citizen Advisory Committee amongst three committees supporting Santa Monica Bay Restoration Project played a substantial role in restoring the bay by operating public participation program. As the community-based management system can minimize social cost through prevention of conflicts between related parties, it is regarded as one of the cost-effective management strategy. The management system adopts more active idea that success of coastal management depends on encouragement of citizen volunteership. Implementation of various efforts by national governments, increase management capacity of sub-national (provincial and local) government capacities, and encouragement of public participation have to be realized in the main framework of newly established MOMAF and other environmentally oriented agencies. Hence, it is expected that coastal eutrophication management will be attained successfully by integration of efforts at all levels, and by incorporation into community-based management strategy.

Appendices

Appendix 1. Objectives proposed by UNEP to treat eutrophication

According to UNEP(1995), integrated participation of both scientific and governmental agencies, and national and regional cooperation is warranted to realize the coastal management such as regulation of coastal eutrophication. At the national level, sustainable use of the oceans depends on the maintenance of coastal ecosystem health, public health, food security, and economic and social benefits including cultural values. This is especially true for the Korean coastal waters. Objectives to develop comprehensive, sustainable and flexible programs of action within the framework of integrated coastal zone management were suggested. The first objective is identification and assessment of problems. It is identification of the nature and severity of problems such as coastal and marine resources, and ecosystem health including their biological diversity. It is a process of identifying and prioritizing contaminants such as sewage, persistent organic pollutants, radioactive substances, heavy metals, hydrocarbons, nutrients, sediment mobilization and litter. It is to assess problems of physical alteration, including habitat modification and destruction in areas of concern. It is also to identify sources of degradation of point sources of coastal and upstream such as waste-water treatment facilities, industrial facilities, power plants, etc.; non-point sources such as urban run-off, agricultural and horticultural run-off, forestry run-off, etc.; and atmospheric deposition caused by vehicle emissions, power plants, industrial facilities, incinerators, and agricultural operations. Identifying areas affected or vulnerable is another part of process such as classifying critical habitats, shorelines, coastal watershed, estuaries, drainage basins, and protected areas.

Next objective is to establish priorities reflecting the relative importance of impacts upon economical and social benefits in relation to source categories (i.e., contaminants) and the areas affected. The costs, benefits and feasibility of options for action should also be considered in establishing priorities. To accomplish the objective, government should apply integrated coastal area management approaches, apply watershed management approaches, apply environmental impact assessment procedures, and take into account of existing or future comprehensive environmental programs. Using community-based participatory approaches, integrating national action with any relevant regional and global priorities, establishing focal points of cooperation, and applying the precautionary approach and the principle of intergenerational equity applications are also recommended.

Setting management objectives for priority problem is another objective proposed by UNEP. It suggested that wherever possible, states should first take immediate preventive and remedial action using existing knowledge, resources, plans and processes. Also, identification, evaluation and selection of strategies and measures should include a combination of specific actions to promote sustainable use of resources such as best available techniques and best environmental practices (e.g. Quality Assurance Programs), waste recovery, recycling and treatment; specific steps to improve affected areas such as quality criteria for measuring progress, land-use planning requirements, and rehabilitation of degraded habitats. Other essential parts of management objective are requirements and incentives to induce action of polluters to comply with measures such as polluter pay principles, technical assistance, cooperation, training of personnel, education and public awareness; arrangement of institution with authority and resources to carry out management tasks; identification of short- and long-term data collection and research need; development of a monitoring and reporting system; and identification of sources of finance.

Next objective listed in UNEP report is identifying criteria for evaluating the environmental effectiveness, economic costs and benefits, equity, flexibility and effectiveness in administration, timing, and inter-media effects. Last but not least is to develop integrated strategies and program support elements such as organizational arrangements to coordinate among sectors and sectoral institutions, legal and strict enforcement mechanisms, financial mechanisms, means of identifying and pursuing research monitoring requirements in support of the program, contingency planning, human resources development, and public participation and awareness.

