NOWPAP POMRAC

Northwest Pacific Action Plan
Pollution Monitoring Regional Activity Centre

7 Radio St., Vladivostok 690041, Russian Federation
Tel.: 7-4232-313071, Fax: 7-4232-312833
Website: http://www.pomrac.dvo.ru
http://pomrac.nowpap.org

REGIONAL OVERVIEW

Case studies of river and direct inputs of contaminants with focus on the anthropogenic and natural changes in the selected areas of the NOWPAP region

POMRAC Technical Report # 10

Northwest Pacific Action Plan
Pollution Monitoring Regional Activity Centre

7 Radio St., Vladivostok 690041, Russian Federation
Tel.: 7-4232-313071, Fax: 7-4232-312833
Website: http://www.pomrac.dvo.ru
http://pomrac.nowpap.org

REGIONAL OVERVIEW
Case studies of river and direct inputs of contaminants with focus on the anthropogenic and natural changes in the selected areas of the NOWPAP region

POMRAC, Vladivostok, Russian Federation

2011

POMRAC Technical Report # 10

Pollution Monitoring Regional Activity Center on UNEP Action Plan for the Protection,
Management and Development of the Marine and Coastal Environment
of the Northwest Pacific Region (NOWPAP POMRAC)

Региональный Центр по мониторингу загрязнения окружающей среды Плана действий ЮНЕП
по охране, управлению и развитию морской и прибрежной среды в регионе
Северо-Западной Пацифики (НОУПАП ПОМРАК)

Pacific Geographical Institute, Far Eastern Branch of the Russian Academy of Science
Тихоокеанский институт географии Дальневосточного отделения Российской Академии наук

Regional Overview: Case studies of river and direct inputs of contaminants with focus on the anthropogenic and natural changes in the selected areas of the NOWPAP region/ Author V.M.Shulkin. Ed. By A.N.Kachur. – Vladivostok: Dalnauka, 2011. – 92 p. – ISBN
Региональный обзор: Поступление загрязняющих веществ в типичные прибрежные акватории региона Северо-Западной Пацифики с акцентом на антропогенные и природные изменения/ Автор В.М.Шулькин, Отв. редактор А.Н.Качур. – Владивосток: Дальнаука, 2011. – 92 с. (на англ.яз.)

ISBN

List of Acronyms

BOD	Biological oxygen demand
CEARAC	Coastal Environment Assessment Regional Activity Center
CEM	Center Environmental Monitoring , Federal Service on Hydrometeorology and Environmental Monitoring, Vladivostok, Russia
CNEMC	China National Environmental Monitoring Center
COD	Chemical oxygen demand
DIN	Dissolved inorganic nitrogen
DIP	Dissolved inorganic phosphorus
DO	Dissolved oxygen
DSi	Dissolved silica
EEI	Economical Environmental Index
EQS	Environment Quality Standard
FPM	Focal Point Meeting
GDP	Gross Domestic Product
GIWA	Global International Waters Assessment
HCH	Hexachlorcyclohexane compounds
HNS	Hazardous Noxious Substances
ICARM	Integrated Coastal and River Basins Management
IGM	Intergovernmental meeting(s)
MEP	Ministry of Environmental Pollution, China
MOE	Ministry of Environment of Korea
MOMAF	Ministry of Maritime Affairs and Fisheries of Korea
MOST	Ministry of Science and Technology of Korea
MPC	Maximum permissible concentration
NIER	National Institute of Environmental Research of Korea
NIES	National Institute Environmental Science, Japan
NFRDI	National Fisheries Research and Development Institute, Korea
NOWPAP	Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region
NPEC	Northwest Pacific Region Environmental Cooperation Centre, Toyama, Japan
PAHs	Polyaromatic hydrocarbons
PCBs	Polychlorbiphenile compounds
PGI	Pacific Geographical Institute, Russian Federation
PHs	Petroleum hydrocarbons
POI	Pacific Oceanographic Institute, Russian Federation
POMRAC	Pollution Monitoring Regional Activity Center
POPs	Persistent Organic Pollutants
RCU	Regional Coordinating Unit
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee on Oceanic Research
SOMER	State of Marine Environment in the NOWPAP region
SS	Suspended Solids
TDP	Total dissolved phosphorus
TN	Total nitrogen
TP	Total phosphorus
TPLCS	Total Pollutant Load Control System
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
YSLME	Yellow Sea Large Marine Ecosystem
WG	Working Group(s)
WQS	Water Quality Standard

Table of Contents

1. Executive Summary

Regional Overview “Case studies of river and direct inputs of contaminants to the marine and coastal environment with focus on the anthropogenic and natural changes in the selected areas of the NOWPAP region” had been prepared by the decision of 7th and 8th POMRAC FPMs approved by the 15th IGM. The goal of this activity was to reveal the relationships between inputs of contaminants from the land-based sources and environmental changes in the adjacent coastal areas. The previous results of NOWPAP activities have shown that such relationships, especially in quantitative terms, could be found only for the selected areas where extensive data sets are available. Therefore, each NOWPAP member state proposed such case study area: Jiaozhou Bay in China, Dokai Bay in Japan, Masan Bay in Korea and Peter the Great Bay in Russia. Experts from the NOWPAP countries have presented data on these areas according to the format proposed by POMRAC Secretariat. These data as well as other published information on the selected areas, were compiled, analyzed and presented in this report.

The goal of this report is to look at the environmental status and trends within some typical and/or important coastal localities of NOWPAP countries, and to correlate this information with the changes of river and direct inputs of contaminants to the sea from the adjacent watersheds.

The structure of the report comprises brief description of geographical features of selected areas: major rivers, coasts, geomorphology, climate, landscape and land-use features, as well as reasons of the study areas choice. Socio-economic factors relevant to the scale of the anthropogenic pressure on the coastal environment within selected areas are also described: population and population density, GDP and types of economic activities, wastewater generation and wastewater treatment efficiency, etc. . The efforts have been made to obtain data on the changes of anthropogenic pressure during the last 30-50 years.

Significant part of the report consists of the description of the environmental problems within case study areas. Chemical pollution and temporal changes in composition of river runoff, as one of the major source of contaminants in the coastal sea areas, are described for the last 15-30 years. Some data are presented for the loads of contaminants with river runoff and through direct wastewater discharge. The degradation and loss of the coastal habitats are the serious environmental problems for China, Japan and Korea, but Russia (within the NOWPAP region) has relatively small scale of such problems due to low population density.

Contamination of different components of the coastal ecosystems is a direct indicator of the negative anthropogenic influence on the marine environment. The most reliable data are presented on the excessive concentration of nutrients and organic substances indicated by COD values for the coastal waters within selected coastal areas. The temporal trends during the last 10-20 years and possible reasons of variability are discussed. Possibility to use the undisturbed bottom sediments in coastal zone to reveal the history of organic and trace metal contamination during the last 10-15 decades is demonstrated. There is a successful example of using bottom sediment cores as proxy of phytoplankton community changes as well.

The eutrophication of coastal areas due to nutrients overloading is one of the most serious environmental problems in the selected case study areas. At the same time, example of Dokai Bay shows clearly the possibility to improve the situation significantly through proper management and through decreasing wastewater discharge. In addition to eutrophication and the changes in nutrient concentrations and excessive phytoplankton blooms, such consequences as the changes in the plankton and benthos communities structure are also described and discussed.

Last chapter of overview attempts to link the different human activities expressed through the changes of contaminants loads to the coastal environment with the scale of the existing environmental problems in the selected case study areas.

This overview is based on the data presented by the experts of POMRAC WG2:

China: Ms. Mingcui Wang, Professor, Department of Marine Environmental Monitoring, China National Environmental Monitoring Center (CNEMC),

Mr. Junlong Li, Engineer,Department of Marine Environmental Monitoring, (CNEMC);

Japan: Professor Tetsuya Kusuda, Graduate School of Environmental Engineering, University of Kitakyshu,

Professor Kiwao Kadokami, Environment and Resources Systems, University of Kitakyushu;

Korea: Dr. Jao Seong Lee, Marine Environment Research Division, National Fisheries Research & Development Institute, Busan, Republic of Korea;

Russia: Dr. Vladimir Shulkin, Pacific Geographical Institute, Russian Academy of Sciences, Far Eastern Branch, Vladivostok, Ms. Galina Semikina, Primorsky Hydrometeoservice.

The compilation, analysis and synthesis with existing published data were carried out by Dr. Vladimir Shulkin

2. Introduction

2.1. Goals of the Overview

It is well known that many environmental problems in coastal ecosystems are caused by the influence of the land based human activities. The eutrophication, contamination by different chemical substances, degradation of habitats are only a few examples. However, the quantitative relationships between anthropogenic loads and impacts on ecosystems are still scarce. The enormous progress has been made in the assessment of the nutrients inputs to the sea from the adjacent watersheds at the local, regional and even global scale, though significant efforts are still needed for similar assessment of other contaminants loads (trace metals, trace organics, etc.). These models of the nutrients inputs, related to the eutrophication problem, estimate the future nutrients loads for the years 2030 and 2050 at a global level as well (Millennium Ecosystem Assessment, 2006). Obviously the understanding of the quantitative links between land based inputs and related impacts on the coastal sea areas is crucial for the proper assessment of future situation. It is clear also that such linkages are site specific, and reliable time series are needed to reveal quantitative relationships. This is the reason why POMRAC FPM has decided to compile and to analyze the data on the most studied and/or most representative coastal areas from the NOWPAP member states.

The main goal of this overview is to look at the environmental status and trends within some typical and/or important coastal localities of NOWPAP countries, and to link this information with the changes of river and direct inputs of contaminants to the sea from the adjacent watersheds, and with some other anthropogenic activities.

Another goal is to compare the relationships obtained from the different coastal study areas and to reveal major variables applicable for any case.

The case study areas have been suggested by the experts and focal points from NOWPAP member states according to the specific situation in each country, and taking into consideration the environmental quality problems due to human activity in the past, and sometimes in the present time. The achievements in the ecologically based management and the availability of the comprehensive data have taken into account at the selection as well. These selected areas are: Jiaozhou Bay in China, Dokai Bay in Japan, Masan Bay in Korea, and Peter The Great Bay in Russia (Fig 1.1). The environmental conditions are quite different in these areas. The Dokai Bay and Masan Bay are surrounded by the highly industrialized and populated areas. Jiaozhou Bay adjoins with Qingdao city from the one side and rural areas from others. Peter The Great Bay is characterized by the combination of populated and industrialized “hot spots” in the inner parts and rather uncontaminated outer parts of the Bay.

Figure 1.1. Location of the selected case study areas within NOWPAP region.

2.2. General Background Information on NOWPAP

NOWPAP is a part of UNEP Regional Sea Program launched in 1972 with aim to support the coordinated efforts of countries to prevent the degradation of the shared sea areas. Now, more than 140 coastal countries are participating in 13 Regional Seas Programs established under UNEP auspices. Five partner programs are also operational. All Programs act through the "Action Plans" – comprehensive regional projects for the coordinated environmentally sound management efforts. Ideally the Action Plans should be underpinned by strong legal framework in the form of a regional Convention and associated Protocols on specific problems, but only some of Regional Sea Programs have such legal basement.

NOWPAP (*Action Plan for the Protection, Management and Development of the Marine and*

Coastal Environment of the Northwest Pacific Region) is one of the action plans that cover the Northwest Pacific region. The natural and socio-economical conditions in this region are extremely diverse. The southern and eastern parts surrounding the Northwest Pacific are the most highly populated of the world and there are enormous pressures being placed on the environment. At the same time the northern part of region is less populated but is a subject of "hot spots" and transboundary influences. The countries of the region, the People's Republic of China, Japan, the Republic of Korea and the Russian Federation have joined forces to participate in NOWPAP.

The overall goal of the NOWPAP is "the wise use, development and management of the coastal and marine environment so as to obtain the utmost long-term benefits for the human beings of the region, while protecting human health, ecological integrity and the region's sustainability for future generations".

The IGM, consisting of senior representatives of the NOWPAP members, provides policy guidance and decision-making for NOWPAP. The plans are implemented through a network of Regional Activity Centers (RACs) - CEARAC, DINRAC, MERRAC and POMRAC. The RACs play a central role in coordinating regional activities in specific fields of priority projects. From the November 2004, NOWPAP's Regional Coordinating Unit (RCU), co-hosted by Japan and the Republic of Korea, oversees the implementation of the programmes and aspects of the regional action plans such as marine emergencies, information management and pollution monitoring. Besides coordination RCU plays a leading role in the implementation of new activities needed the joint efforts of all RACs, for example marine litter issues and some other problems.

CEARAC is hosted by the Northwest Pacific Region Environmental Cooperation Centre (NPEC) in Toyama, Japan. Its main activities are to monitor and assess harmful algal blooms, to develop new monitoring tools using remote sensing and to assess land-based sources of marine litter.

DINRAC is based in the Policy Research Centre for Environment & Economy of the Ministry of Environmental Protection (MEP) in Beijing, People's Republic of China. The objectives of DINRAC are to develop a region-wide data and information exchange network, to promote regional cooperation and exchange of information on the marine and coastal environment in the NOWPAP region and eventually to serve as a NOWPAP Clearinghouse.

MERRAC is established in the Maritime and Ocean Engineering Research Institute under Korea Ocean R&D Institute (MOERI/KORDI) in Daejeon, the Republic of Korea by the joint effort of UNEP and IMO to develop effective regional cooperative measures in response to marine pollution incidents including oil and hazardous and noxious substance (HNS) spills. MERRAC is also working on marine-based sources of marine litter.

POMRAC is located at the Pacific Geographical Institute (PGI) of the Far East Branch of the Russian Academy of Sciences in Vladivostok, Russian Federation. POMRAC is responsible for cooperative measures related to atmospheric deposition of contaminants and river and direct inputs of contaminants into the marine and coastal environment. Some regional Overviews on these issues have been prepared and published till now. In 2007, POMRAC started a new project on integrated coastal zone and river basin management and compiled the state of marine environment report.

Several activities have been implemented jointly by several RACs and RCU. First of the was Marine Litter Activity (MALITA). This activity has been completed successfully in 2007 due to the joint efforts made by RACs and RCU and strong support by the member states. The next stage of this activity is the NOWPAP Regional Action Plan on Marine Litter (RAP MALI) which is implemented since 2008. Another jointly implemented activity was Regional Overview of Legal Aspects of the Protection and Management of the Marine and Coastal Environment of the Northwest Pacific Region. This overview was updated by national experts and published in 2007. State of Marine Environment Report (SOMER). POMRAC in the collaboration with other RACs prepared SOMER – State of Marine Environment in the NOWPAP region – a comprehensive review of marine environmental problems in the region based on the analysis of data and information from different sources.

New mild term strategy for the future activities of the NOWPAP is under approval now.

3. Geographical scope of the selected case study areas

3.1. Jiaozhou Bay (China)

Jiaozhou Bay, which is a typical semi-enclosed bay in China, locates at the western Yellow Sea and the south bank of Shandong Peninsula. Jiaozhou Bay covers about 390 km^2, with average depth only 8.8m, and the maximum water depth is about 64m. The bay mouth is narrow, only about 2.5km wide.

Qingdao city, which surrounds along the coast of Jiaozhou Bay, covers 10,654 km^2 areas, with the population of 7.63 million people (2009), dominates 7 districts and 5 cities. There are more than a dozen important rivers in Qingdao inputting into Jiaozhou Bay, such as Dagu River, Yang River, Moshui River, Licun River, Banqiaofang River and Wantou River. The Dagu River being the primary contributor with an annual average discharge of about $5.35*10^8$ m^3 and annual sediment load of $95.92*10^4$ tons which accounted for 81% and 74%, of the total inputs into Jiaozhou Bay, respectively. Most of small rivers have become canals of industrial and domestic waste discharge with the advance of economic activity and increased population in the region.

The climate of Jiaozhou Bay watershed has monsoon character with distinct marine influence. The average annual temperature is 12.2ϵC with a maximum 37 ϵC in August and minimum -16.4 ϵC in January. Long-term range of annual rainfall is 340-1243 mm with an average of 775.6 mm, with 58% of that in summer and 23% in winter.

In 1903, the establishment of Tsingtao Brewery was a milestone during the industrialization stage of Qingdao City. Since 1970s, with the development of China’s modern industrialization, information technology, urbanization and other processes, the economy and society of Qingdao kept developing rapidly, and the population increased a lot. Now many river downstreams except Dagu River are used as the main sewage channel for industrial wastewater, municipal sewage, etc. Thus, with the amount of land-sourced pollutants discharging into Jiaozhou Bay growing, Jiaozhou Bay seawater quality and the marine ecosystem were deteriorating, and some marine ecological problems such as red tides and other types of disasters occurred many times in the past twenty years.

As a semi-closed sea area, there is a close relationship between the environmental quality of Jiaozhou Bay and the economic and social situation of Qingdao.

In recent years, Qingdao government made a lot of environmental protection plans for the Jiaozhou Bay, such as “Blue Sea Action Plan of Jiaozhou Bay” and “Environmental Protection Plan of Jiaozhou Bay and Qingdao City”. As a result the ecological environment of Jiaozhou Bay improved gradually. Therefore, the Jiaozhou Bay study area has a typical significant demonstration for the other coastal cities in China.

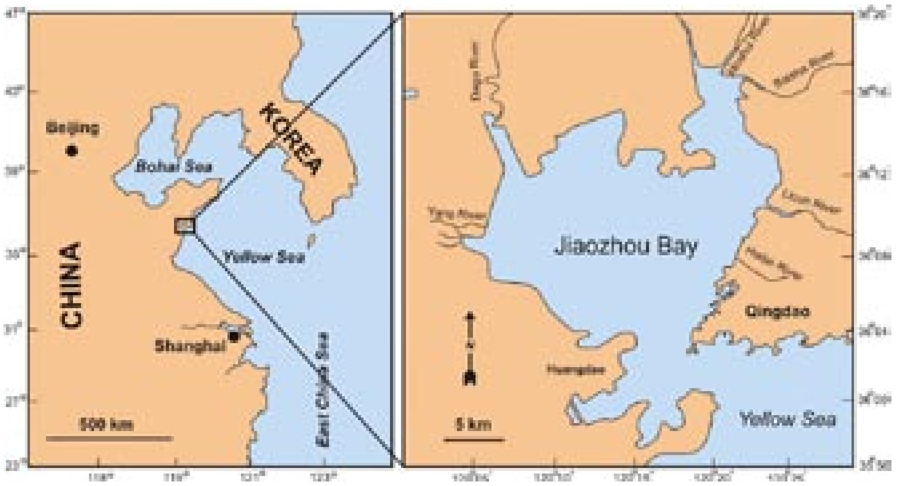

Figure 3.1. The sketch map of the Jiaozhou Bay.

3.2. Dokai Bay (Japan)

The Kitakyushu City region with Dokai Bay inside was selected as the study area for two reasons. Although the industrial output of Kitakyushu City region has been declining in recent years, factories of the city have already discharged a vast amount of contaminants into the adjacent coastal sea area. This is because many heavy industry and chemical factories are located in the city since the first steel factory in Japan was constructed there. Kitakyushu City region was one of the four Japan's key industrial zones for a long time. Secondly, the city region is an area where the largest amount of anthropogenic contaminants were discharged into the sea, as many large steel and chemical factories have been operating inside the city region at present.

Kitakyushu City with Dokai Bay in the middle is located in the northeast of Kyushu Island and is opposite Honshu Island across the Kanmon Strait (Fig. 3.2). It covers an area of 488 km^2 and is one of the Japan's cabinet-designated cities. The north of the city faces the sea (Hibiki Nada) and the east faces the Seto Inland Sea (Suo Nada) via the Kanmon Strait. Mountain areas cover about 40% of the city region. The total length of the coastline of the city is 210 km, of which 80% is artificial with facilities such as ports. The remaining 20% is natural coastline. The largest river flowing through the center of the city is the Murasaki River: 22.4 km long with 113.0 km^2 of catchment area. There are many small rivers less than 10 km long in the city. The Onga River, which passes by the city, is the largest in the city region: 61 km long with 1026 km^2 of catchment area and an 18.4 m^3/s flow rate in 2000.