Appendix 2. Water quality standards of rivers

Classification	Class	Applicable object by purpose of use	pH	BOD (mg/l)	Suspended Solids (mg/l)	DO	Coliform bacillus (MPN per 100 ml)
Living Environment	I	Service water source Class A Natural environment preservation	6.5-8.5	Under 1	under 25	above 7.5	under 50
	II	Service water source Class B Water for fisheries Class A Water for swimming use	6.5-8.5	under 3	under 25	above 5	under 1,000
	III	Service water source Class C Water for fisheries Class B Water for industrial use Class A	6.5-8.5	under 6	under 25	above 5	under 5,000
	IV	Water for industrial use Class B Water for agricultural use	6.0-8.5	under 8	under 100	above 2	-
	V	Water for industrial use Class C Living environment preservation	6.0-8.5	under 10	no refuse floating on water	above 2	-
Protection of Human Health	Whole waters	Cd: under 0.01mg/l, As:under 0.05mg/l, CN:not to be detected, organic phosphor.: not to be detected, Pb:under 0.1mg/l, Cr^{6+}:under 0.05mg/l, PCB:not to be detected, anion surface active agent (ABS): under 0.5mg/l					

1. Water for fisheries Class A : for use of aquatic living organism in waters of low eutrophy,
2. Water for fisheries Class B : for use of aquatic living organism in waters of middle eutrophy,
3. Preservation of natural environment : environmental preservation of natural scenery, etc.
4. Service water source Class A : use after passing through simplified purification by filtration, etc ,
5. Service water source Class B : use after passing through simplified purification by precipitation filtration, etc ,
6. Service water source Class C : use after passing through high purification through pretreatment, etc.,
7. Water for industrial use Class A : use after passing through ordinary purification by precipitation, etc ,
8. Water for industrial use Class B : use after passing through high purification by treatment with chemicals, etc ,
9. Water for industrial use Class C : use after passing through special purification; and
10. Living environment preservation: to the extent that it gives people no unpleasant feelings in daily life.

Appendix 3. Water quality monitoring items and date

Classification			Items	Date and Term
Inshore	Living Environment (11)	Generals	pH, DO, COD, Suspended solid, coliform, Oil and grease (6)	- Feb., May, June, Aug., Sept., and Nov. (six per year)
		Nutrients	Total nitrogen (NO_2^-, NO_3^-, NH_3^+)	
		Others	Total phosphorous (PO_4^+) (2), Temperature, Salinity, Transparency (3)	- PCB and organic phosphorous (one per year in Nov.)
	Protection of Human Health (10)		Cr^{+6}, As, Cd, Pb, Cu, Zn, CN, Hg, PCB, Organic phosphorous	
Offshore	Living Environment		Inshore items	- One per year (Aug.)
	Protection of Human Health		Inshore items except of PCB and organic phosphorous	

Appendix 4. Water quality standards of marine environment

Classification	PH	COD (mg/l)	DO (%)	Suspended solids (mg/l)	Normal nucleic acid extract (fraction) (mg/l)	No. of coliform bacillus (MPN per 100 ml)	Total N	Total P
I	7.8-8.3	under 1	Saturation rate above 95	under 10	not to be detected	under 200	under 0.05	under 0.007
II	6.5-8.5	under 2	Saturation rate above 85	under 25	not to be detected	under 1000	under 0.1	under 0.015
III	6 5-8 5	under 4	Saturation rate above 80	-	-	-		under 0.03

1. In case where DO is indicated as concentration, Class I shall be above 6 mg/l, and Classes II and III, above 5 mg/l.
2. Class I means water suitable for inhabitation, breeding and spawning of aquatic living organisms.
3. Class II means water suitable for sightseeing and making good use of leisure time at sea, such as sea bathing, etc., and for aquatic living organism other than those as referred to Class I.
4. Class III means water used for other purpose, such as water for industrial use, anchorage of ships, and etc.
5. The total N means the sum of NO_2-N, NO_3-N and NH_3-N.
6. The total P means the form of PO_4-P.

Appendix 5. Water quality measurements in major coastal areas from 1991 to 1995

(a) Inchon coastal area

Year	COD (mg/l)	Suspended solids (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
1991	1.2	6.8	0.061	0 003
1992	1.1	3 7	0.076	0.009
1993	1.3	3.9	0.145	0.009
1994	1.6	3.6	0.188	0.010
1995	1.6	3.1	0.236	0.012

(b) Kunsan coastal area

Year	COD (mg/l)	Suspended solids (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
1991	2.2	10.4	0.335	0.019
1992	2.3	8.7	0.328	0.018
1993	2.7	16.8	0.731	0.019
1994	2.0	14.3	1.200	0.031
1995	2.0	14.3	0.973	0.055

(c) Mokpo coastal area

Year	COD (mg/l)	Suspended solids (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
1991	1.8	9.0	0.198	0.008
1992	1.8	11.5	0.224	0.023
1993	1.9	10.2	0.275	0.020
1994	2.0	11.4	0.314	0.014
1995	1.9	11.4	0.611	0.019

(d) Masan Bay

Year	COD (mg/l)	Suspended solids (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
1991	4.3	7.8	1.117	0.012
1992	3.1	12.2	1.071	0.024
1993	4.0	7.4	1.127	0.049
1994	5.6	7 6	1.569	0.036
1995	3.8	4 2	1.735	0 052

(e) Pusan coastal area

Year	COD (mg/l)	Suspended solids (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
1991	1.6	7.8	0.795	0.005
1992	1.2	10.6	0.796	0.006
1993	1 7	8.4	1.038	0.034
1994	2.2	7.6	1 051	0.029
1995	2.2	5.1	1.348	0.029

(f) Yongil Bay

Year	COD (mg/l)	Suspended solids (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
1991	1.9	7.9	1.448	0.025
1992	2.3	5.9	1.261	0.042
1993	1.8	4.3	1.106	0.037
1994	1.8	3.2	1.093	0.032
1995	2.1	5.2	1.203	0.030

Appendix 6. Yearly construction plan of wastewater treatment facilities in coastal area in Korea

(Unit , 1000 tons/day, billion won)

Classification		Sum	till '95	Yearly plan					
				Sub-sum (96-2000)	'96	'97	'98	'99	2000
Sum	Number	75	12	63	4	7	8	12	32
	Capacity	6,279	1,934	4,345	291	314	1,310	691	1,739
	Cost	2948.4	861.8	2086.6	313.8	321 5	377.1	508 6	565.6
South sea	Number	39	7	32	3	3	3	5	18
	Capacity	3,229	957	2,272	141	122	340	533	1,136
West sea	Number	21	4	17	-	3	4	3	7
	Capacity	2,151	727	1,424	-	112	895	80	337
East sea	Number	15	1	14	1	1	1	4	7
	Capacity	899	250	649	150	80	75	78	266

Appendix 7. Discharged water quality standards

(Unit , mg/l)

Classification	BOD	COD	SS	Total nitrogen	Total phosphorous
Sewer treatment	under 30→ under 20	under 50→ under 40	under 70→ under 20	60	8
Wastewater treatment	under 30→ under 30	under 50→ under 40	under 70→ under 30		

Appendix 8. Permissible wastewater discharge standards

(Unit ; mg/l)

Effluent	over 2,000 m3/day			under 2,000 m3/day		
	BOD	COD	SS	BOD	COD	SS
Clean	50→30	50→40	50→30	50→30	50	50→40
A	80→60	80→70	80→60	100→80	100→90	100→80
B	100→80	100→90	100→80	150→120	150→130	150→120
Specified	30	50→40	70→30	30	50→40	70→30

Appendix 9. Comparison of studies on nonpoint sources of Korean and the Unites States

	Korea	the United States
Legal system	Not defined as pollutants	Examination of nonpoint pollution from 1972
Recognition on nonpoint sources	Regarded as pollutants	Implementation of nonpoint source charge in 1992 (Wisconsin state)
Research progress	• Examination of nonpoint sources from 1980 • Scientific approach on total load quantity -late 1980's - model development (1989, 1994)	• Development of effluent models in 1970's • Best management plan(BMP) development in late 1970's • Connecting GIS wih nonpoint source models
Level of data	No full establishment of rainfall and effluent data	Nationwide database establishment on nonpoint source data

(Source : MOE. 1995 Report of basic examination and research on nonpoint sources)

Appendix 10. Total effluent quantity of nonpoint sources in major watersheds (MOE, 1995)

(Unit ; ton/yr)