Dokai Bay itself is a semi-enclosed bay, located in the north-western end of Kitakyushu (Fig. 3.2). Surface area of the bay is 11 km^2, volume is 88Ч10^6 m^3, average depth 8 m, width 1 km and bay length 11 km.

The prevailing winds bring clouds and sometimes snow to the western side of the city in winter, while the Seto Inland Sea side is in milder climate and less rain than the western side. In the city, it was 17.0 °C in average temperature, 2259.5 mm in annual rainfall, and 1845.5 hours in sunlight in 2006.

There are a large number of active factories in the city region, and most of them are located in the coastal area facing the sea. In particular, many large factories such as steel, chemical and electric power plants are located along the coast (mainly reclaimed land) facing the Hibiki-nada and the Kanmon Strait, and they discharge vast quantities of effluent. Sewage treatment plants located in the same area also discharge effluents into the sea and the Kanmon Strait.

Agricultural areas spread throughout the south of the city facing the Seto Inland Sea and the north-west of the city facing the sea. The population of the city is about one million, and residential areas are spread across the city, except in mountainous and agricultural areas.

Figure 3.2. The sketch map of the Kitakyushu area with Dokai Bai

3.3. Masan Bay (Korea)

Masan Bay, located in the south-eastern part of Korea peninsular, is one of the semi-enclosed coastal bays (Fig. 3.3). The length of bay along north to south direction is about 8.1 km and mouth width along the east-west direction is about 5 km, which shape likes a cone. The averaged depth of the bay is less than 15 m, and water circulation is limited by complex geological morphology. The averaged tidal range is about 1.3 m. The residence times of bay water is estimated to be 10 to 12 days, about 14% of bay water would be exchanged with outer seawater. The coastal line and surface area of Masan Bay in present are 12.6 km and 16.8 km^2, respectively.

The annual air temperature range in subject area is varied from -11.3 to 39.0єC and average temperature is 15єC for five years. Also, the annual average precipitation is 1,562 mm. Masan bay is faced with Masan, Changwon and Jinhae city. The largest city area and watershed area are Masan and Changwon city, respectively. The ratio between watershed and total area is highest at Changwon city.

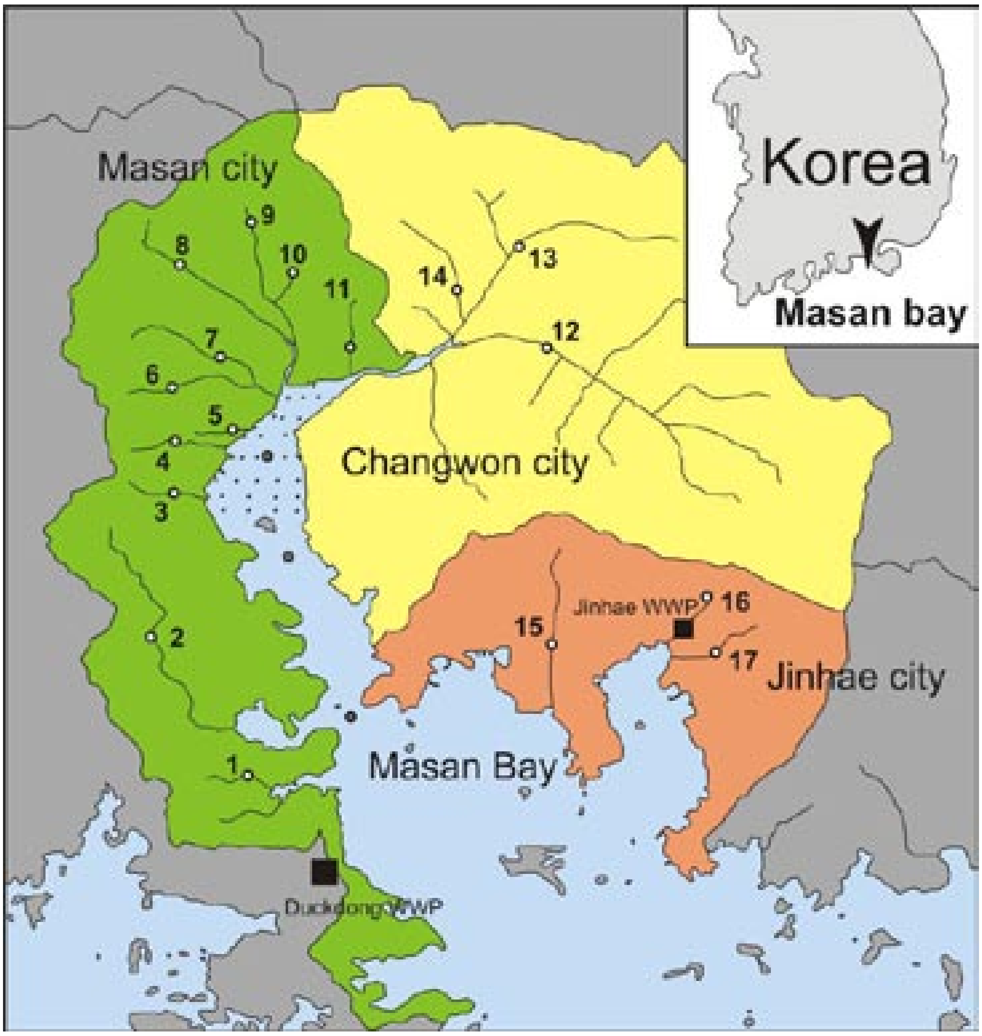

Figure 3.3. The sketch map of the Masan Bay

Table 3.1. Summary of rivers and point wastewaters inflow into Masan bay.

	Name of river, sampling points	Length	Discharge
		(km)	(m^{-3} d^{-1})
Masan city, total area 333.3 km^2, watershed area 92.3 km^2	Sujeong, 1	2.0	6,823
	Woosan, 2	7.5	47,218
	Wolyong, 3	2.42	4,987
	Janggun, 4	2.5	7,400
	Cheoksan, 5	2.8	9,117
	Kyubang, 6, 7	7.1	23,671
	Samho, 8,9,10	18.2	105,889
	Palyoung, 11	3.3	18,158
Changwon city, total area 294.6 km^2, watershed area 126.3 km^2	Namcheon, 12	5.2	56,715
	Changwon, 13	7.9	20,749
	Naedong, 14	14.7	10,264
Jinhae city, total area 113.1 km^2, watershed area 46.2 km^2	Daecheon, 15	4.5	31,012
	Seockdong, 16	4.3	31,012
	Sinyicheon, 17	3.9	31,012
	All rivers		404,027
Wastewater treatment plants	Duckdong WWT	-	282,819
	Jinhae WWT	-	52,135

3.4. Peter the Great Bay (Russia)

Peter the Great Bay is situated at the northwest part of the NOWPAP sea area between 42є17` and 43є20` N and 130є41` and 133є02` E (Fig. 3.4). It is a pretty big bay with area more than 6000 km2 consisting of the open part and several smaller bays. Some of these bays are semi enclosed.

Peter the Great Bay has been selected as a case study area due to unique combination of diverse natural conditions and uneven spatial distribution of anthropogenic load. We can find here subareas with rather pristine conditions, as well as localities heavy contaminated by human activities. The important role of the Peter the Great Bay and his watershed in the socio-economical structure of the Russian Far East is another reason to select this region for the detailed analysis of the relationships between processes at the watersheds and adjoining sea areas.

According with the coast line types, relief of the bottom and adjoining land, the Peter the Great Bay can be divided on the several sub-areas (Fig. 3.4).

Southwestern part of the Peter the Great Bay (Fig. 3.4) is situated between mouth of Tumen River at the south and Bruce Cape at the north. This sub-area includes semi-enclosed Posyet Bay which in turn consists of several smaller bights: fully enclosed Expedition Bight, semi-enclosed Novgorodskaya Bight and outer part Reid Pallada Bight. Archipelago Rimsky-Korsakov and Furugelm Island occupied by the State Marine Reserve is another peculiarity of southwestern sub-area.

Amursky Bay is semi-enclosed northwestern part of the Peter the Great Bay (Fig. 3.4). The

Figure 3.4. The sketch map of Peter the Great Bay

east border of this sub-area are Murav`ev-Amursky peninsula, where Vladivostok city is situated, and Russkyi and Popova islands. The line between Bruce Cape and small Zheltukhina island is conventionally adopted as south border of Amursky Bay.

Ussuryisky Bay is another big compartment of the Peter the Great Bay (Fig. 3.4). The line between Zheltukhina and Askold islands is conventionally adopted as south border of Ussuryisky Bay.

The area between east coast of Ussuryisky Bay and Povorotnyi Cape, including as smaller compartments Strelok Bay, Vostok Bay and Nakhodka bay, is eastern sub-area of Peter the Great Bay (Fig. 3.4).

The last sub-area within Peter the Great Bay is his open part between outer borders of above mentioned sub-areas and line between Tumen River mouth and Povorotnyi Cape which is conventionally adopted as outer border of Peter the Great Bay as a whole (Fig. 3.4). Despite the relative and conventional origin, the outer borders of the sub-areas within Peter the Great Bay have natural background as well. For example the outer south borders of the sub-areas and Peter the Great Bay as a whole are rather close to the position of 50 m and 200 m isobaths, respectively, and the south border of Amursky Bay is close to the limit of direct influence of the Razdolnaya River runoff during floods.

The some morphometric characteristics of the sub-areas within Peter the Great Bay and the characteristics of the major rivers are presented in the Table 1.

The provision of the watershed of the Peter the Great Bay by the rivers is plenty. The density of the river network reaches up 0,73 km/km^2 compare with averaged 0,3 km/km^2 for the Russian Far East as a whole. The Tumen River is largest river inputting to the Peter the Great Bay at his south border (Table 3.2). The prevailing of the southward Primorskoe (North Korean) current along the outer border of the Bay restricts the influence of the Tumen River runoff on the coastal waters of the Peter the Great Bay. The rather detailed investigation northward of the Tumen River mouth has shown that Tumen river runoff affects the coastal area between river mouth and Posyet Bay only (The State of Environment, v.1, 2, 3, 2001). This is a reason for the excluding of Tumen river runoff at the assessment of river loading on the sub-areas of Peter the Great Bay rather than southwestern corner, and on the Bay as a whole.

Razdolnaya River is second largest river at the Peter the Great Bay watershed (Table 3.2).

Razdonlaya River inputs to the north inner part of the Amursky Bay and is a major natural factor determined the hydrochemical features of this sub-area.

The Artemovka, Shkotovka and Suhodol are major rivers provided the fresh water supply to the Ussuryisky Bay sub-area, though discharge of each of these rivers does not exceed 10-12% of the Razdolanya River discharge (Table 3.2).

The river input to the eastern sub-area of Peter the Great Bay is provided by the Partizanskaya River with discharge only two times less than Razdolnaya River (Table 3.2).

At the assessment of the river input is necessary to take into account that besides major rivers with measured discharge, there are streams and rivers without any discharge data. The difference between watershed areas of the measured rivers and all watershed of Peter the Great Bay gives possibility to assess the additional input from the unmeasured rivers. For Peter the Great Bay the contribution of non counted watersheds reaches up 25% of the measured rivers watersheds which provide up to 36% of the accounted fresh water runoff (without Tumen River), because specific discharge of small mountainous non counted rivers is usually higher than for the big and more plain rivers.

Table 3.2. Some characteristic of the sub-areas of Peter the Great Bay and major inputting rivers.

Sub-areas of Peter the Great Bay	Area, km^2	Coast line**, km	Major inputting rivers	Watershed, km^2	Runoff, km^3
Southwestern part	1498**	395	Tumen River	33200	9.05
	3***		Tsukanovka	170	0.12
			Brusya	160	0.04
			Gladkaya	458	0.08
Amursky Bay	997**	151	Narva	332	0.13
	101***		Barabashevka	576	0.32
			Amba	242	0.19
			Razdolnaya	16800	2.46
Ussuryisly Bay	1889**	165	Artemovka	1460	0.29
	21***		Shkotovka	714	0.22
			Suhodol	443	0.14
Eastern part	921**	275	Partizanskaya	4140	1.32
	42***		Accounted watershed*	25757	5.31
			Non counted watershed*	6498	1.89
Outer part	3616**		All watershed*	31735	7.20

* - estimations for Peter The Great Bay as a whole are carried out without Tumen river runoff and watershed; ** - without islands; *** - area of the islands.

The coast line of the Peter the Great Bay is quite ragged due to quasi longitudinal orientation of the major geological structures at the watershed and quasi latitudinal orientation of the coast. As a result the former river valleys transformed during the Pleistocene-Holocene sea level rising to the bays, bights and inlets. Amursky and Ussurisky bays are the most obvious examples of such transformation. Elevated part of watersheds transformed to the peninsulas and islands, and Muraviev-Amursky peninsula with Russkyi and Popov islands as its continuation is an example.

The coast line of southwestern and northeastern sub-areas of Peter the Great Bay is more ragged and has longer length compare with Amursky and Ussuryisky Bays (Table 3.2).

The relief of the Peter the Great Bay watershed is formed by the Eastern Manchurian highland at the west and by the southern ridges of the Sikhote-Alin mountains at the east. The Khanka-

Razdolnaya plain with Razdolnaya valley divides these two upland areas: Eastern Manchurian highland at the west and southern ending of the Sikhote-Alin ridges at the east with Khanka-Razdolnaya plain between.

The underwater relief of Peter the Great Bay is characterized by the rather wide shallow water plain with gradual increase of depth southward down to 100-120 m. Most wide underwater plain is observed at the Amursky and Ussuryisky Bays, and most narrow – within southwestern sub-area. The beginning of continental slope with sharp increase in depth from 100 m to 1000 m is close to the outer border of Peter the Great Bay (Fig. 3.4). Each sub-area within Peter the Great bay has own peculiarities of bottom relief in accordance with geomorphologic structure and features of history during Pleistocene-Holocene.

The climate of the Peter the Great Bay is determined by monsoon atmospheric circulation. From October-November until March the transport from the land of the cold and dry air mass prevails. The freeze sunny weather with north and northwestern winds is a result. The averaged January temperature is -16-17єC at the north of Amursky and Ussuryisky Bays, and -10-11C at southwestern coast. Atmospheric deposition does not exceed 10-18 mm during the winter though can be concentrated within 3-5 snowfalls. The inner part of the Amursky Bay is ice covered from January till March.

The wind direction is unstable during the spring, and the air temperature is pretty low due to cold water mass influence. The quantity of dull days in spring reaches up 40-50%.

The summer monsoon begins from May-June. The influence of the cold Okhotsk Sea prevails during the first half of summer, and weather is rather chilly with fogs and drizzling rains. Gradual warming of air and surface waters of Peter the Great Bay leads to the moderately warm temperature and high humidity during July-August. The averaged July temperature in Vladivostok and Nakhodka is 18-19єC.

The autumn weather is most comfortable within Peter the Great Bay: rather warm and dry, though monsoon situation means regular cyclonic activity through the year and especially during the warm period. The cyclones lead to the storms and atmospheric precipitation.

The annual atmospheric precipitation reaches up 830 mm near Vladivostok and 700-750 mm at the northern parts of Peter the Great watershed. The annual number of days with precipitation along the coast of Peter the Great bay is between 100 and 115 days. 80-95% of rains occur from March to November, and August is characterized by the most intensive precipitation.

Landscape structure of the Peter the Great Bay watershed is characterized by the combination of the plain, valley, hilly, low-mountain and midland landscapes. The plain and valley landscapes are presented by wetlands, bushes and meadows. The significant part of these landscapes is occupied by the agriculture lands. The diverse forests are prevailed on the mountainous landscapes. The leaved, broadleaf, coniferous forests and the mixture of them are the major kinds of forested landscapes. The basaltic plateaus with elevation 600-900 m are specific habitats within Peter the Great Bay watershed. The dark-coniferous and broadleaf-coniferous forests are the typical landscapes at the plateaus.

Land-use features are determined by the superposition of the landscape peculiarities and socio-economical factors. The distribution of the main land-use categories within Peter the Great Bay watersheds (Table 3.3) shows clearly the prevailing of the forests for the watershed as a whole, and complete domination for the north-eastern sub-area. The agriculture land is the second important category with 27% of the whole watershed. The quota of the residential areas constitutes 6% of the whole watershed due to influence of the Vladivostok and other city areas, where the contribution of the residential lands reaches up 59-63%. The lands used for the industrial and military purposes do not exceed 10% of the watershed as a whole. The quota of the protected areas reaches up 5% for the watershed as a whole.

The accounting of the land-use categories is realized by the administrative units (districts in Russia) which are not coincided strictly with watersheds. The sum of the land-use categories for the sub-areas presented in Table 2 is 23 614 km^2 , and summary watershed areas of the Peter the Great bay within Russian Federation borders is 21 755 km^2 (Table 3.2). It is seems rather similar and indicates the relevance of the land-use assessments (Table 3.3).

Table 3.3. The structure of the land-use categories at the Peter the Great Bay watershed and its sub-areas in 2007 (km^2).

#	Area, sub-area*	Agricultural	Residen tial	Industrial &military	Protected areas	Forests	Water	Stockpiles
1	Southwestern	1415	104	572	709	1116	37	177
2	Razdolnaya area	3994	160	1085	167	2964	48	1003
3	Northeastern	500	121	219	242	4898	4	779
4	Vladivostok	70	329	102	35	25	0	0
5	Other cities	419	669	293	4	1092	0	259
6	All watershed	**6398**	**1383**	**2271**	**1157**	**10095**	**89**	**2218**

Note: southwestern sub-area 1 includes Khasanskyi district; Razdolnaya area 2 includes Oktober, Mikhailovskyi, Ussuryiskyi, Nadesdinskyi districts; northeastern sub-area 3 includes Shkotovskyi and Partizanskyi districts; other cities 5 include Ussuryisk, Artem, Fokino, Bolshoy Kamen, Nakhodka and Partizansk.

4. Jiaozhou Bay

4.1. Social and economic situation at present time and during last decades.

Since 1970s, the economy of Qingdao kept developing rapidly, the average economic growth rate was about 12.6%, GDP increased from 3.8 billion RMB in 1978 to 485 billion RMB in 2009 (Figure 4.1).

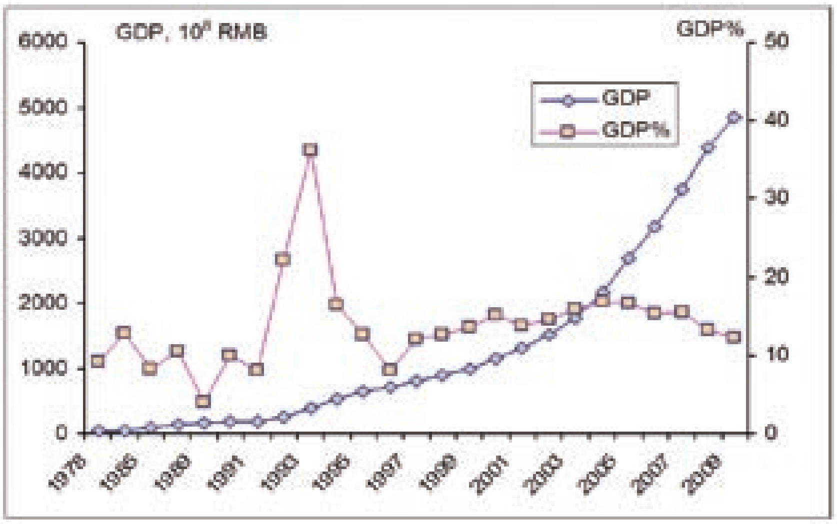

Figure 4.1. The GDP and GDP growth rate of Qingdao from 1978 to 2009

Since 1970s, the population of Qingdao City increased a few annually, with an annual natural population growth rate of 6.0 ‰, the total population increased from 5.85 million in 1978 to 7.63 million in 2009 (Figure 4.2).