	Han River	Nakdong River	Kum River	Yeongsan River
Total phosphorous	3,440.59	3,412.42	3,412.42	2,156.45
Total nitrogen	45,079.43	43,785.30	43,785.30	27,147.46
Ammonia	8,827.74	8,562.38	8,562.38	4,760.00

Appendix 11. Indicators of yearly condition on sewage treatment (MOE, 1996)

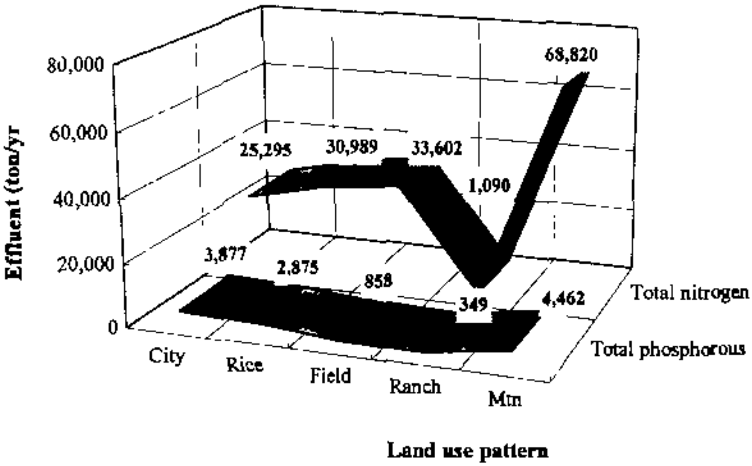
(Unit ; thousand persons, %)

	1991	1992	1993	1994	1995	1996	2000	2005
Total population (x 1000 persons)	43,268	43,663	44,056	45,076	46,183	46,598	46,789	48,430
Treatment population (x 1000 persons)	14,144	16,117	17,258	18,621	20,879	23,299	29,000	38,744
Distribution rate* (%)	33	36	39	42	45	50	62	80

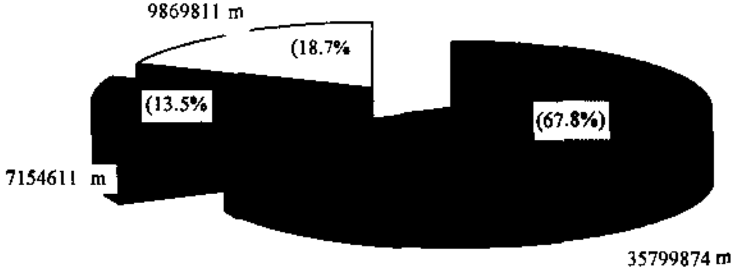
(Source : MOE, 1996)

* Distribution in other countries: UK 95% ('82), France 64% ('85), America 73% ('86), Japan 49% ('94)

Appendix 12. Yearly effluent quantity of nonpiont sources according to land use pattern (Source : MOE, 1995)

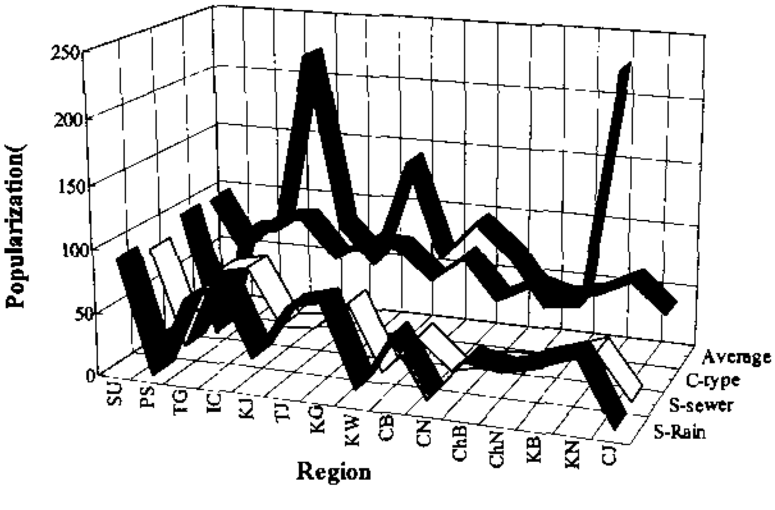


Appendix 13. Sewer pipe system comparison of confluence and separation type (Source : MOE, 1996)



Appendix 14. Conditions of sewage pipe facilities in Korea

(revised in MOE, 1996)



1. SU: Seoul, PS: Pusan, TG: Taegu, IC: Inchon, KJ: Kwangju, TJ: Taejon, KG: Kyeonggi, KW: Kangwon, CB: Chungbuk, CN: Chungnam, ChB: Chonbuk, ChN: Chonnam, KB: Kyeongbuk, KN: Kyeongnam, CJ: Cheju.
2. S-Rain; separation type sewer pipe system for rain only, S-sewer; separation type sewer system, C-type; confluence type sewer pipe system.

Appendix 15. Main watershed environmental management organizations

Classification	Governed watershed	Organization	Remark
Han River	Influence sphere including main stream of Han River, Bukhan River, and Namhan River	13 persons (7 officials, 7 residents and 2 specialists)	4 corporation committees
Nakdong River	Influence sphere including upstream and downstream of Nakdong River, and Kumho River	12 persons (6 officials, 4 residents and 2 specialists)	
Kum River	Influence sphere including upstream and downstream of Kum River, and Mankyung River	8 persons (4 officials, 3 residents and 1 specialist)	
Yongsan River	Influence sphere including Yongsan River and Somjin River	12 persons(6 officials, 4 residents and 2 specialists)	

Appendix 16. The arrangements of four pollution management options that should be selected by the Robbins Company (Berube and Nash, 1991)

Options	Effect on Compliance	Capital and Operation and Maintenance Cost
Do nothing	Out of compliance	Fines up to $ 10,000 per day
Upgrade present system	In compliance now but probably not in the future	$ 250,000 capital $ 120,000/yr O&M
Build a full wastewater treatment plant	Full compliance	$ 500,000 capital $ 120,000/yr O&M
Modify the process and build a closed-loop system	Full compliance	$ 250,000 capital $ 21,000/yr O&M

Appendix 17. The Quality Assurance Program (QA/QC): Summarized and Revised from John Keenan Taylor, 1987, *Quality Assurance of Chemical Measurements*, Lewis Publishers, Florida.

The 'quality assurance program' is necessary part of the production of dependable data. Any involved laboratory, implementation of suitable approaches to quality assurance is needed. In deciding the details of particular QA program, the costs and benefits of various approaches will need to be considered. Also, the size and diversity of an organization is another important determining factor in making decisions related to formalization of the quality assurance program. Laboratories engaged essentially in small operations and/or those involved in diversified programs, implementing a formal quality assurance program may be difficult except generic QA practices applicable. However, massive operations (e.g., nationwide) concerned with narrowly defined programs (i.e., one to two parameters) of work are easily adapted to formal QA programs. Recommended aforementioned national implementation of nutrient analysis (i.e., nitrogen and phosphate) is a large operation concerned with confined parameters. Quality assurance must be balanced between the use of highly motivated personnel operating in an atmosphere that promote excellence and the use of the formal programmatic and systematic approach which defines all operational aspects of quality assurance. Just because it is confined program, national QA/QC program of nutrient analysis should not look too narrowly at what it does. Nutrient analysis involve a number of participants and numerons repetitive measurements. A formal quality assurance program is imperatively a necessity. The time and effort dedicated to its development should be more than compensated by cost-effective and highly reliable analytical data. Any particular QA/QC program must be considered for a comprehensive knowledge of the nature of the measurement process used, an examination of how errors may be propagated, and facilitation in identifying ascribed causes to aid in the development of credible quality assurance program. QA/QC operation should be a flexible program to be able to adapt continuous process of operational improvements such as identification and trouble-spots related to diverse operations (e.g., contamination, reagents, house keeping practices, record keeping, and etc.). Following is an example of basic guidelines for developing QA/QC plan.

1. Adoption and enunciation of a quality assurance policy by management (e.g., government authority).

2. Elucidation of respective responsibilities of various organizational levels in implementing the program.

3. Development of internal motivation to reduce a natural dislike to regulations and requirements (i. e., the quality assurance program must be both realistic and perceived as such), and to produce high-quality outputs. This is a program oriented and usually requires the development of a quality assurance manual.