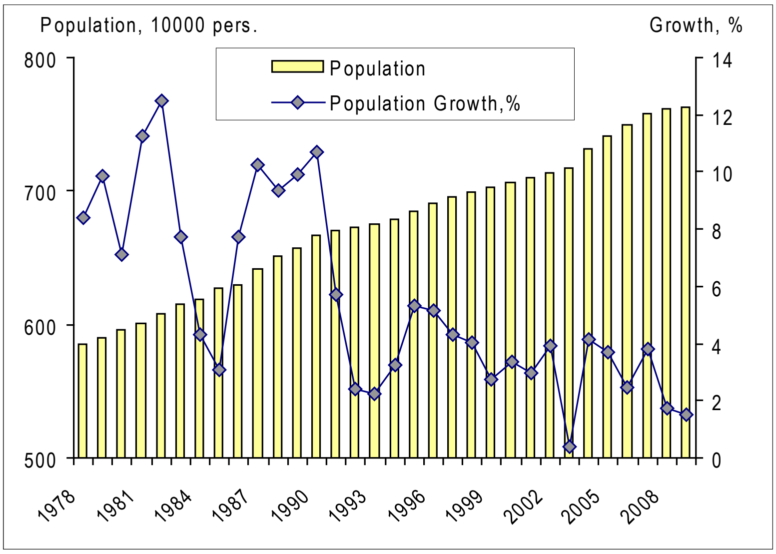

Figure 4.2. The Population and Population natural growth rate from 1978 to 2009

Since 1970s, the per capita GDP (GDPp) of Qingdao increased from 663 RMB/person in 1978 to 57251 RMB/person in 2009 (Figure 4.3), the annual increase 11.6%.

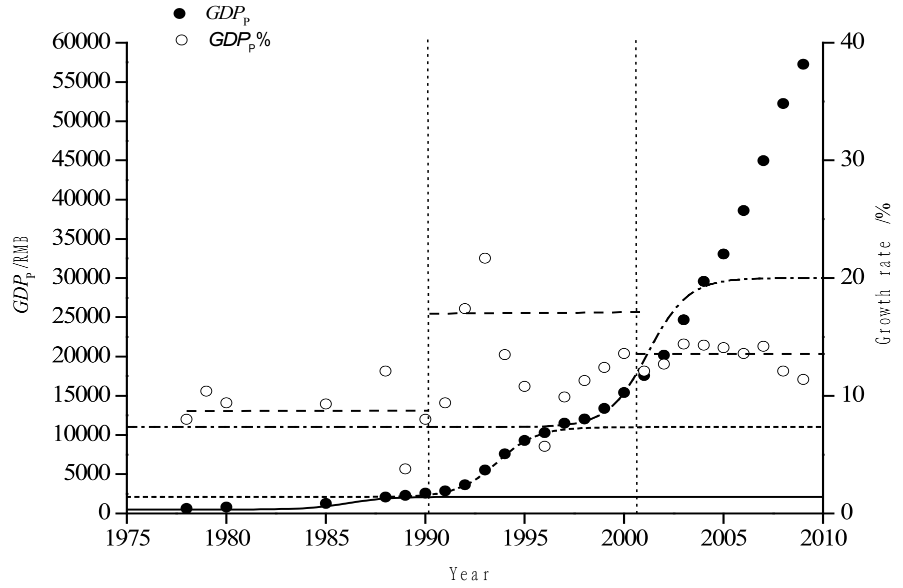

Figure 4.3. The GDPp and GDPp growth rate of Qingdao from 1978 to 2009

This increase has been provided by the industrial and tertiary activity. The volume of agriculture production has been elevated about three times during last 30 years as well, but the contribution of agriculture to the total output dropped from 25% to 5%. This is accompanied by the 1.5 times reduction of cultivated areas. Such intensification of agriculture was tied with tremendous increase of chemical fertilizers used from $1.9*10^3$ tons in 1949 to about $50*10^3$ tons in 1978, and to $325*10^3$ tons in 2004 (Fig. 4.4).

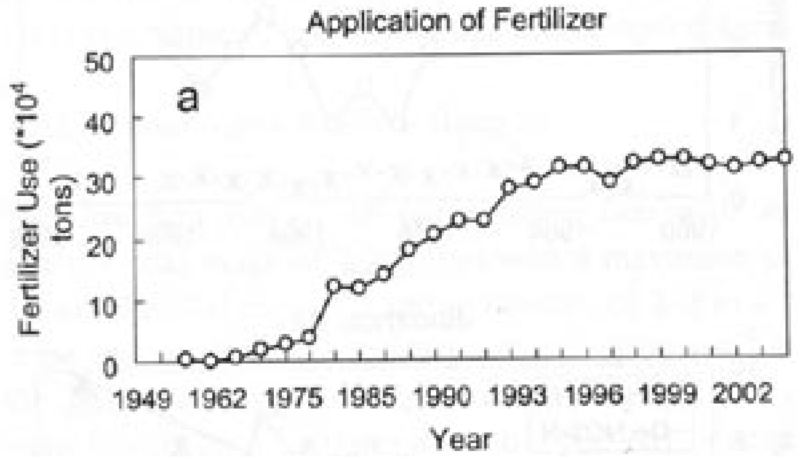

Figure 4.4. The application of chemical fertilizers at the Jiaozhou Bay watershed (from Zhang, 2007 by Qingdao Municipal Statistic Bureau, 2005).

The significant powering of the marine sector of economy took place at the Qingdao area during last decades. The cargo reached up $163*10^6$ in 2004 that is 200 times compare with 50th of last century. The output of fishery was two orders of magnitude less than farming output before 1970, but now these industries are comparable (Fig. 4.5).

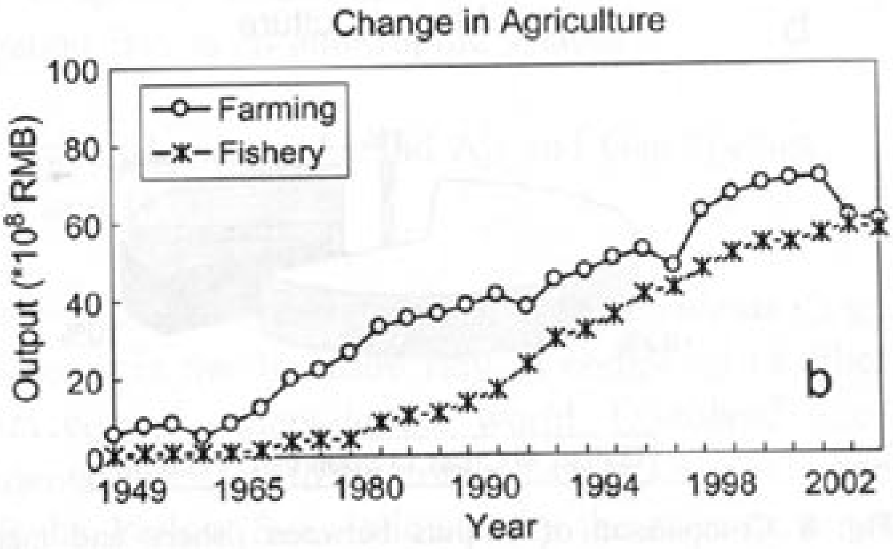

Figure 4.5. Inter annual change of the farming and fishery output for the Qingdao area (from Zhang, 2007 by Qingdao Municipal Statistic Bureau, 2005).

Besides fishery itself, the aquaculture (fish cages and shrimp ponds) is the fast developed economical activity in the Jiaozhou Bay. During last 10-15 years the output of aquaculture reached up 60-70% of the total fishery output (Fig. 4.6). Shell-fish, fish, shrimps are the main species for the breeding.

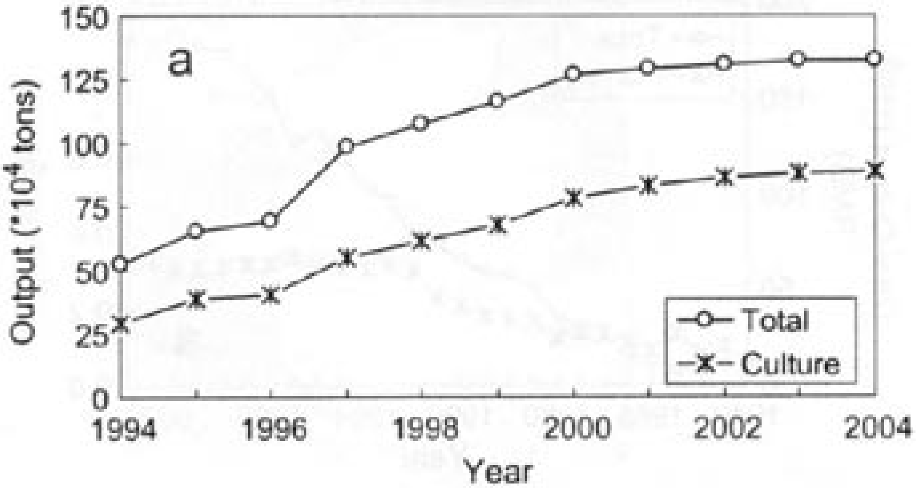

Figure 4.6. The contribution of aquaculture to the total fishery output (from Zhang, 2007 by Qingdao Municipal Statistic Bureau, 2005).

The rapid economical development of the Qingdao area has accompanied by the increase of wastewater generation and discharge (Fig. 4.7). This process was not as fast as elevation of GDP or population (Fig. 4.2, 4.3) due to continuous efforts on the wastewater treatment, but still 35-40% increase of wastewater discharge has been still observed from 1993 to 2004. The decrease trend is observed for the industrial wastewater contribution (Fig. 4.7).

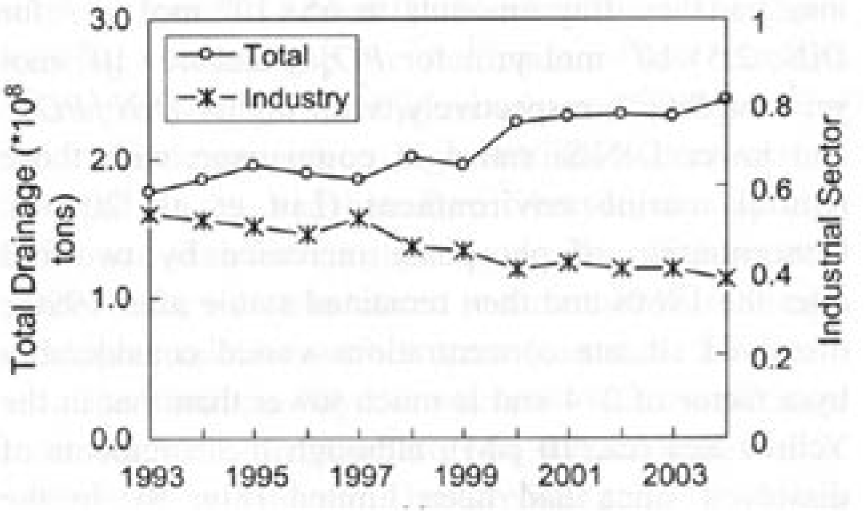

Figure 4.7. Wastewater discharge into Jiaozhou Bay and contribution of industrial wastewaters (from Zhang, 2007 by Qingdao Municipal Statistic Bureau, 2005).

Statistics show that amount of industrial waste water emissions in Qingdao have the relationship with the GDP, especially the increase of industrial added value (GDPId), and municipal sewage emissions to some extent have the relationship with the population growth. Thus, to predict the total amount of sewage discharging into Jiaozhou Bay, some researchers proposed economical-environmental index (EEI) as sewage flow per GDP unit.

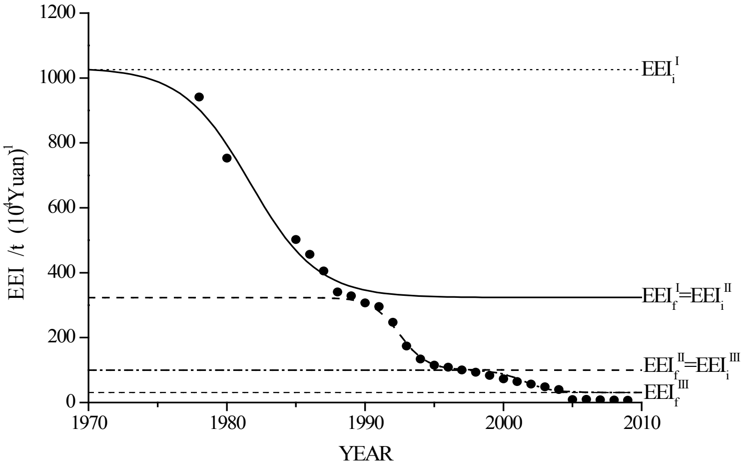

Figure 4.8. Qingdao EEI trends from 1978 to 2009

According to the statistics, Qingdao EEI rapidly dropped from 941t/(10^4 RMB) in the late 1970’s to 307 t/(10^4 RMB) by the early 1990s, and continue to dropping to about 40 t/(10^4 RMB) in 2009. The analysis result shows that, since the late 1970s, Qingdao EEI has experienced two development stages, and during the third development stage currently, and the three EEI development stages in accord with the change trends of Qingdao GDP. The phenomenon means that the change rule of Qingdao EEI not only related with economy and population, but also related with industrial added value closely.

4.2. Environmental problems in the coastal zone, including rivers and coastal sea areas

4.2.1. Chemical pollution and temporal changes in composition of river runoff.

Dagu River is the biggest and less contaminated river inputting to the Jiaozhou Bay from the north. Another rather clean river is Yang River inputting to the western part of the Bay (Table 4.1, Fig. 3.1). Other rivers input to the eastern part of the Bay, drained the Qingdao city area, and have a pretty high concentration of nutrients and suspended solids (Table 4.1). The data on the regular monitoring of these rivers confirm it (Fig. 4.9). The COD parameter reached very high values in the Moshui, Licun, and especially Haibo rivers, though in Dagu River COD_{Cr} varies from 19 to 39 mg/l, and COD_{Mn} – from 3.6 to 9.7 mg/l, that is close to the rather uncontaminated streams. Despite the significant inter annual variability typical for the rivers under strong anthropogenic press, there is obvious trend of 2-3 times decrease COD values in the rivers drained the Qingdao city watershed during last decade (Fig. 4.9). Simultaneously two fold decrease of COD from 39 to 19 mg/l was observed in the Dagu River. This trend reflects the significant and successful effort of the government and society to improve the water quality in terms of COD, though a lot should be done to return Moshui and Licun rivers to the conditions of Dagu River for example.

Table 4.1. Brief characteristic of the main rivers inputting the Jiaozhou Bay*

	Length, km	Watershed, km^2	Runoff, km^3/y	Sediment load, 10^3 tons/year	NH_4 mgN/l	NO_3 mgN/l	PO_4 mgP/l
Dagu	179	5634.2	0.535	959	0.31	0.25	0.012
Baisha	35	202.9	0.029	5.1	0.54	3.68	0.038
Moshui	42	356.2	0.029	47.6	8.64	3.08	1.507
Yang	41	87.2	0.056	258	0.22	1.19	0.005
Licun	15	108	0.011	29.4	2.34	0.05	2.339

* - from Yao et al., 2010

The amount of dissolved oxygen is utmost important indicator of water quality. Concentration of dissolved oxygen less 3 mg/l means severely polluted waters in China (Grade IV) and in Russia as well. The annually averaged dissolved oxygen content in Dagu River varies between 7.9 and 8.99 mg/l that is close to saturation. But this parameter does not exceed 3 mg/l in the rivers Haibo, Licun and Moshui of the eastern part of the Jiaozhou Bay watershed. Extremely low dissolved oxygen concentration, practically anoxia, took place in the Haibo River in 2000-2001. Since that oxygen content grow up to 2-3 mg/l. The increase trend is observed in the Licun and Moshui rivers as well (Fig. 4.9), reflecting the improvement of water quality.

Concentration of the nutrients in the Dagu River is in accordance with Grade II Chinese Water Quality Standards, but rivers draining Qingdao city watershed contain nutrients more than Grade V, that is heavily polluted in terms of nutrients concentration. There is obvious decrease of phosphorus concentration and improvement of the pollution status in these rivers during last decade (Fig. 4.9). Suchlike trend for ammonia nitrogen is not so clear (Fig. 4.9).

Contamination of Dagu River by petroleum hydrocarbons - PHs (oil) is absent: 2-5 times less than Grade I Water Quality Standards 0.05 mg/l. Rivers of the eastern part of watershed, draining Qingdao city, contained oil concentration 1-6 mg/l, that is worse than Grade V Water Quality Standards. During last decade obvious improvement of situation took place, and petroleum products concentration has decreased significantly below Grade IV in the Licun and Moshui rivers, and below Grade V in the Haibo Rivers (Fig. 4.10)

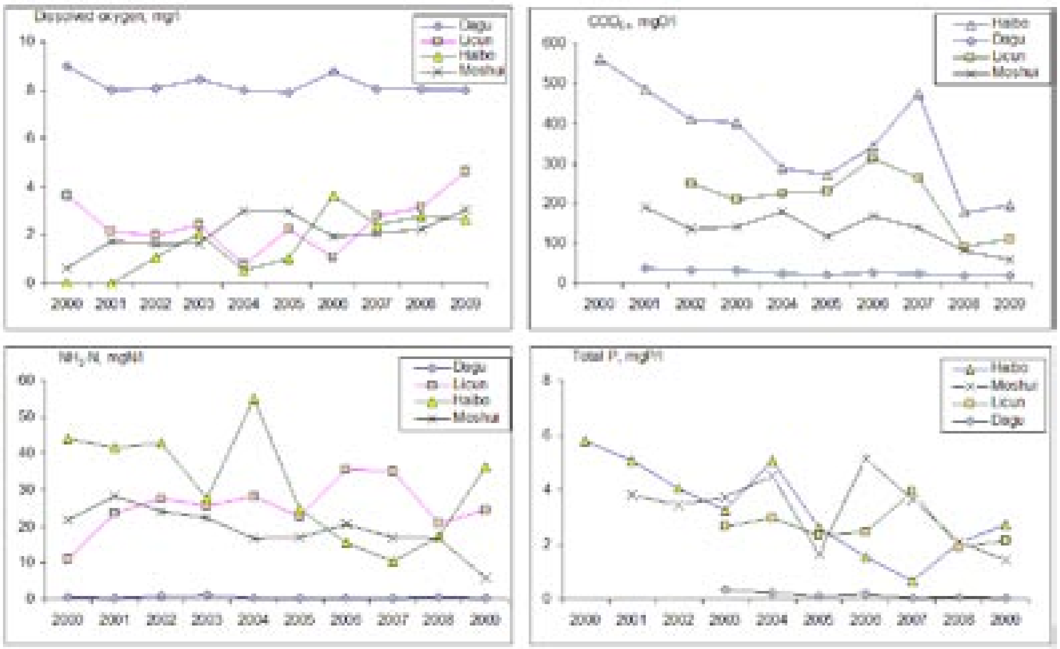

Figure 4.9. The inter annual change of some chemical characteristics of the rivers input the Jiaozhou Bay

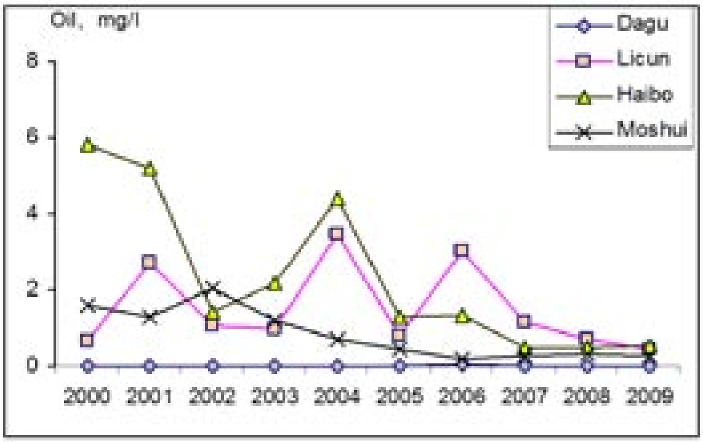

Figure 4.10. The change of the petroleum products (oil) concentration in the rivers input to the Jiaozhou Bay during last decade.

4.2.2. Loads of contaminants through rivers and by direct inputs.

Since 1980s to the late 1990s, the total amount of wastewater discharged into Jiaozhou Bay increased rapidly, the average growth rate was about 5%. After 1990s, the rate was reducing gradually, the average growth rate was about 0.5%, and the amount now is about 8.2Ч10^8 m^3·a^{-1} (Fig. 4.11).

The wastewater discharged into Jiaozhou Bay consists of industrial waste water (F_{W_ID}), municipal sewage (F_{W_DD}) and agricultural wastewater ($F_{\mathrm{W\_AD}}$). From the 1980s to now, the total amount of municipal sewage wastewater discharged into Jiaozhou Bay (F_{W_DD}) increased rapidly, the average growth rate was about 11%, in twenty years it increased about seven times. The increase has close relationship with the population of Qingdao, especially the improvement of life quality and the evolution way of life. But because of the lack of the total amount of agricultural wastewater ($F_{\mathrm{W\_AD}}$) monitoring data, we can only get the data by using the total wastewater minus the industrial waste water and municipal wastewater. And the results show that from 1980s to the late 1990s, the agricultural wastewater increased a little rapidly, the average growth rate was about 6%, after that time the speed growled slowly, the average growth rate was below 1%. Thus, based on our estimated data, industrial wastewater discharged into Jiaozhou Bay accounts for about 10 percents of the total wastewater discharged into Jiaozhou Bay, and the proportion of municipal wastewater and agricultural wastewater was 15% and 75% separately.

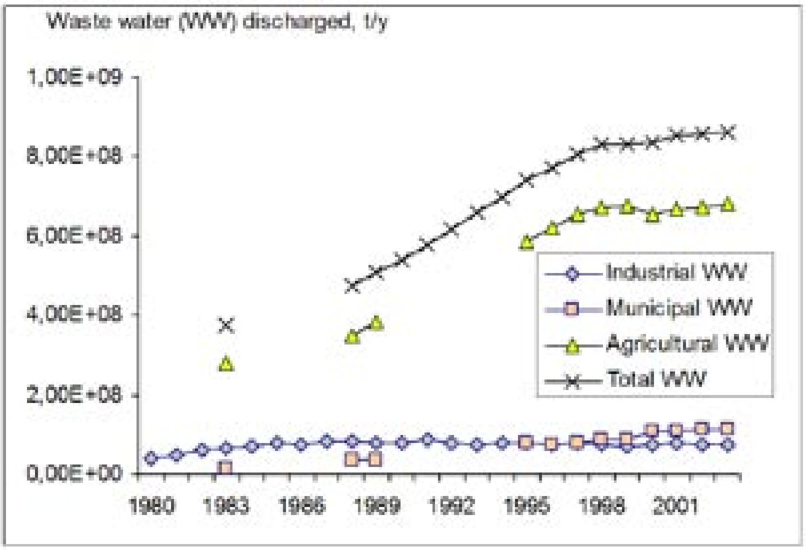

Figure 4.11. The industrial wastewater (diamonds), municipal wastewater (squares), agricultural wastewater (triangles), total wastewater, (crosses) in Qingdao from 1980 to 2009

There were nearly 12 sewage treatment plants in Qingdao in 2005, the drainage network coverage was up to 98%, the sewage treatment rate was up to 63.6%, and by now, the number of sewage treatment plants was up to nearly 19 with treatment ratio increase up to 90.1% (Table 4.2).

Table 4.2. The amount of life sewage discharge and treatment ratio of Qingdao

Year	Life sewage discharge (10^4t)	Treatment amount (10^4t)	Treatment ratio (%)
2001	13475	6769	50.2
2002	13999	6754	48.2
2003	13721	7258	52.9
2004	15053	8957	59.5
2005	16488	10478	63.55
2006	21809	16494	75.6
2007	22318.6	17916.9	80.3
2008	23487.6	20909.8	89.0
2009	25244.5	22733.6	90.1%

The efficiency of the industrial wastewaters treatment within Qingdao city area is provided by the operation of the more than 400 wastewaters treatment facilities, which support the compliance of the discharged wastewaters with the existing standards for the effluents (Table 4.3).

Table 4.3. Status of industrial wastewater treatment

	The amount of industrial wastewater (10^4t)	Wastewater meet the standards (10^4t)	Wastewater meet the standards ratio(%)
2001	9587.68	9474.37	98.82
2002	9292.41	9285.54	99.93
2003	9294.77	9287.78	99.92
2004	9130.38	9123.33	99.92
2005	8856.28	8948.85	99.92
2006	9521.18		99.92
2007	9412.17		99.92
2008	9665.3		99.92
2009	10401.7		99.92

The dissolved inorganic nitrogen (DIN) discharged into Jiaozhou Bay, include the land-sourced DIN (riverine plus wastewaters), the aquaculture-sourced DIN and the atmospheric-sourced DIN (Fig. 4.12).

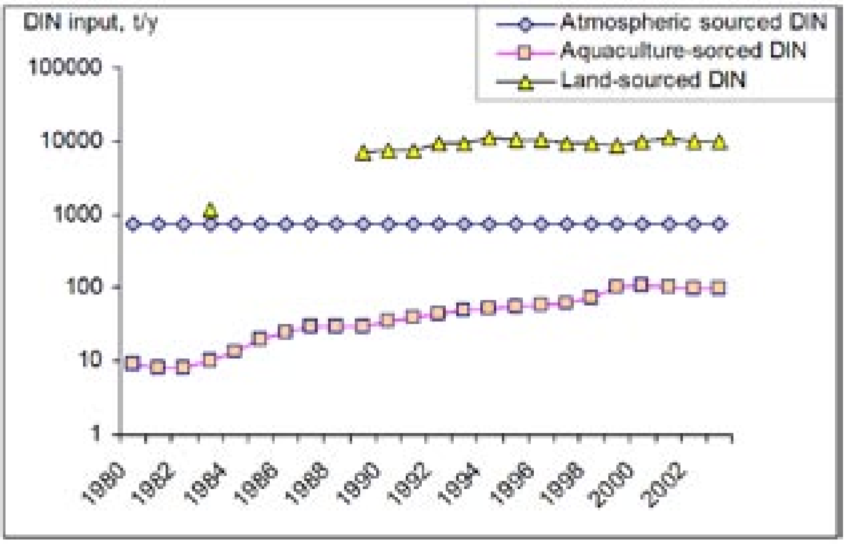

Figure 4.12. The annual input of DIN into Jiaozhou Bay from 1980 to 2009 from the different sources.

Based on monitoring data, the average concentration of land-sourced (DIN) discharged into Jiaozhou Bay was about 15.0±3.0 $\mathrm{mg \cdot dm^{-3}}$ from 1980s. Thus, with the total land-sourced wastewater, we can estimate the amount of land-sourced DIN discharged into Jiaozhou Bay ($F_{\mathrm{DIN\_LS}}$). The results showed that the amount of land-sourced DIN discharged into Jiaozhou Bay increased a lot from 1980s to the late 1990s, with the 1000 $\mathrm{t \cdot a^{-1}}$ in the early 1980s increased to 11 000 $\mathrm{t \cdot a^{-1}}$ in the late 1990s, the average growth rate was about 15% annually, and maintained about 11000 $\mathrm{t \cdot a^{-1}}$ after the 1990s (Fig. 4.12). This constant input of land based DIN is in accordance with the absence of clear trend of DIN concentration in river waters (Fig. 4.9).

Based on monitoring data, the average concentration of land-sourced Total Dissolved Phosphorus (TDP) discharged into Jiaozhou Bay was about 1.5±0.2 $\mathrm{mg \cdot dm^{-3}}$ from 1990s, in which the average PO_4-P concentration was about 0.5±0.1 $\mathrm{mg \cdot dm^{-3}}$. Thus, with the total land-sourced wastewater, we can estimate the amount of land-sourced TDP ($F_{\mathrm{TDP\_LS}}$) and PO_4-P ($F_{\mathrm{PO4\text{-}P\_LS}}$) discharged into Jiaozhou Bay. The results showed that the amount of land-sourced TDP (F_{TDP_LS}) and PO_4-P (F_{PO4-P_LS}) discharged into Jiaozhou Bay increased a lot from 1980s to the late 1990s, with the 600 $t \cdot a^{-1}$ and 200 $t \cdot a^{-1}$ in the early 1980s increased to 1200 $t \cdot a^{-1}$ and 400 $t \cdot a^{-1}$ separately, in the late 1990s, the average growth rate was about 4% annually, and maintained about 1200 $t \cdot a^{-1}$ and 400 $t \cdot a^{-1}$ after the 1990s basically (Fig. 4.13). After 2004, the decrease of land-sourced phosphorus input is expected due to observed trend of total phosphorus concentration drop during last years (Fig. 4.9)

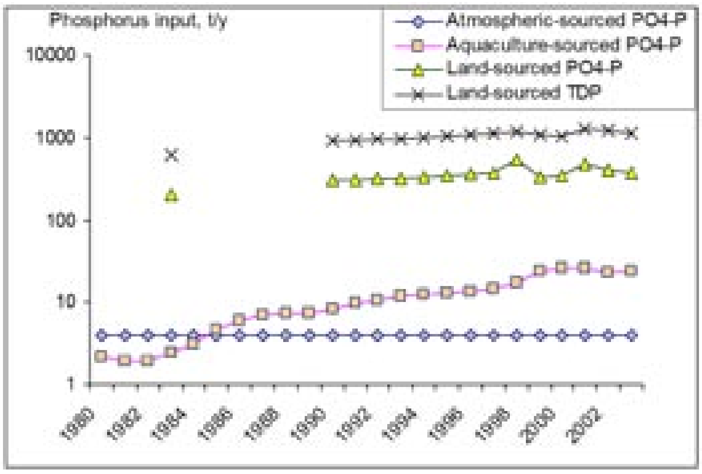

Figure 4.13. The annual input of phosphorus into Jiaozhou Bay from 1980 to 2009 from the different sources.

The land-sourced COD_{Cr} discharged into Jiaozhou Bay were monitored began from the 1980s, and based on the monitoring data, the average concentration of land-sourced COD_{Cr} discharged into Jiaozhou Bay was about 140±60 $mg \cdot dm^{-3}$ from 1980s, which was a little more than the First Grade of China seawater environmental quality(100 $mg \cdot dm^{-3}$, GB 8978-1996). Thus, with the total land-sourced wastewater, we can estimate the amount of land-sourced COD_{Cr} (F_{COD_LD}) discharged into Jiaozhou Bay. The results showed that the amount of land-sourced COD_{Cr} (F_{COD_LD}) discharged into Jiaozhou Bay increased a lot from 1980s to the early 1990s, the average growth rate was about 25% annually. Last decade some decrease trend of land-sourced COD_{Cr} input is observed (Fig. 4.14). This is in accordance with clear cutback of COD concentration in the inputting rivers from the beginning of XXI century (Fig. 4.9).

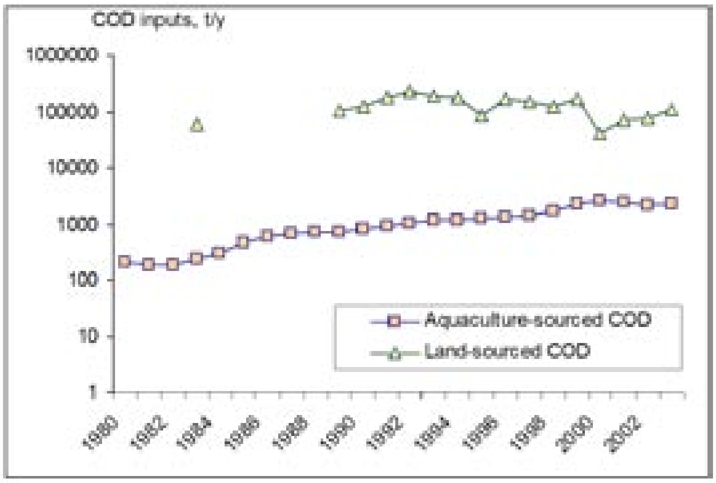

Figure 4.14. The annual input of COD into Jiaozhou Bay from 1980 to 2009 from the different sources.

The land-sourced petroleum products (petroleum hydrocarbons, PHs, oil) discharged into Jiaozhou Bay were monitored began from the late 1980s, and the oil monitoring data showed that the average concentration of land-sourced PHs discharged into Jiaozhou Bay was about 0.8±0.5 mg·dm^{-3}. Thus, with the total land-sourced wastewater, we can estimate the amount of land-sourced petroleum products discharged into Jiaozhou Bay. The results showed that the amount of land-sourced petroleum products discharged into Jiaozhou Bay decreased a lot from 5000 t·a^{-1} in the 1980s to 300 t·a^{-1} in recent years, the average decrease rate was about 40% annually (Fig. 4.15). And the analysis results show that the land-sourced petroleum products discharged into the eastern Jiaozhou Bay mainly comes from Haibo and Licun Rive et., and the one discharged into the western Jiaozhou Bay mainly comes from Dagu River, the petroleum products amount of both accounted for about 85%. The clear decrease trend is observed for the petroleum hydrocarbons (PHs) from the beginning of 90th reflecting the decline of the PHs in the river waters (Fig. 4.10).

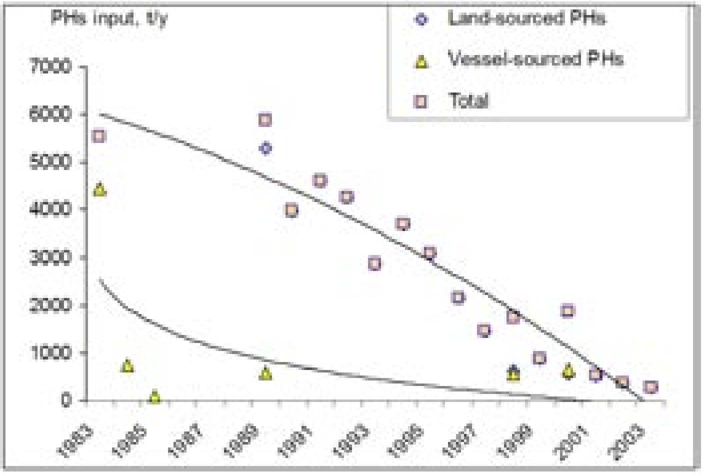

Figure 4.15. The annual input of petroleum hydrocarbons (PHs) into Jiaozhou Bay from 1980 to 2009 from the different sources.

There is limited data for the separate assessment of contaminants input to the Jiaozhou Bay through rivers and direct outputs of wastewaters. Using the available data on the direct loads of contaminants (Table 4.4) and existing data on the chemical composition of the inputting rivers (Figure 4.9) and the rivers discharge (Table 4.1 by Yao et al., 2010), one can evaluate the contribution of rivers and direct wastewater outputs (Fig. 4.16).

Table 4.4. The loads of contaminants through rivers and directly

Year	The amount of wastewater discharged into Jiaozhou Bay directly (10^4t/y)	The amount of water discharged into Jiaozhou Bay from river, (10^4t/y)	The amount of contaminant discharged into Jiaozhou Bay directly, (t/y)				
			COD_{Cr}	TN	NH_3	TP	Oil
2006	10842.75	35428.14	38858.79	4688.45	2595.02	276.5	138.68
2007	13360.39		10534.54	616.82	2436.70	237.41	23.14
2008		46661.2					
2009	22245.00	46793.2	10518	6474	2816		

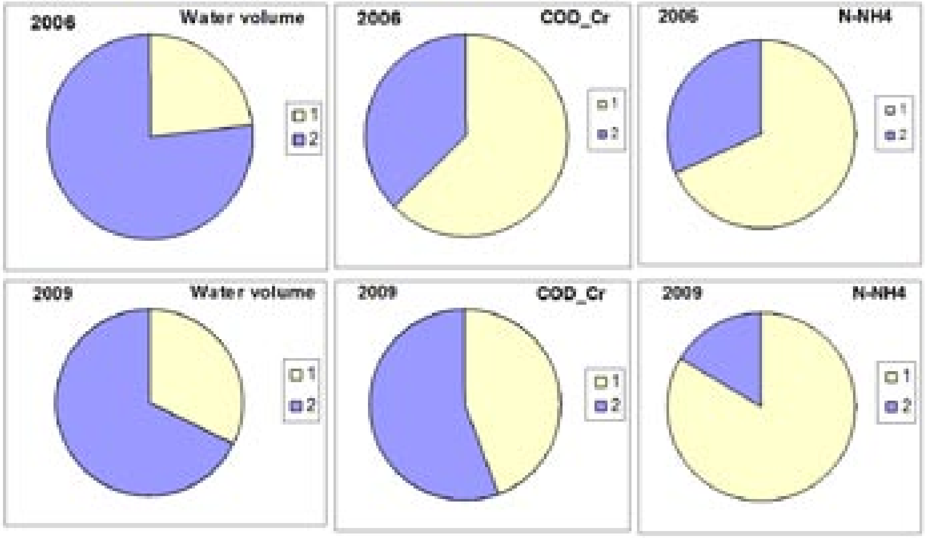

Figure 4.16. The contribution of direct outputs of wastewaters (1) and river runoff (2) to the total land-based input of water and some contaminants to Jiaozhou Bay in 2006 and 2009

Obviously the direct inputs of organic matter (COD) and ammonia nitrogen exceed the riverine runoff, though there is some trend of the relative decrease of wastewaters contribution.

4.2.3. Degradation, changes and loss of coastal habitats

Degradation of coastal habitats within Jiaozhou Bay is connected with reclamation of sea areas for the construction of the port facilities. During the past 70 years, the water area of Jiaozhou Bay had decreased by one-third because of the reclamation of the intertidal flats and dumping of garbage from Qingdao City. Thus before 1960 the water area of Jiaozhou Bay was 535-579 km^2 including 285 km^2 of intertidal areas. In 1980 water area decreased to 400 km^2 due to intertidal areas decline down to 142 km^2. In 2003 the water area of Jiaozhou Bay was 362 km^2 with intertidal areas about 85 km^2 (Dai et al., 2007).

Another significant reason of the natural coastal habitats degradation is intensive aquaculture within the Jiaozhou Bay. For example the production of scallops increased dramatically from 540 t/y in 1980 to 81000 t/y in 1995. After that due to disease the scallops production declined, but the density of the hydrotechnical constructions for the aquaculture purposes continue to be very high along the north and west coast of the Jiaozhou Bay.

4.2.4. Pollution of the marine ecosystems

As for many other costal areas more or less comprehensive inter annual data on the pollution within Jiaozhou Bay is available for the nutrients only (Fig. 4.17). Since the 1960s, the annual DIN concentration of Jiaozhou Bay seawater has been increasing basically. In 1960s, the annual DIN concentration of Jiaozhou Bay seawater was about 30 $\mu g \cdot dm^{-3}$, while during the early 1980s, the DIN concentration was increasing gradually, and it was growing up to 90 $\mu g \cdot dm^{-3}$ in the 1980s. But during the 1980s to 1990s, the DIN concentration were increasing rapidly, which was growing up to 180 $\mu g \cdot dm^{-3}$ in the middle of the 1990s and 220 $\mu g \cdot dm^{-3}$ in the end of the 1990s. In the recent years, the DIN concentration has kept on increasing also, but the increasing range was smaller.

Since the 1960s, the annual PO_4-P concentration of Jiaozhou Bay seawater has been increasing until the end 1990s. In 1960s, the annual PO_4-P concentration of Jiaozhou Bay seawater was about

4.5 µg·dm^{-3}, while during the early 1980s, the PO_4-P concentration was increasing gradually, and it was growing up to 18.5 µg·dm^{-3} in the 1980s. During the 1980s to 1990s, the PO_4-P concentration were increasing continually, which was growing up to 34.0 µg·dm^{-3}. After the early 1990s, the PO_4-P concentration had kept on decreasing until was stable, the average concentration was about 16.0 µg·dm^{-3} in recent years.