4. Development of external motivation by specific requirements for a specific project. This is also a problem oriented and requires the development of project plans.

5. Development of quality assurance policy of a laboratory which reflects its basic measurement philosophy and the goals and objectives it desires to reach.

6. Development of an acceptable procedure to carry out basic operation or activity in a laboratory that is known or believed to influence the quality of its outputs. This is called GLP (good laboratory practice) which ordinarily is essentially independent of the measurement techniques used.

7. Development of an acceptable way to perform some operation associated with a specific measurement technique and known or believed to influence the quality of measurement. This is called GMP (good measurement practice). Both GLP and GMP describe in rather specific terms the ways certain operations will be conducted.

8. Development of a procedure adopted for repetitive use when performing a specific measurement or sampling operation. It

may be a standard method or one developed by the user. This is called SOP (Standard operations procedure). The SOPs define how specific measurements will be made.

9. Development of a detailed instructions for the performance of all aspects of a specific measurement program. This is called PSP (protocol for a specific purpose). This step incorporates all of the above for specific measurement activities. PSPs are needed for recurring measurement activities. Ordinarily, PSPs will need to be developed for a specific project of a type not previously encountered and especially for monitoring programs such as nutrients (i.e., nitrogen and phosphates). PSPs need to be reexamined for their adequacy at each time of reuse and revised as necessary (flesability).

After the quality assurance program is planned, it must be developed accordingly. This involves all levels of laboratory personnel. Following are a summary of development of a quality assurance program:

1 a. Management (e.g. government authority) must decide to develop a formal program, establish the policy that will be followed, and commit appropriate resources for both its development and implementation.
  b. Magement appoints a leader to develop the details of the program.
  c. Management will certify the program at various stages of its development and establish a mechanism for its oversight and implementation.
  d. Management designates a quality assurance officer or coordinator to oversee the program development. He or she will periodically review the program and conduct systems audits to provide test materials, and conduct internal performance audits on a routine and continuing basis.

e. Management designates a study director, validates results, assures availability of staff, and assures that deficiencies are corrected.

2. a. For creation of national nutrient pollution monitoring program, the leader will chair a committee.
   b. The leader must get the cooperation and involvement of staff in developing the details and will follow appropriate procedures to obtain consensus approval.

3. a. The staff will provide technical recommendation and guidance, particularly in the development of the GLPs, GMPs, and SOPs. SOPs are best developed on a case-by-case basis. Interdisciplinary groups will address the GLPs and disciplinary groups will develop GMPs.

4. Identify and Document the quality assurance procedures already implemented, partially or fully, in the ongoing or related programs. These will be compared with any requirements of the program and also with experience of others.

5. Consensus approval is obtained. This will include concurrence by the internal participants of the program, management, and any external group or organization requiring a formal QA program, in the order mentioned.

6. A laboratory will set priorities based on external stipulations, importance of operations, or what can be readily formalized from a present program or related program to reduce frustration and counterproductive attempt in covering too much of laboratory activities.

7 The quality assurance office will be independent of daily operations and report directly to management so that unbiased evaluation of operations can be obtained.

8. The supervisory staff has the responsibility for direct implementation of the quality assurance program. Work of technical staff will be reviewed by the supervisors for its technical excellence and conformance with quality assurance requirements. They will also provide training related to both aspects and decide on corrective actions.

9. The individual members of the technical staff will have key responsibilities for the quality of the data output and for all related laboratory operations. Thus, the staff must be adequately trained to carry out both its technical and quality assurance responsibilities. The QA program will provide definite instructions in regard of staffs' ability to distinguish between normal random fluctuations and abnormal deviations, and other such matters encountered in the laboratory operations.

The quality assurance program and practices of a laboratory will be documented usually in the form of a manual (i.e., hardcopy and digital format). This will include the QA program documents such as GLPs, GMPs, and SOPs. The manual will also include implementation directives. It is an instruction kit in the production of quality data. It will need to be well organized and indexed, comprehensive but concise, and descriptive but brief. And lastly, quality assurance programs should be implemented as a minimum federally mandated programs to the appropriate laboratories. Here are some of the examples of QA requirements which may be needed during the national pollutant (e.g. nutrients) monitoring program.