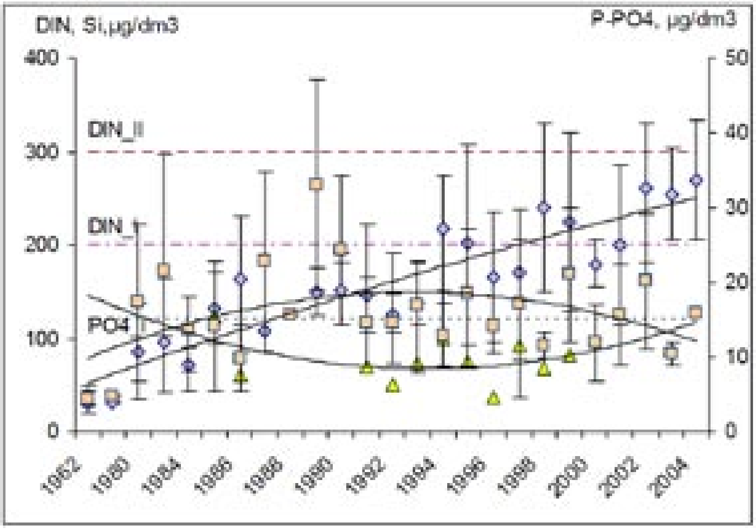

Figure 4.17. The DIN (diamonds), PO4-P (squares), and SiO3-Si (triangles, Δ) annual average concentration of Jiaozhou Bay from 1960 to 2009

Since the 1980s, the annual SiO_3-Si concentration of Jiaozhou Bay seawater has been decreasing. During the middle of 1980s to the middle of 1990s, the SiO_3-Si concentration was decreasing from 120 µg·dm^{-3} to 70 µg·dm^{-3} rapidly. After that, the SiO_3-Si concentration was stable, the average concentration was about 70 µg·dm^{-3} in recent years.

Since the 1980s, the annual COD concentration of Jiaozhou Bay seawater has been decreasing basically. During the early 1980s to the early 1990s, the annual COD concentration of Jiaozhou Bay seawater was about 1.2 mg·dm^{-3}, and the highest concentration was about 1.6 mg·dm^{-3}. While after the 1990s, the COD concentration was decreasing faster, and it was decreasing from 1.2 mg·dm^{-3} in the 1990s to 0.8 mg·dm^{-3} now.

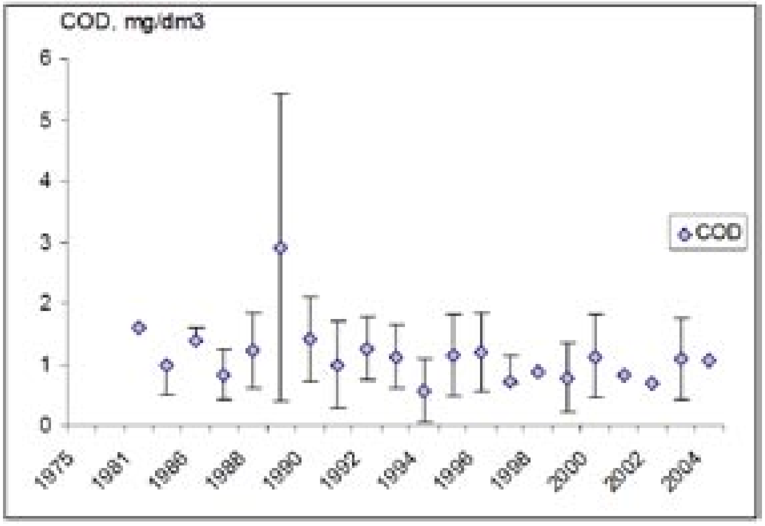

Figure 4.18. The COD annual average concentration of Jiaozhou Bay from 1980 to 2009

Since the 1960s, the petroleum hydrocarbons (PHs) annual average concentration of Jiaozhou Bay seawater has been increasing until the early 1990s. In the early 1980s, the PHs annual average concentration of Jiaozhou Bay surface seawater was about 60 µg·dm^{-3}, which was a little higher than China Seawater Environmental Quality Grade I (50 µg·dm^{-3}). The PHs concentration was increasing rapidly, and it was growing up to 220 µg·dm^{-3} in the end 1980s, which was close to China Seawater Environmental Quality Grade III (300 µg·dm^{-3}). But since the 1990s, the PHs concentration had been decreasing annually, and now the annual average concentration is about 40 µg·dm^{-3} and which is a little lower than China Seawater Environmental Quality Grade I (Fig. 4.19).

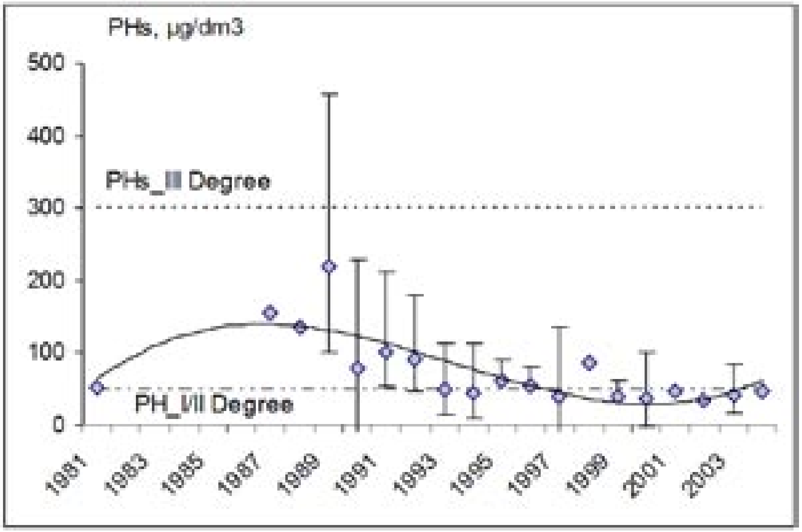

Figure 4.19. The PHs annual average concentration of Jiaozhou Bay from 1980 to 2009

According to detailed investigation (Dai et al., 2007) of the sediment core with Pb^{210} dating the sedimentation there was undisturbed in the middle of the Jiaozhou Bay (water depth 16 m). Before the 1960s, the sedimentation rate of Jiaozhou Bay maintained relatively stable at 3 mm/year. After that sedimentation rate gradually increased to 6 mm/year due to intensification of land-use, rapid population growth, deforestation and urbanization since the 1990s. Climate changes such as large flood events were not observed in the past hundred years in Jiaozhou Bay, so the general accelerating trends in sedimentation rate in the 1980s would rather reflect the increasing effect of human impacts. With the rapid urbanization and economic growth at the end of 1990th the sedimentation rate reached up maximum 16 mm/y. Last decade shows some decrease of sedimentation down to 6.4 mm/y (Dai et al., 2007). Southward at the more deep (20.5 m) part of the Jiaozhou Bay the sedimentation rate by the Pb^{210} was 17.2 mm/y, and simultaneous Cs^{137} dating was 16.8 mm/y, reflecting the natural variability of the sedimentation pattern.

Distribution of the trace metals along the recent sediment core is often used to study the pollution history of aquatic system, because sediment data are more reliable than dissolved metal concentrations in a water system. Qingdao city has few trace metals industries and severe contamination of the wastewaters by metals is absent. The averaged concentration of 0.76 µg/g Cd, 29 µg/g Pb, 67 µg/g Cu and 87 µg/g Zn in the bottom sediments of the Jiaozhou Bay (Dai et al., 2007) confirms it. At the same time there is obvious trend in the distribution of trace metals along the sediment profile (Fig. 4.20). The simultaneous variations of the Li concentration show the variability of sediment grain size as a main reason of the Co, Ni, Cr, Zn, Pb distribution along the core. At the same time for Cu, Cd, and in less degree Zn, Pb show some enrichment of surface and subsurface (Cd) layers. The diagenetic process is a possible reason of it.

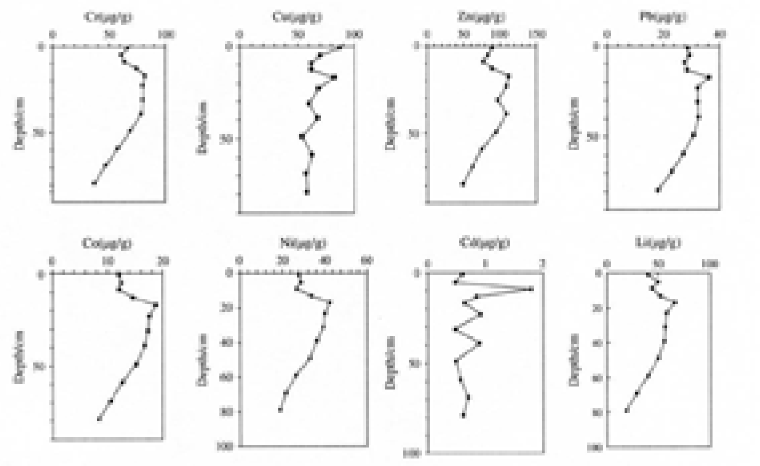

Figure 4.20. The distribution of metals across the upper 80 cm of the bottom sediments in the middle of the Jiaozhou Bay (from Dai et al., 2007).

Thus the structure and trace metal distribution in the recent bottom sediments of Jiaozhou Bay allow to outline period before 1980th with relatively low sedimentation rate, slight trace metal pollution and without significant eutrophication. Period from 1980s till 200 was the time of fast development of Qingdao City, enhanced input of fine silty sediments, contaminated by some trace metals and organic matter. The peak of this period was the end of 1990s. From the 2000 the measures against contamination and excessive input of the sediments were implemented. The result was a decrease of sedimentation rate.

4.2.5. Eutrophication and the changes in the structure of biological communities

According with Fig. 4.16 and research of (Shen, 2001), nutrient concentrations in Jiaozhou Bay from the 1960s to the 1990s, have increased 1.4 times for PO_4-P, 4.3 times for NO_3-N, 4.1 times for NH_4-N, but the SiO_3-Si concentration has remained at a very low level from the 1980s to the 1990s and the SiO_3-Si limiting has been increased.

Since the 1960s, the annual average DIN/PO_4-P ratio of Jiaozhou Bay seawater had been increased continually; otherwise SiO_3-Si/DIN ratio had been decreased (Fig. 4.21).

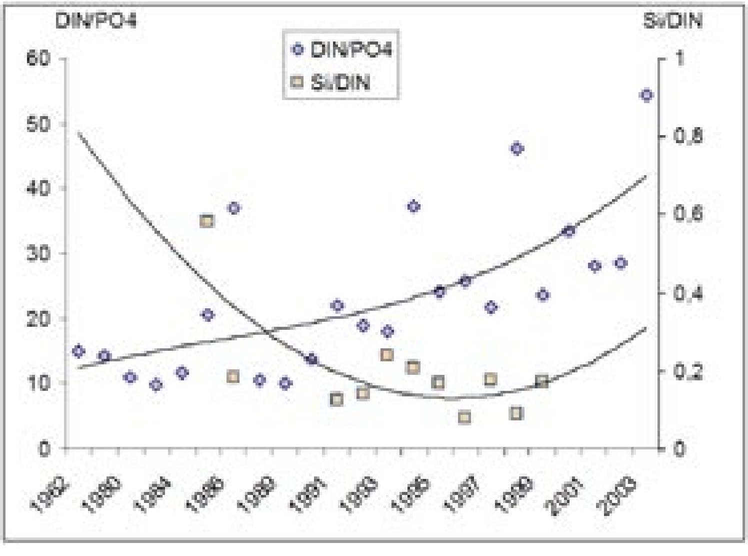

Figure 4.21. The DIN/PO4-P and SiO3-Si/DIN ratio of Jiaozhou Bay from 1960 to 2009

This is mainly because the DIN concentration was far higher than the PO_4-P concentration, while the SiO_3-Si concentration had been decreased continually. In fact, during the 1960s to 1980s, the DIN/PO_4-P ratio of Jiaozhou Bay increased slowly. The ratio increased from 13 in the 1960s to 18 in the end 1980s, which is close to the Redfield ratio. While from the 1980s to now, the DIN/PO_4-P ratio of Jiaozhou Bay increased rapidly, and it rose up to 30 in the middle of the 1990s, and to 50 in the early 21st, which was far higher than Redfield ratio. In contrast, from the middle of the 1980s to the early 1990s, the SiO_3-Si/DIN ratio of Jiaozhou Bay was decreasing continually, the value dropped from 0.6 down to 0.2, and then it remained 0.2 for many years. In a word, the DIN/PO_4-P ratio of Jiaozhou Bay was close to Redfield ratio before the 1990s, but then it deviated from Redfield ratio greatly. The SiO_3-Si/DIN ratio was less than 1.0, it means the SiO_3-Si concentration of Jiaozhou Bay was always at a very low status. Thus, the nutrient structure of Jiaozhou Bay has changed and therefore should influence the structure and abundance of nutrients in the sediments.

Since the 1960s, the annual average Eutrophication Index (EI) of Jiaozhou Bay seawater had been increasing continually, it was consistent with the study results of Shen (2002). It indicates the eutrophication status of Jiaozhou Bay had been deteriorating. was close to Redfield ratio before the 1990s, but then it deviated from Redfield ratio greatly. The SiO_3-Si/DIN ratio was less than 1.0, it means the SiO_3-Si concentration of Jiaozhou Bay was always at a very low status. In fact, the EI value rose slowly from 0.03 in the 1960s to 0.2 in the 1980s, and it indicated the Jiaozhou Bay wasn't in Eutrophication status yet. But from the 1980s to the 1990s, the EI value rose from 0.2 to 1, it indicated the Jiaozhou Bay began to show eutrophication status slowly. And from the 1990s to now, although the EI value increased slowly, but it always remained the level of 1, sometimes it could reach up to about 2, it indicated the Jiaozhou Bay remains in eutrophication status now (Fig. 4.22).

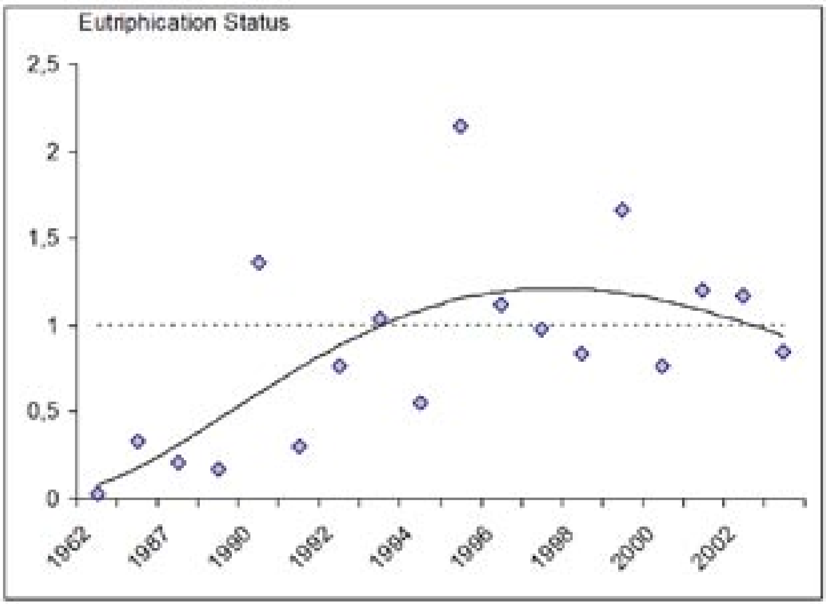

Figure 4.22. The eutrophication index (EI) of Jiaozhou Bay from 1960 to 2009

From the 1930s to 2009, the investigation results of phytoplankton in Jiaozhou Bay indicated that there are about 313 species phytoplankton in Jiaozhou Bay, in which there are 224 species diatom, 69 species c, 8 species green alga, 8 species golden alga, 2 species blue-green algae, 1 specie cryptophyta, 1specie rhaphidophyceae.

The survey result shows that diatoms dominate and dinoflagellates take the second place in the structure of phytoplankton in Jiaozhou Bay. Based on the investigation data in recent years, diatom species, dinoflagellate species, golden alga species and blue-green algae species accounts for 68 %, 26%, 3% and 3% in the structure of phytoplankton communities respectively. In the structure of diatom, the *Chaetoceros, Coscinodiscus, Thalassiosira, Nitzschia, Navicula and Rhizosolenia* are predominant. And in the structure of dinoflagellate, *Protoperidinium, Ceratium* and *Gonyaulax* are predominant.

Although the diatom is always predominant in the structure of phytoplankton communities in Jiaozhou Bay, the inner feature of the phytoplankton communities changed significantly, the features are as follows:

(1) Some larger and chain group diatom species decreased significantly, such as *Chaetoceros, Coscinodiscus* and *Protoperidinium.* While some smaller Nanoplanktonic diatom species increased partly, such as *Thalassiosira, Nitzschia* and *Navicula.*

(2) Some smaller dinoflagellate and golden alga species increased significantly from the end 1980s, such as *Prorocentrum* and *Alexandrium.*

(3) Some invasive species appeared successively, such as *Lithodesmium undulatum, Alexandrium tamarense, Alexandrium catenella, Prorocentrum dentatum* and *Scrippsiella trochoidea.*

The first red tide appeared in 1978 in Jiaozhou Bay. Since the beginning of 1990s, Jiaozhou Bay had been hypereutrophic and the frequency of red tide was continually increasing. The list of the red tide events in Jiaozhou Bay during 2000-2009 is presented in Table 4.5.

Table 4.5. Red tide events HAB occurred in Jiaozhou Bay in 2000-2009

HAB event	HAB area	Causative species	Squares
20/07/2000	Centre of Jiaozhou Bay	*Noctiluca scintinllans*	92km^2
04/04/2001	Fushan Bay	*Noctiluca scintinllands*	small
11/06-12/06/2001	Jiaozhou Bay	*Noctiluca scintillands*	5km^2
07/07 -13/07/2001	Mouth of Jiaozhou Bay	*Mesodinium rubrum*	9.8km^2
28/06 -02/07/2002	Fushan Bay	*Mesodinium rubrum*	60km^2
04/07 -10/07/2003	Tuandao Bay、Huiquan Bay、Taipingjiao Bay、Fushan Bay	*Mesodinium rubrum*	450km^2
02/2004	North-eastern Jiaozhou Bay	*Guinaradia delicatula*	Small
09/02 -28/02/2004	East part of Jiaozhou Bay	*Rhizosolenia delicatula*	70km^2
22/03 -25/03/2004	North-eastern Jiaozhou Bay	*Thalassiosira nordenskЦldii*	70km^2
07/2004	North part of Jiaozhou Bay	*Coscinodiscus asteromphalus*	Small
10/08/2004	Fushan Bay	*Mesodinium rubrum*	50km^2
12/06 -17/06/2005	Lingshan Bay	*Heterosigma akashiwo*	80km^2
07/06 -10/06/2007	Shazikou Bay	*Heterosigma akashiwo*	70km^2
20/08 -23/08/2007	Eastern Qingdao	*Skeletonema costatum*	15 km^2
25/09 -28/09/2007	Shazikou Bay	*Gonyaulax spinifera*	8km^2
28/06 -29/06/2008	Jiaozhou Bay	*Heterocapsa sp.*	5 km^2
07/08 -08/08/2008	Southern Qingdao	*Chattonella antiqua*	86 km^2
2009	Fushan Bay	*Noctiluca scintinllands*	small
2009	Fushan Bay	*Noctiluca scintinllands*	small

5. Dokai Bay

5.1. Social and economic situation at present time and during last decades.

The present Kitakyushu City was established in 1963 through the merger of five cities. The former cities were (from east to west) the port city of Moji, the business city of Kokura, the industrial cities of Tobata and Yahata, and the port and industrial city of Wakamatsu. The first modern steel factory was constructed in 1901 to take advantage of coal from an adjacent region, which is in the backyard of Kitakyushu, and this was the start of industry in the Kitakyushu City region. After that, a large number of factories, including coal chemical factories started operations, and helped to lead the modernization of Japan. After World War II, these factories were restored after destruction from bombing, and contributed to economic growth in Japan. From the end of the war to the early 1970's, as measures to prevent pollution had given way to the higher priority of production, untreated effluents from factories flowed into the sea. Effluents from households (except for human waste) also flowed into the seas through rivers, as there was no sewerage system.

Population changes in the past 50 years in Kitakyushu City are shown in Fig. 5.1. The population was over one million in 1961, reaching a peak of 1.068 million in 1979. Since then, it has been decreasing, and the current population (2009) is around 983,000. The reason for the decline is mainly decreasing birth rates.

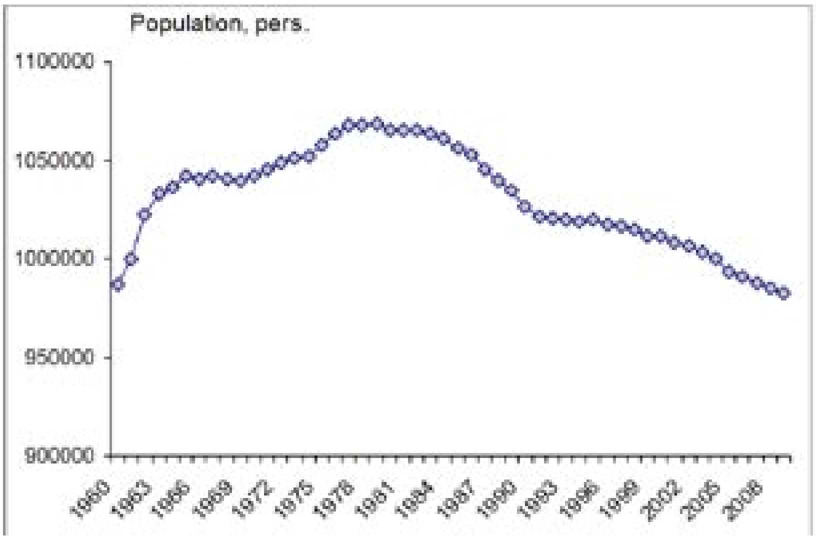

Figure 5.1. The population dynamic in the Kitakyushu City in 1960-2008

In the past 30 years, the areas of rice cultivation greatly (about two times) decreased, while the areas of buildings and traffic facilities increased, and an area for golf links was newly added. From these results, it was confirmed that artificial areas increased with a corresponding decrease of natural areas.

Changes in industrial output in Kitakyushu City region from 1979 are shown in Fig. 5.2. The industrial output from the late 1990's to the early 2000's reflects the prolonged recession following the bursting of the economic bubble, though economic conditions in the city have since recovered.

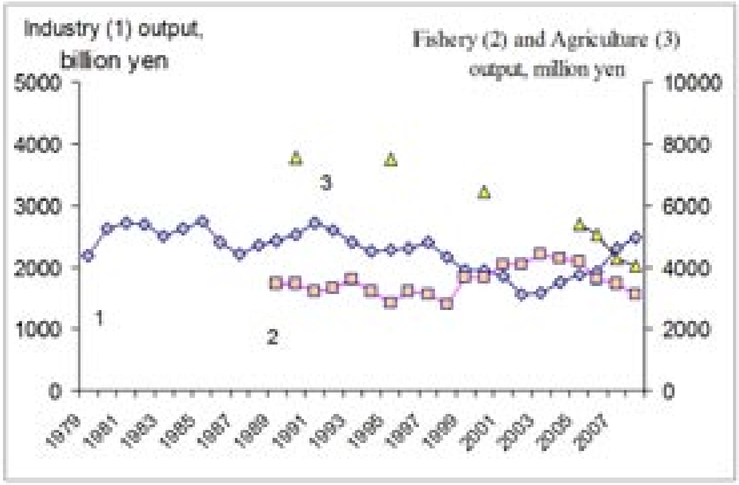

Figure 5.2. Industry (1), fishery (2) and agriculture (3) output in Kitakyushu city area.

Changes in fishery output in Kitakyushu City region are shown in the same Fig. 5.2. Though from 1989 to 2000, fishery output was almost constant, it soon increased and reached a peak in 2003. Since then, fishery output has decreased to a level similar to that before 2000. Fishing catches also showed the same temporal trend as the fishery output shown on Fig. 5.2.

The agriculture output in the Kitakyushu City area decreased by half since 1990 (Fig. 5.2) in the accordance with the same decrease of crop acreage.

The distribution and volume of pesticides and fertilizers since 1985 are shown on Fig. 5.3. The distribution of fertilizers dropped by half between 1985 and 2000, as did the acreage under cultivation. This is especially true for the chemical fertilizers use. The organic fertilizers distribution has been even increased in the middle of 90th, but due to prevailing of the chemical ones, the summary usage of fertilizers decreased. However, the distribution of pesticides dropped off dramatically in this period – to one fourth of the former use in just 15 years (Fig. 5.3). After 2000, there were no large changes in the distribution of pesticides and fertilizers.

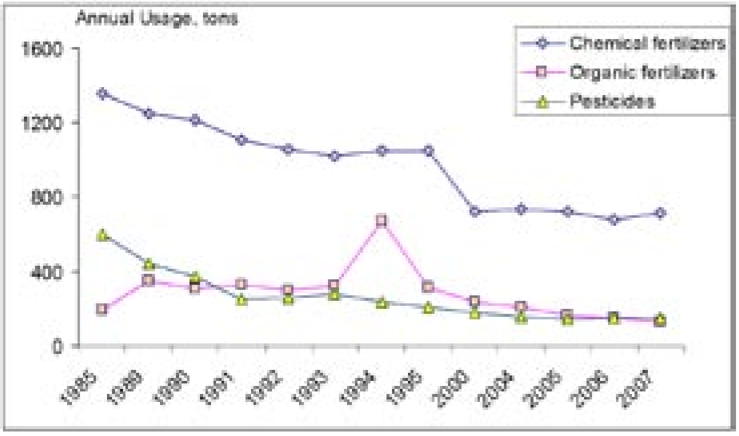

Figure 5.3. The annual usage of fertilizers and pesticides in the Kitakyushu City area.

There are 5 main sewage treatment plants in Kitakyushu City. Their summary treatment capacities cover population 989438 inhabitants that is cover all population. These facilities use a standard activated sludge process. The area provided by wastewater treatment plants has been expanding since the first sewage treatment facility was constructed in 1963 in the west of Kitakyushu City to 90% in 1990 and 99.8% in 2005 (Fig. 5.4).

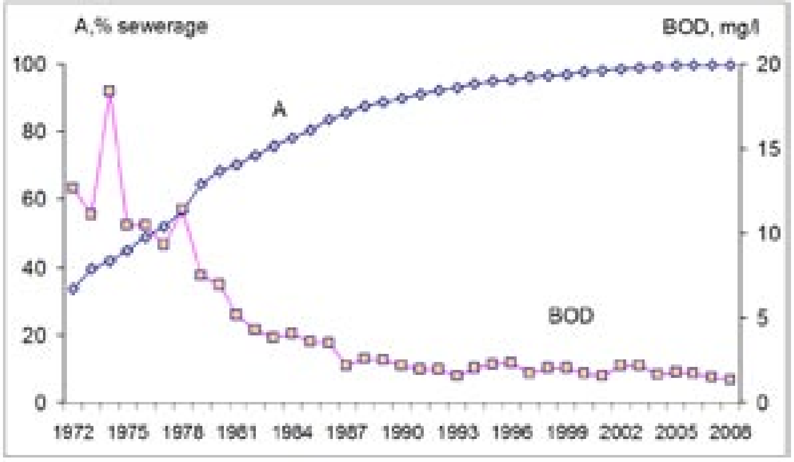

Figure 5.4. The changes in sewerage coverage and averaged BOD in the rivers within Kitakyushu City area.

Although there are two types of sewer systems in Kitakyushu City region; the separate and the combined sewers, the combined sewer system has been undergoing conversion to the separate sewer system since 2004. As of 2009, fully 79% of the sewer system is the separate sewer. Since early rains are dirtier than later rains because they wash accumulated matter from roads and elsewhere, they are also a cause of pollution in aquatic environment. In order to deal with early rains, two reservoirs that store rain water have been constructed since 1998. The rainwater in these reservoirs is transferred to a sewage treatment facility and is discharged after treatment.

5.2. Environmental problems in the coastal zone, including rivers and coastal sea areas

5.2.1. Chemical pollution and temporal changes in composition of river runoff

River water quality within the Kitakyushu City area is examined every month at 27 sampling points on the 16 rivers, presented mainly on Figure 3.2. There is significant spatial variability of the BOD parameter among the rivers (Fig. 5.5).

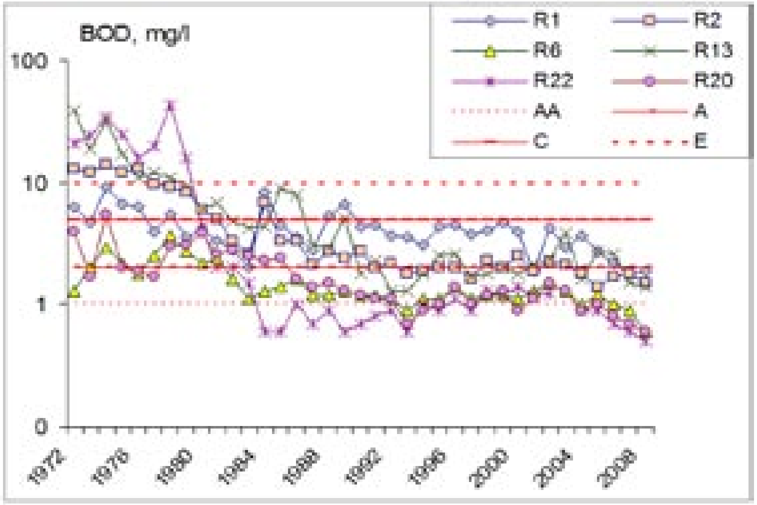

Figure 5.5. The inter annual change of annually averaged BOD in the typical rivers within the Kitakyushu area (R1, R2, R6, R13, R20, and R22, see Fig. 3.2) in the comparison with Environmental Quality Standards for different water use (AA, A, C, E).

In the 1970s even less contaminated rivers (upstream of Egawa River, Itabitsugava River, and Okuhata River) exceeded most strict BOD standard for Class AA waters (1 mg/l) and were between Class A (2 mg/l) and Class C (5 mg/l) waters. Many rivers and streams were severely polluted with BOD more than 10 mg/l. However, the water quality improved in 1980's and has met environmental standards since 1987. There is one river where the BOD has exceeded the environmental quality standards for Class C water since 2000. The reason for high BOD is thought to be internal production, such as algae bloom.

The relationship between the sewerage coverage ratios and averages of BOD in rivers is shown on Figure 5.4. It is clear that the sewerage coverage ratio is strongly related to the improvement of river water.

Health related items (28 items) and monitored substances (26 items) that are also examined at monitoring points are not detected at all the monitoring points.

5.2.2. Loads of contaminants through rivers and by direct inputs.

There are no data regarding pollutant loads delivered through the rivers. However, if the flow rates of rivers do not differ annually, the changes in BOD concentrations could reflect changes of organic substance loading. The decrease rate of BOD was 89 % when comparing the averages of 1972 to 1974 and 2006 to 2008 (Fig. 5.5).

Although the details of effluents from the sewage treatment facilities were obtained, effluent volumes were not among the data. In addition, since water quality and quantity data concerning effluents from industrial sources was not obtained, pollutant loads from sewage treatment facilities and factories could not be calculated. However, the water quality of Dokai Bay, an enclosed sea with major factories and Kitakyushu City's second largest sewerage treatment facility located nearby, seems to reflect the expected pollutant loads. A comparison of the average COD_{Mn} in the mouth of the bay (St. D2) from 1971 to 1975 with that from 2005 to 2009 indicates that the decline of COD_{Mn} amounts to 43%. (Fig. 5.6). From this result, the reduction rate of organic pollutants would appear to be 40% to 50% during this period.

5.2.3. Pollution of the marine ecosystems.

Seawater at 18 sampling points around Kitakyushu City is examined every month (Fig. 3.2). Figure 5.6 shows the inter annual variation of the COD in the sea from 1968 to 2009.

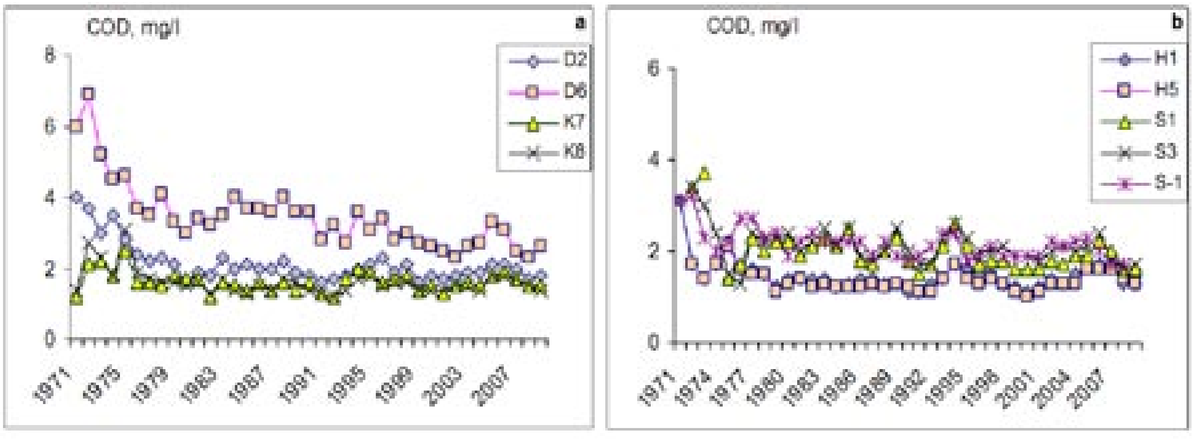

Figure 5.6. Inter annual change of annually averaged COD at the sea monitoring stations around Kitakyushu City area (see Fig. 3.2 for location)

As shown in the Figure 5.6, seawater in Dokai Bay itself (St. D2, D6) was heavily polluted in the 1970s. The water quality, however, improved and outer part of the Dokai Bay (St. D2) has met environmental quality standards less than 2 mg/l since 1976, mainly due to the installation of a sewer system and strict regulations on effluents from factories. There is one monitoring site in the inner part of the Bay (St. D6) where the COD exceeds the environmental quality standard. The reason seems to be internal production such as an algal bloom.

Water of the Kanmon Straight including Stations K7 and K8 situated in close vicinity of the Kitakyushu port facilities had COD more than 2 mg/l before 1976. After that, annually averaged COD varied at 1.2-1.9 mg/l without any difference between different parts of Kanmon Straight (Fig. 5.6a).

Hibiki-nada is part of the eastern NOWPAP sea area adjacent to the Dokai Bay from the west, and had slightly elevated COD at the beginning of 1970th exceeded EQS 2 mg/l at the St. H1 closest to the Dokai Bay. But since 1976-1977 COD from any stations of Hibiki-nada were less 2 mg/l. Station H7 situated near Shirashima Is. 12 km westward of Dokai Bay has COD ranged 0.7-1.6 mg/l with average for 1981-2008 1.1 mg/l compare with averaged 1.4 mg/l at the St. H1 for the same period.

The east adjoining sea area is part Suo-nada (Fig. 3.2). This is a part of Seto Inland Sea which is more eutrophic compare with eastern NOWPAP sea area. As a result averaged COD at the stations S1, S3, S16 for 1981-2008 ranged 1.9-2.2 mg/l. Before 1980 averaged COD at the same stations were 2.2-2.6 mg/l, that is some improvement of the water quality took place (Fig. 5.6b)

Data on the phosphorus and nitrogen concentrations in the Dokai Bay and adjacent sea areas are available for the period since 1987. The secular variations of total phosphorus concentrations are shown on Figures 5.7. There is obvious decrease trend within Dokai Bay and especially in the inner part of the Bay (St. D6) (Fig. 5.7c). Outside Dokai Bay there is not any trend of the annually averaged total phosphorus since 1987, though some correspondence was observed between variability of the averaged phosphorus concentrations in the different parts of the adjacent sea areas (Fig. 5.7a, 5.7b).

The inter annual changes of the annually averaged total nitrogen concentrations in Dokai Bay and within adjacent sea areas somewhat similar to phosphorus. In Dokai Bay total nitrogen dropped 4-5 times from 1987 till 2002, and since that shows near constant concentration 0.46-0.55 mg/l in outer part (St. D2) and 1.5-1.9 mg/l in inner part (St. D6) (Fig. 5.8c). In Hibiki Nada, the sampling points that are affected by Dokai Bay showed high nitrogen concentrations in the 1980's. However, in the 1990's nitrogen concentrations in Hibiki Nada as well as in Suo Nada did not change along with the improvement of water quality in Dokai Bay (Fig. 5.8a, b). Concentration of total nitrogen in Kanmon Straight, at least in vicinity of Kitakyushu City (St. K7, K8), continue to be elevated compare with Hibiki Nada and/or Suo Nada (Fig. 5.8a), and this is distinct feature of nitrogen distribution against phosphorus one.

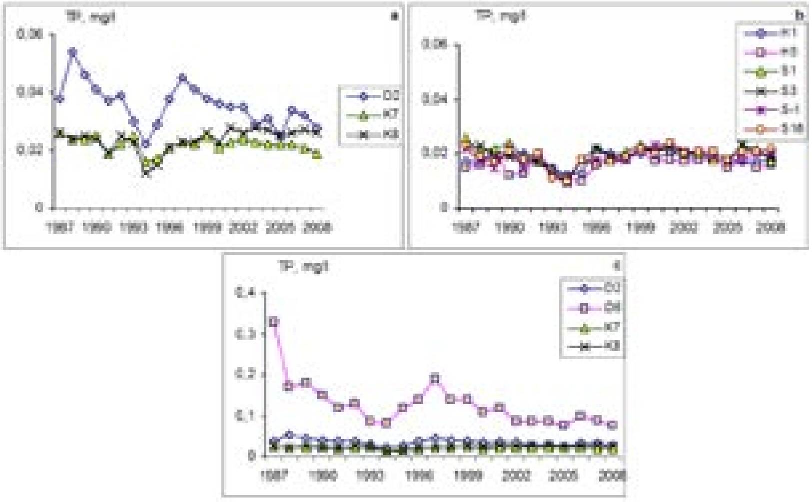

Figure 5.7. Annual changes of the annually averaged total phosphorus concentration at the sea monitoring stations around Kitakyushu City area.

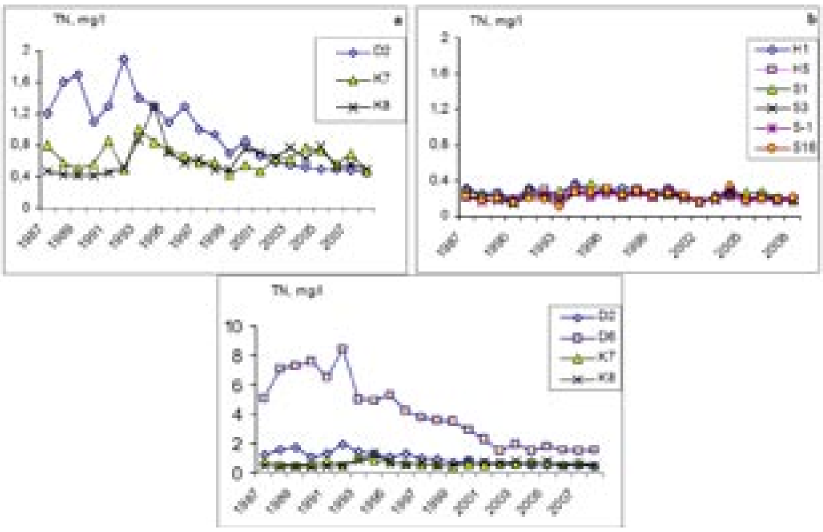

Figure 5.8. Annual changes of the annually averaged total nitrogen concentration at the sea monitoring stations around Kitakyushu City area.

Health related items (28 items) and monitored substances (26 items) that are also examined at the monitoring points are not detected at all of the monitoring points.

Since detailed and in-depth surveys of the seawater, sediment and aquatic life in Dokai Bay, exposed to heavy industry and chemical factories, have been carried out for a long time, the following explanation focuses on the bay.

The first environmental survey was conducted in 1933. From the survey, it was found that the seawater and sediment near the outlets of factories was heavily polluted by organic matter that included tar, sulfate, Ca and Mg. Consequently, it was concluded that Dokai Bay was not suitable as a fishing ground. From the next full-scale survey, carried out in 1966, low concentrations of DO (0 to 3 mg/L), high concentrations of suspended solids (765 to 1229 mg/L) and 6.6 to 7.7 of pH were found. These values showed that the sea had greatly changed from its original condition. In addition, high concentrations of COD (74.6 mg/L), CN (0.64 mg/L) and As (0.15 mg/L) were detected in the Dokai Bay in 1968 and 1969. Furthermore, other surveys detected phenol (6.8 to 7.5 mg/L) and CN (0.7 to 0.8 mg/L). From these data, it was fair to say that the environment of Dokai Bay at that time was poisonous, and Dokai Bay was in fact referred to as the "Sea of Death."