1. a. Inspection and preventative maintenance of equipment and instruments;
   periodic inspection and testing for proper operation.
   b. Validation of methods.
      a. Remedial actions taken in response to detected defects.
      b. Monitoring of temperature-controlled spaces and equipment.

c. Evaluation of analytical measuring devices.

d. Evaluation of compatibility among instruments.

e. Labeling of all reagents and solutions.

f. Banning the use of substandard and deteriorated materials.

g. Availability of a laboratory procedural manual; exclusive use of documented methods.

h. Manuals located in the immediate bench area.

i. Manuals current and designed to reflect an annual supervisory review.

j. Manuals and methods specify calibration procedures.

k. Manuals and methods include written approval of all changes.

l. A list of all analytical methods applied on file and available for inspection of concerned parties.

2. a. Record and document routine precision of each method used.

b. At least one standard and one reference sample are included in each run.

c. Control limits are recorded.

d. A written course of action is followed when controls are outside of acceptable limits.

e. Qualitative chemical analysis is checked daily with reference samples.

f. Report of quantitative analysis includes the units of concentration or activity.

g. When kits are used, each will be tested when opened and at least once each week of use.

3. a. Records of observations will be made concurrently with the performance of each step in the examination of specimens.

b. Records will reflect the actual results of all control procedures.

c. Records will be retained for two years.

d. Personnel record will be maintained on a current basis.

e. Daily accession records shall be maintained, containing:

laboratory id(name and address), sample site, sample date, sample received, condition of sample, name of sample collection, name of sample receiver, name of sample analyzer, date of analysis, type of test performed, result of test and date of completion.

4. a. Inspections for compliance will be allowed.
   b. All personnel will have education, training and experience adequate for their duties. Sufficient staff must be available to conduct studies. Clothing must be appropriate for duties and for preventing cross contamination.
   c. Study director will have appropriated training and experience, has overall responsibility for conduction of study, assures that protocols are followed, and is solely responsible for authorizing changes in protocols.
   d. Quality assurance unit will be established. This is responsible for assuring management that regulations are followed, maintains master schedule chart, maintains copies of all protocols that must be followed, periodically inspects each phase of a study for compliance, submits periodic reports to management, noting problems and corrective actions needed, determines that no unauthorized deviation for final report regarding interim inspections, and maintains records of above for use of management on request.
   e. Facilities will be appropriate for measurements and handling of test items, administrative and personnel facilities must also be adequate, including sanitation facilities as appropriate.
   f. A written protocol is required for each study that defines all aspects of how it is to be conducted and the records that are to be kept.
   g. Final report will contain full information, specified in regulation, raw data, documentation, protocols, specimens, and it must be retained, and various retention times are specified, depending on the nature of the records.

h. Disqualification will result in non-acceptance of data. QA program will carry various grounds for disqualification which are specified, and reinstatement possible.

Quality assurance practices will improve the odds for obtaining reliable products. An effective quality assurance program can be decisive in the selecting priorities. Measurement programs for water pollutant analysis (i.e., nitrogen and phosphate) in which data are collected over a period of time for monitoring or historical purposes must ensure that compatibility (historically and among laboratories) and is achieved. The need for a credible quality assurance program to ensure this requirement is obvious. All producers (e.g., central government supervised regional authorities) of such data must demonstrate competence before their data can be accepted. When several participants are involved, which is expected in national monitoring program, peer performance of all contributors must be achieved. In such large program, adherence to the above requirements may be best monitored and the validation of data facilitated by the use of a reference laboratory. One of the major function of such a laboratory is to provide reference material and various control samples to ensure the continuing intercalibration of the participating laboratories. The goal of introducing a quality assurance program into an organization is acceptance rather than resignation. In the international arena, international agreements may mandate a formal QA program to accept the data produced by a particular country. Thus, there is a pressing need of developing quality assurance program in any environmental management program in Korea including systematic water pollutant monitoring system. Quality assurance can enhance the quality of outputs and provide the basis for their evaluation. However, no matter how adequate at the time of its development and adoption, its use may identify the need for additions or amendments, and prompt actions of this nature should be taken as necessary.

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