However, new environmental quality standards and effluent standards were put into force in 1969 and 1970, and wastewater and sewage treatment was accelerated. As a result of these efforts, all items including COD met environmental quality standards in 1973 for the first time. Since the environmental quality standards for nitrogen and phosphorus were established in 1997, nitrogen concentrations have dropped considerably. The concentrations in 2005 were one-fourth of those in 1990, and phosphorus concentrations decreased 13% during the same period. Accompanied by the decrease in nutrients, the size of the anoxic water-mass in the innermost part of the bay has been decreasing year by year.

The unique survey on organic micro-pollutants in coastal sea waters around Kitakyushu City has been carried in 2007 (Kadokami et al., 2008). In this survey, 285 chemical pollutants known in coastal waters were studied, and the effects on aquatic organisms were evaluated. The total number of chemicals actually detected was 180, and the mean concentration of each location ranged from 0.24 to 15.8 μg/l. The risk of the detected chemicals to marine organisms was calculated by using the quotient method, which is the division of a concentration by end points such as a no-observed-effect concentration. Polycyclic aromatic hydrocarbons and pesticides contributed to the most damage according to the assessment. The quotient values were at high levels where toxic effects are expected to occur.

The first full-scale survey of bottom sediments was conducted in 1968. The survey found that heavy metals, CN, and organic matter containing petroleum hydrocarbons accumulated across a wide swath of the bottom of Dokai Bay. In response, Kitakyushu City Government decided to dredge the polluted sediment, and carried out a detailed survey in 1971 to determine exactly where to dredge. The volume of polluted sediment was estimated to be 4,800 thousand m^3. Dredging was conducted to remove 350 thousand m^3 of sediment that was heavily polluted with Hg (above 30 mg/L).

From 1989 to 1990, another full-scale sediment survey was performed. The results have shown that although pollution from organic matter was no different than in the previous survey, concentrations of sulfates and heavy metals were much lower than before the dredging.

Besides this full-scale sediment surveys, since 1972 once a year concentration of contaminants are checked in the bottom sediments sampled at the water quality monitoring points. Data for the typical metal pollutants – Hg, Pb, Cd are presented on Figure 5.9.

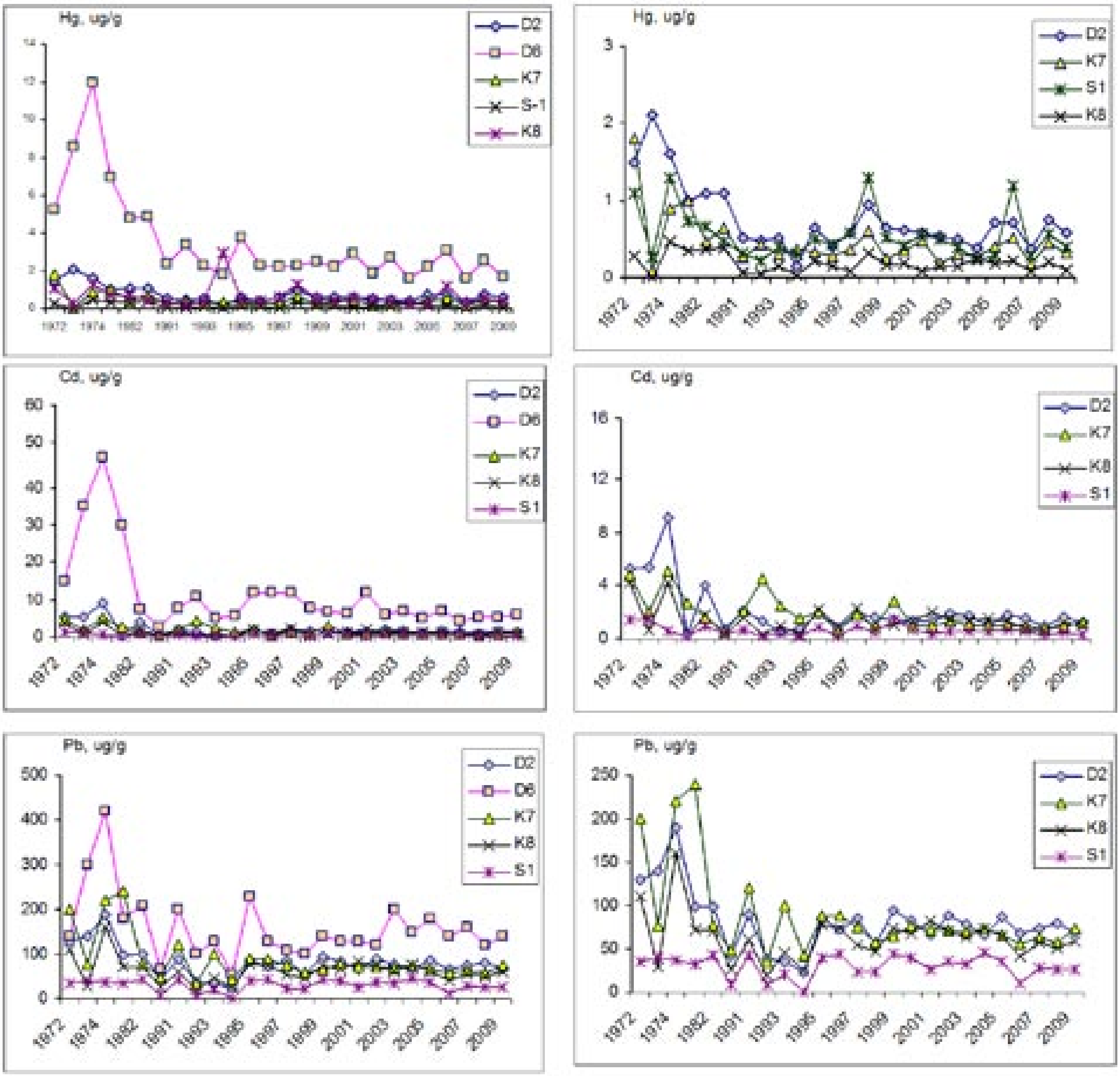

Figure 5.9. Inter annual change of Hg, Cd and Pb concentration in the bottom sediments in the Dokai Bay (D2, D6), Kanmon Straight (K7, K8) and Suo Nada (S1).

The significant diminishing of pollutants concentration in sediments is obvious for the last 30-40 years. The most sharp and substantial decrease took place in the Dokai Bay from 1970th till end of 1980th (Fig. 5.9) reflecting the dredging and removal of contaminated sediments. After that sediments from the inner part of Dokai Bay (D6) continue to have constant but rather elevated concentrations Hg, Cd and Pb. The enrichment above background level is 5 times for Pb, 10 – for Cd, and 20 – for Hg. Sediments of outer part of Dokai Bay (D2) also demonstrate most significant decrease of metal concentration from 1970th till end of 1980th, but reached concentrations prevail the background level for 3, 4, and 10 times for Pb, Cd and Hg, respectively. After 1991-1992 concentrations of metals in the sediments of outer part of Dokai Bay are rather stable, and observed variability is explained by natural factors (grain size variations, first of all). Similar distribution of these metals is observed in the sediments of Kanmon Strait in the vicinity of Kitakyushu City (K7, K8) (Fig. 5.9). Sediments of the Suo Nada area (S1) have rather variable due to natural reasons but without any trend concentration of Pb, but concentrations of Hg and Cd show some decrease trend during last 30-35 years to 0.56±0.16 ug/g for Cd and to 0.15±0.06 ug/g for Hg, that practically to the background level.

Moreover, in 2007, in order to better understand the pollution caused by micro-pollutants in Dokai Bay, approximately 900 organic chemicals and heavy metals were examined. The results of the survey are summarized in Tables 5.1 and 5.2. Concentrations of heavy metals did not notably differ from those in1990 and after that (Table 5.1, Fig. 5.9).

Table 5.1. Concentrations (ug/g dry weight) of heavy metals in sediments of Dokai Bay in 2007

Substance	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
As	7.9	6.5	13.6	11.6	11.8	15.7	23.2
Cd	0.69	0.83	2.39	2.75	2.78	4.77	21.1
Cr	14.1	17.6	71.3	55.5	65.8	91.7	67.0
Cu	8.4	10.6	29.3	44.9	71.7	160	160
Pb	20.5	25.7	115	117	121	144	90.2
Hg	0.084	0.171	0.996	1.12	1.95	3.88	2.98
Ni	6.0	6.2	10.3	9.2	16.2	24.3	23.3
Zn	85.8	99.3	421	385	353	480	470
Se	1.08	0.86	0.80	0.71	0.88	2.00	3.32
Mn	148	153	308	208	233	273	249

Site 1 is at the mouth of Dokai Bay (D2) and Site 7 is at the innermost of the bay (D6); other sites are located between the both sites.

One hundred ninety two of the 900 organic chemicals were found. Since their concentrations, as well as those of the metals, increased with their proximity to the innermost part of the bay, their source would appear to be factories and the sewage treatment plant located in that area. The highest concentration (247 mg/kg dry) was 28 times higher than in the mouth of the bay. Four-fifths of the amount of the detected contaminants seem to be discharged from factories, and polycyclic aromatic hydrocarbons accounted for two-thirds of the amount. Other detected substances seemed to have domestic sources, since chemicals from agricultural activities were not detected. These results confirmed that sediment in the bay is still heavily polluted by heavy metals and organic chemical substances, which are mainly discharged from industries and households.

Table 5.2. Concentrations (ug/kg) of organic micropollutants in sediments of Dokai Bay

Category	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Insecticides (159)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	64 (2)	113 (2)
Herbicides (108)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (1)	72 (4)
Other pesticides (35)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	16 (1)
Sterols (7)	2233 (5)	1939 (4)	10 019 (5)	11 357 (4)	9039 (5)	14 146 (5)	14 620 (5)
Antioxidants (6)	1685 (2)	3389 (3)	5156 (3)	7032 (3)	5251 (3)	4303 (3)	6048 (3)
Fragrances and cosmetics (11)	49 (5)	78 (4)	933 (6)	1007 (5)	692 (5)	1644 (4)	1443 (4)
Disinfectants (4)	2 (2)	4 (2)	11 (3)	55 (3)	96 (4)	229 (4)	260 (4)
Fatty acid methyl esters (36)	16 (5)	51 (5)	13 (3)	113 (4)	53 (4)	79 (2)	103 (2)
Fire retardants (13)	108 (1)	0 (0)	10 (1)	41 (2)	21 (2)	75 (2)	162 (3)
Plasticizers (14)	539 (6)	1049 (7)	1966 (6)	2824 (6)	2477 (7)	6772 (6)	10 245 (7)
Metabolites of detergents (3)	53 (2)	163 (2)	391 (2)	252 (2)	203 (2)	676 (2)	1201 (2)
PPCPs (18)	5 (2)	8 (2)	79 (3)	154 (3)	110 (3)	447 (2)	1641 (3)
Compounds leached from tires (28)	74 (6)	178 (6)	484 (8)	703 (8)	816 (7)	1746 (7)	2224 (11)
Petroleum hydrocarbons (26)	1221 (24)	1826 (23)	5892 (24)	9035 (25)	7927 (25)	30 092 (25)	37 549 (25)
Other domestic substances (29)	0 (0)	0 (0)	0 (0)	14 (1)	13 (1)	69 (5)	66 (3)
Intermediates in org. synthesis (59)	56 (6)	150 (7)	857 (9)	1539 (13)	2556 (13)	6152 (15)	5076 (16)
Intermediates for dye (26)	18 (1)	45 (1)	521 (1)	1168 (1)	1004 (4)	2083 (7)	1558 (7)
Intermediates for pesticide (6)	0 (0)	0 (0)	0 (0)	0 (0)	3 (1)	33 (1)	32 (1)
Intermediates for resin (8)	0 (0)	2 (1)	4 (1)	14 (2)	13 (2)	50 (2)	58 (1)
Solvents (17)	19 (5)	57 (5)	428 (6)	388 (8)	168 (7)	623 (8)	569 (7)
PAHs (46)	2338 (30)	5115 (32)	41 436 (32)	77 492 (32)	83 112 (31)	176 860	110 028
PCBs and PCNs (90)	0 (0)	3 (1)	340 (15)	167 (10)	81 (7)	360 (13)	134 (5)
Other industrial substances (38)	340 (3)	168 (4)	592 (3)	501 (3)	184 (3)	586 (4)	453 (4)
Total (888)	8756 (105)	14 225 (109)	69 131 (131)	113 855 (135)	113 820 (135)	247 106 (154)	193 670 (154)

Parentheses show the number of chemicals. Site 1 is at the mouth of Dokai Bay (D2) and Site 7 is at the innermost of the bay (D6); other sites are located between the both sites.

Dokai Bay was still rich in marine products in the early 1900's. However, the destruction of the sea was a concern as early as 1917, because of adverse effects brought on by effluents from steel factories. After a peak catch of fish in 1928, the catch declined because of pollution. The results of the survey in 1933 said that the catch of fish had declined by half only four years after the peak in 1928. At that time, 17 kinds of fish were considered endangered. Contamination in the bay worsened, and by 1943 aquatic organisms could no longer survive in the water there. This situation continued to deteriorate for 30 years, until 1970, except for 3 years following World War II.

Water quality in the bay has not remarkably changed, and has met the environmental quality standards every year since 1973, when all environmental quality standard items met the criteria for the first time. Around 1980, though fish were found in the bay, a current scientific survey had not been conducted. For this reason, a biological survey of fish, crustaceans, benthic organisms and algae was carried out from 1989 to 1990 along with an environmental survey to elucidate the effects of the improvement of water quality on aquatic organisms. The survey revealed 115 kinds of fish and crustaceans, which indicated that many aquatic organisms had returned after one decade of improvement in the water quality. In addition, it was estimated that some species had reproduced in the bay. The species found in the survey were the same as those found before the pollution. Hg and PCB in collected fish and shrimp were also measured. The concentrations of PCB and Hg were found to be ND - 0.86 ppm and ND - 0.20 ppm, which are considered safe enough to eat.

5.2.4. Degradation and loss of the coastal habitats.

Temporal changes in the size of reclaimed lands in Kitakyushu City region is presented on the Fig. 5.10. The area that had been reclaimed prior to 1962 is unknown. From 1963 to 1975, 22.5 km^2 of the seashore was reclaimed, and then 7.08 km^2 and 6.03 km^2 of seashore were reclaimed from 1975 to 1988 and from 1988 to 2008, respectively. In addition, a reclaimed island (373 ha) was built in Suo Nada on the border of a neighboring town in the early 1990's. Since reclamation, 80% of the shoreline in Kitakyushu City has become unsuitable for wildlife habitation because of the artificial shore. However, Kitakyushu City Government constructed an artificial habitat on the reclaimed land facing Hibiki Nada, where migratory birds can land.

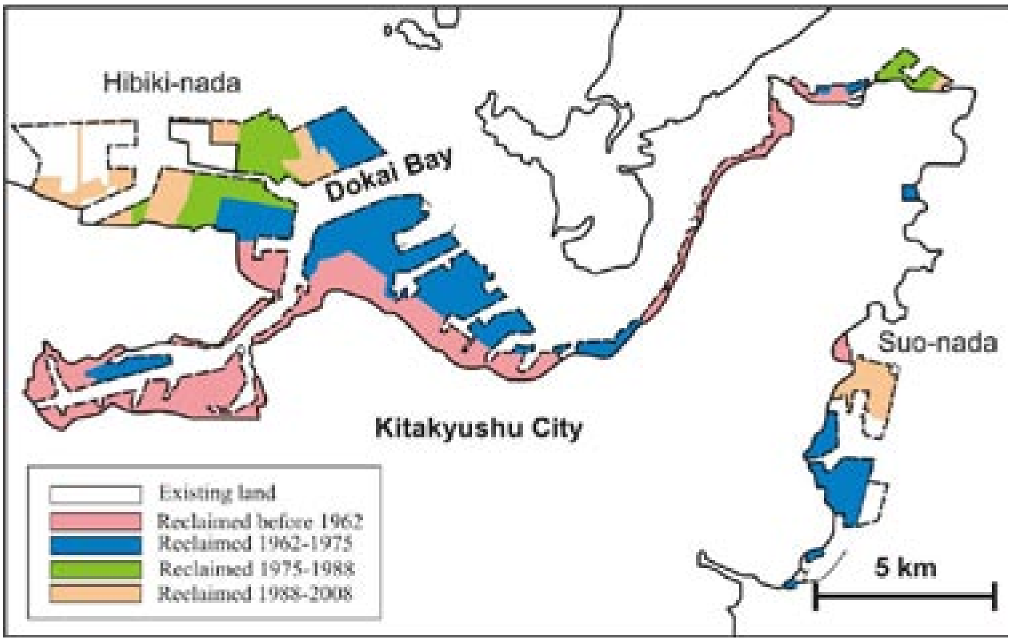

Figure 5.10. The coastal habitats loss due to reclamation for the port and city facilities.

The most important area in the remaining 20% of natural seashore is the Sone tidal flat that faces Suo Nada in the Seto Inland Sea. This tidal flat is the largest in the Seto Inland Sea, covering 517 ha. Many species, including endangered species such as the Japanese horseshoe crab (*Tachypleus tridentatus)* and the Chinese black-headed gull *(Larus saundersi)*, live there. However, there is concern that the sea current has slowed due to construction of the reclaimed island described above, which is located nine km offshore from the tidal flat. Recently, the catch of sediment fish and shellfish in Suo Nada has declined because of the decrease of shallow sea area. Environmental changes in Suo Nada should be given particular attention in the future.

5.2.5. Eutrophication and changes in the structure of biological communities.

The secular variations of total nitrogen and total phosphorus concentrations in the Dokai bay and adjacent coastal sea areas since 1978 are shown on Figures 5.7 and 5.8. Both concentrations in Dokai Bay have met environmental quality standards since 2001, even though they are still high. The sampling points in the western side of coastal sea area, which are affected by Dokai Bay, showed high nitrogen concentrations in 1980's, but since the 1990's the concentration has been stable as a result of the improvement of water quality in the bay.

Water quality was further improved by introducing environmental quality standards that targeted nitrogen and phosphorus. In the Dokai Bay nitrogen concentrations fell by 75% over 15 years - the average concentration between 1988 and 1990 was 7.9 mg/l, while it was 1.9 mg/L between 2003 and 2007. Phosphorus concentrations also decreased from 0.16 mg/L to 0.11 mg/L over the same period, which indicated that eutrophication conditions had improved. Nitrogen and phosphorus concentrations in Suo Nada in the Seto Inland Sea did not remarkably change from 1987 to 2008.

Accompanying the water quality improvement, planktons composing red tides changed from one species of *Skeletonema spp.* before 1990 to several species in 2005, even though the number of red tides did not remarkably change between 1980 and 2007 (Fig. 5.11). The anoxic water-mass that occurs in the innermost part of the bay in summer also decreased. As a result, the number of algae species increased from 31 to 48 species, and the algae found in the mouth of the bay in 1992 were found in the middle of the bay in 2007. Since anaerobic conditions in the inner part of the bay were improved by reducing the size of anoxic water-mass, the diversity of aquatic organisms increased. The dominant species in the innermost part of the bay was polychaete in 1990, while in 2007 the dominant species were bivalves and squillas.

Figure 5.11 illustrates the inter annual variations in occurrences of red tides in the inner part of Dokai Bay. Although the quality of the seawater has improved, the frequency of red tides, which mainly occur in summer, did not change between 1980 and 2006. The planktons composing the red tides, however, have changed from a single to multiple species.

Dokai Bay was heavily contaminated in 1960's. It was called the "Sea of Death" because of the absence of aquatic life. After that, water quality was improved by establishing strict regulations against effluents, by building a sewer system and by dredging sediment that was polluted with high concentrations of Hg. In the ecological survey on aquatic animals in Dokai Bay that was carried out in 1988 and 1989, 115 species of fish and crustaceans were found, from which it was concluded that Dokai Bay had recovered to the point that aquatic organisms were able to once again live in the bay. In addition, since larvae of benthic organisms and fish eggs were found in the bay, reproduction of those species was also confirmed. After enacting environmental quality standards for nitrogen and phosphorus, the quality of both seawater and sediment has improved still further. As a result, the variety of algae has increased from 31 species to 48 species, and algae that were only found in the mouth of the bay in 1992 were found in the middle of the bay in 2007. Since anaerobic conditions in the inner part of the bay were improved by reducing the size of anoxic water-mass, the diversity of aquatic organisms increased. The dominant species in the innermost part of the bay was polychaete in 1990, but in 2007 the dominant species were bivalves and squillas.

As mentioned above, the problem of contamination caused by organic substances in Dokai Bay had been mostly solved by 1973, and eutrophication has improved since the early 1990's, which has gradually resulted in the current distribution and diversity of aquatic organisms in the bay.

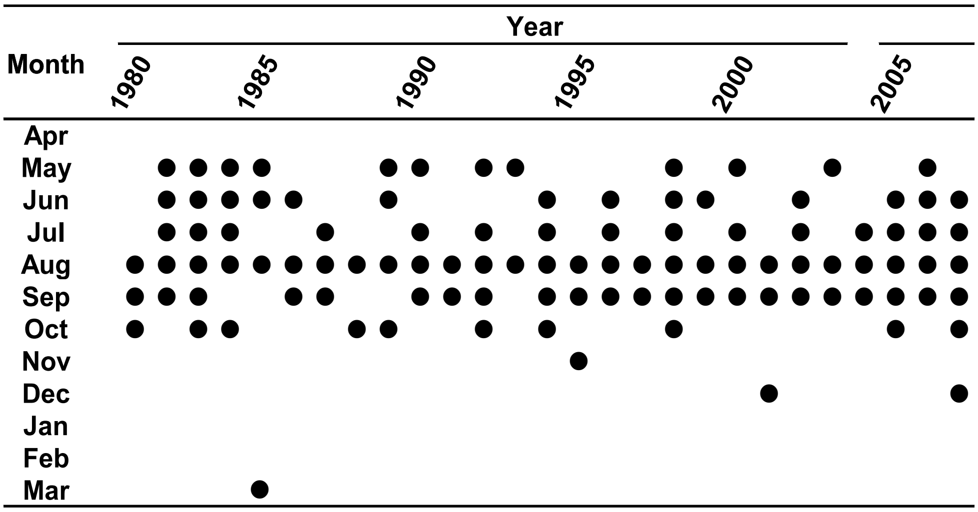

Figure 5.11. Inter annual variations in occurrences of red tides in the inner part of Dokai Bay. Black circles show that a red tide occurred at the time of survey once a month.

6. Masan Bay (Republic of Korea)

6.1. Social and economic situation at present time and during last decades

The watershed of Masan Bay is one of the developed city area in the middle of the Southern Gyeongsang Province, 35 km westward of Busan. There are three cities within Masan Bay area: Masan, Changwon and Jinhae (Fig. 3.3). The population of bigger Masan and Changwon cities becomes rather stable during last 12-14 years, though population of smaller Jinhae city shows some increase – 2-3% annually (Fig 6.1). The overall population of Masan Bay cities agglomeration varies around 1 million persons during last decade with very high population density around 2682 persons/km^2.

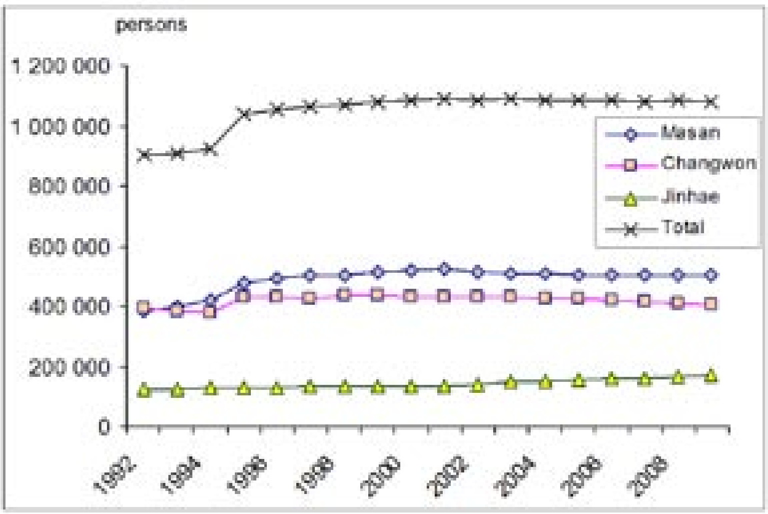

Figure 6.1. The dynamic of population in the Masan, Changwon and Jinhae cities

The regional gross domestic products (GDP) in Masan, Changwon and Jinhae cities is about $4.5*10^9$ USD per year. The contribution of primary, secondary and tertiary enterprises to the GDP is 2.9; 41.7 and 55.4%, respectively.

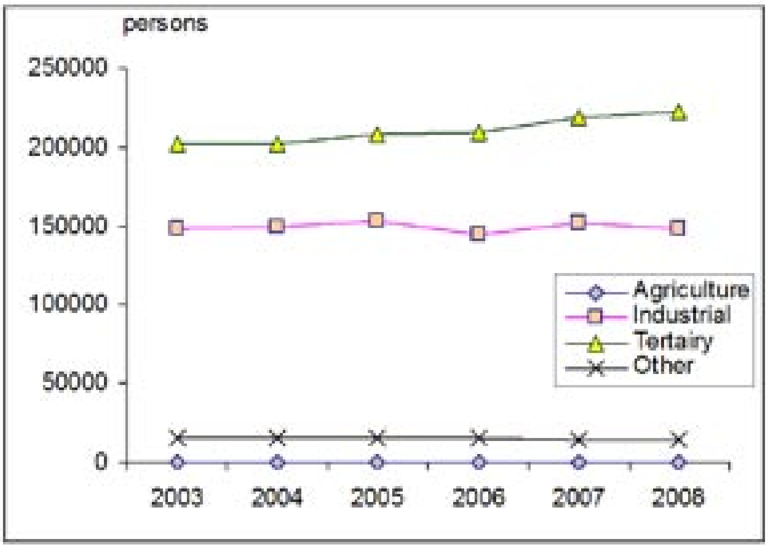

Figure 6.2. The number of employees in the different enterprises in the Masan, Changwon and Jinhae cities

This is supported by the number of employees working at the agriculture/fishery/forestry, industrial and tertiary (service, trading, logistic etc.) enterprises (Fig. 6.2). The prevalence of the employees working at the tertiary business enterprises is obvious and is characterized by the increase trend last 5 years. The textile production, port logistics, newest business (e-products, robototechnics etc.) are the most developed fields of economical activity in Masan, Changwon and Jinhae cities.

At the same time land-use structure within city agglomeration has 72% coverage by forests and 15% by arable lands (Fig. 6.3).

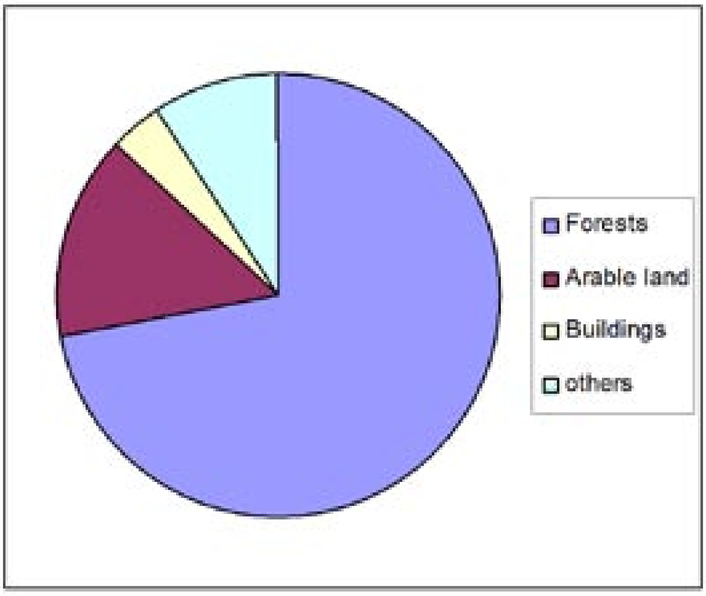

Figure 6.3. The land-use structure of the Masan, Changwon and Jinhae city areas.

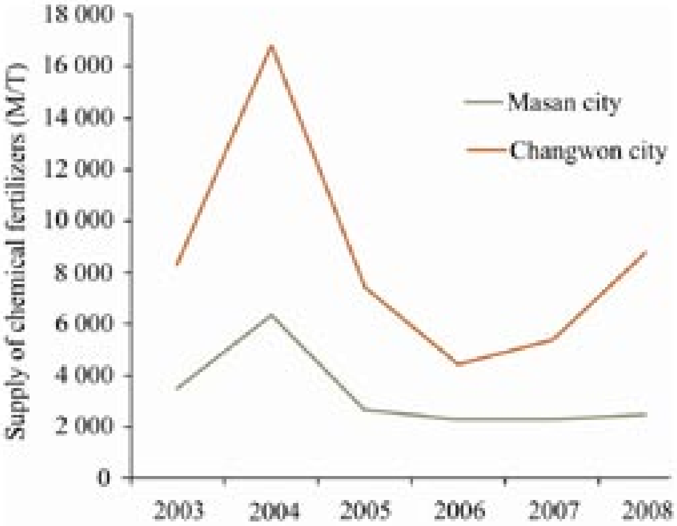

Figure 6.4. Supply of chemical fertilizers on the arable lands within Changwon and Masan cities.

This rather significant amount of arable lands within Masan Bay watershed is accompanied by the intensive use of chemical fertilizers (Fig. 6.4). In 2004 the annual usage of chemical fertilizers reached up 467 t/km^2, and even in 2008 after considerable decrease, the annual usage of chemical fertilizers was about 224 t/km^2. For the comparison the annual usage of chemical fertilizers for the agriculture at the Dokai Bay watershed (Japan) was 42 t/km^2, and at the Jiaozhou Bay watershed (China) – 60-80 t/km^2. The elevated level of the chemical fertilizers usage is inevitable source of additional runoff of the nutrients to the Masan Bay.

The amount of the wastewaters production is varied from about 3000-6000 m^3/day in Jinhae to 15000-20000 m^3/day in Masan, and 35000-50000 m^3/day in Changwon. The total volume of wastewaters production in Masan Bay area was about 90000 m^3/day in 1997, and has decreased significantly to 58000 m^3/day in 2006 (Fig. 6.5), reflecting the efforts to reduce the anthropogenic press on the environment during last decade.

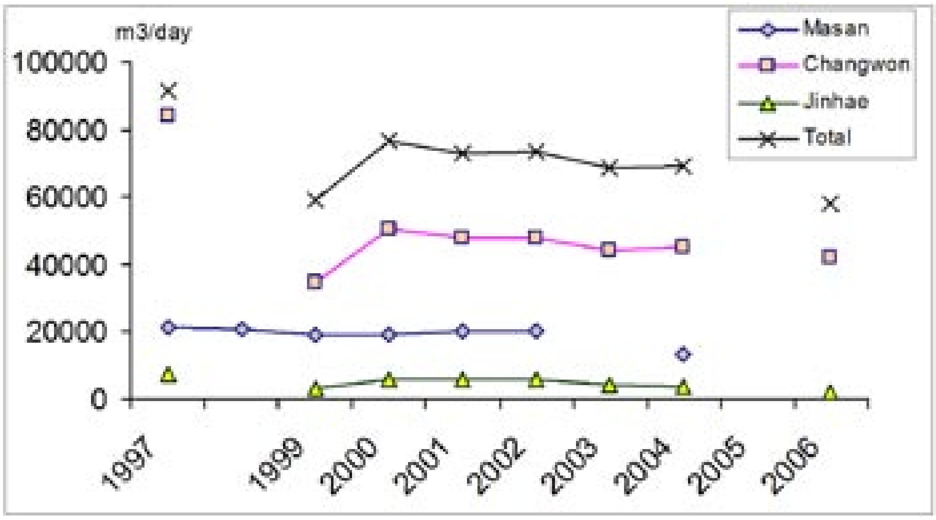

Figure 6.5. The dynamic of wastewaters production in the Masan, Changwon and Jinhae cities, and in the Masan Bay area as a whole.

We have not data on the sewage treatment coverage of the Masan Bay area, but it should not be less than 70% - average sewage treatment coverage for the Gyeongnam province as a whole (POMRAC Technical report #4).

6.2. Environmental problems in the coastal zone, including rivers and coastal sea areas

6.2.1. Chemical pollution and temporal changes in composition of river runoff.

The averaged chemical composition of the rivers inputting to Masan Bay (regular monitoring data on 2009) is presented in Table 6.1. The water quality characteristics are rather variable. The decreased dissolved oxygen concentration and increased COD values, as well as elevated level of TN and TP are observed in the Samho – the biggest river of the watershed (Table. 6.1). It unambiguously points the high anthropogenic press on the river water quality. At the same time weighted averages for all rivers at the Masan Bay watershed do not exceed the Korean water quality standards for river water.

Table 6.1. Chemical composition of river waters from Masan Bay watershed (2009 data)

area	river	Discharge	DO	pH	COD	NH_4	NO_3	TN	TP	PO_4	Si	TOC
		m^{-3} d^{-1}	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Masan city, 92.3 km^2	Sujeong	6,823	4.89	7.06	7.3	6.25	0.97	9.19	0.94	0.75	6.81	5.24
	Woosan	47,218	8.39	7.56	2.97	0.03	2.02	5.23	0.04	0.02	4.04	1.61
	Wolyong	4,987	7.29	7.57	12.66	6.51	3.37	14.52	2.04	0.64	5.37	3.93
	Janggun	7,400	7.42	7.30	7.83	3.36	3	10.8	0.61	0.42	4.89	2.1
	Cheoksan	9,117	3.99	7.15	15.65	9.5	1.4	15.7	1.93	0.62	3.67	4.83
	Kyubang	23,671	7.79	7.73	10.57	4.84	2.43	11.8	0.83	0.41	4.39	3.67
	Samho	105,889	3,88	7,19	23,57	0,02	1,21	14,5	1,62	0,62	3,79	4,59
	Palyoung	18,158	6.56	7.39	3.49	7.92	0.77	1.37	0.12	0.16	3.64	4.46
Changwon city, 126.3 km^2	Namcheon	56,715	8.33	7.29	7.69	1.44	1.79	9.43	0.31	0.15	5.22	2.25
	Changwon	20,749	6.13	7.44	9.32	1.7	1.64	15.5	0.7	0.23	5.79	3.32
	Naedong	10,264	6.27	7.34	16.5	4.69	1.8	13.29	0.61	0.2	6.45	4.04
Jinhae city, 46.2 km^2	Daecheon	31,012	6.54	7.39	7.26	3.18	3.68	11.4	0.45	0.22	7.32	2.41
	Seockdong	31,012	4.77	6.76	14.1	5.06	1.47	14.8	1.1	0.4	6.62	3.45
	Sinyicheon	31,012	5.86	7.31	15.1	2.73	1.91	13.2	0.56	0.28	6.69	2.6
	All rivers*	404,027	**6.7**	**7.30**	**12.9**	**2.36**	**1.80**	**11.5**	**0.84**	**0.35**	**5.02**	**3.33**

* weighted average

For the time being we have not data on the changes of chemical composition of the river input to the Masan Bay.

6.2.2. Loads of contaminants through rivers and by direct inputs

The annual runoff of some chemical substances to the Masan Bay through rivers in 2009 is presented on Figure 6.6. It is obviously that despite the different concentration in the rivers (Table 6.1), the runoff and the influence on the adjacent sea area is depend on the river discharge first of all. As a result, the Samho River runoff is a main factor controlling the input of organic matter and nutrients to the Masan Bay (Fig. 6.6a). The joined runoff of Namcheon, Changwon and Naedong Rivers entering to the head of the Masan Bay (Fig. 3.3) is a second principal component of organic matter and nutrients input. At the highly elevated ammoniac and nitrate concentration in the Changwon city rivers, their runoff becomes the main source of nitrogen input to the Masan Bay (Fig. 6.6b).

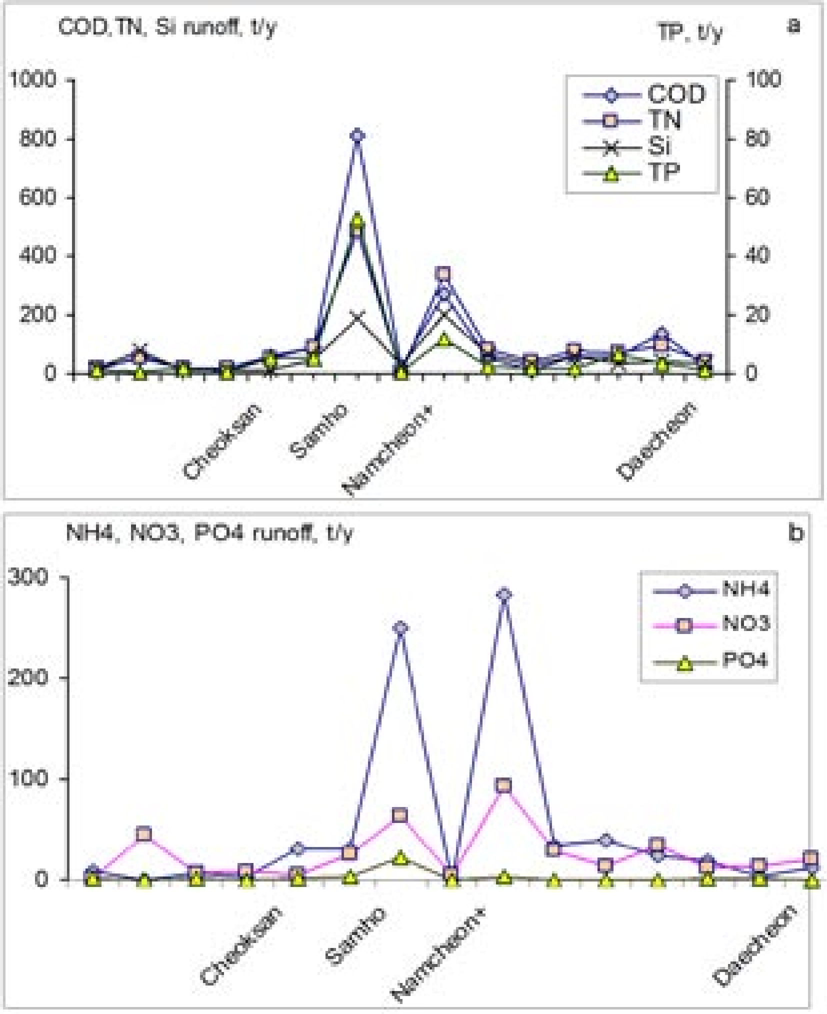

Figure 6.6. The annual runoff of some chemical substances by different rivers of the Masan Bay watershed.

6.2.3. Degradation, changes and loss of coastal habitats

Masan Bay area is an example of the large scale reclamation of coastal areas for the construction of industrial complexes, port facilities, settlements and for other business purposes. Even visual comparison between images of Masan Bay 50 years ago and nowadays (Fig. 6.7) allows evaluate the about 30% decrease of sea area within inner part of the bay.

Figure 6.7. The dynamic of coastal sea reclamation in Masan Bay from 1960th (top) and 2009 (bottom).

6.2.4. Pollution of the marine ecosystems.

The annually averaged data on the sea water quality for the 3 monitoring points within inner part of Masan Bay (circles on Fig. 3.3) is presented on the Fig. 6.8. Salinity shows significant inter annual variability without any trend supposedly due to inter annual variation of atmospheric precipitation and river discharge. Dissolved oxygen shows weak increase trend during last 15 years, though significance of this trend is questionable. Similar weak trend but decrease takes place for the COD inter annual change. At the same time the decrease trend of the annually averaged nutrients (DIN, DIP, DSi) concentration is much more pronounced (Fig. 6.8). Part of this decline last 5 years can be explained by the elevated salinity level, which is connected in turn with decrease of river discharge. But such significant decrease trend of nutrients in the coastal sea area unambiguously reflects the reduction of nutrients runoff from the land-based sources last 15 years. The improvement of the technologies and enhanced efforts to wastewaters treatment is a main reason of this trend.

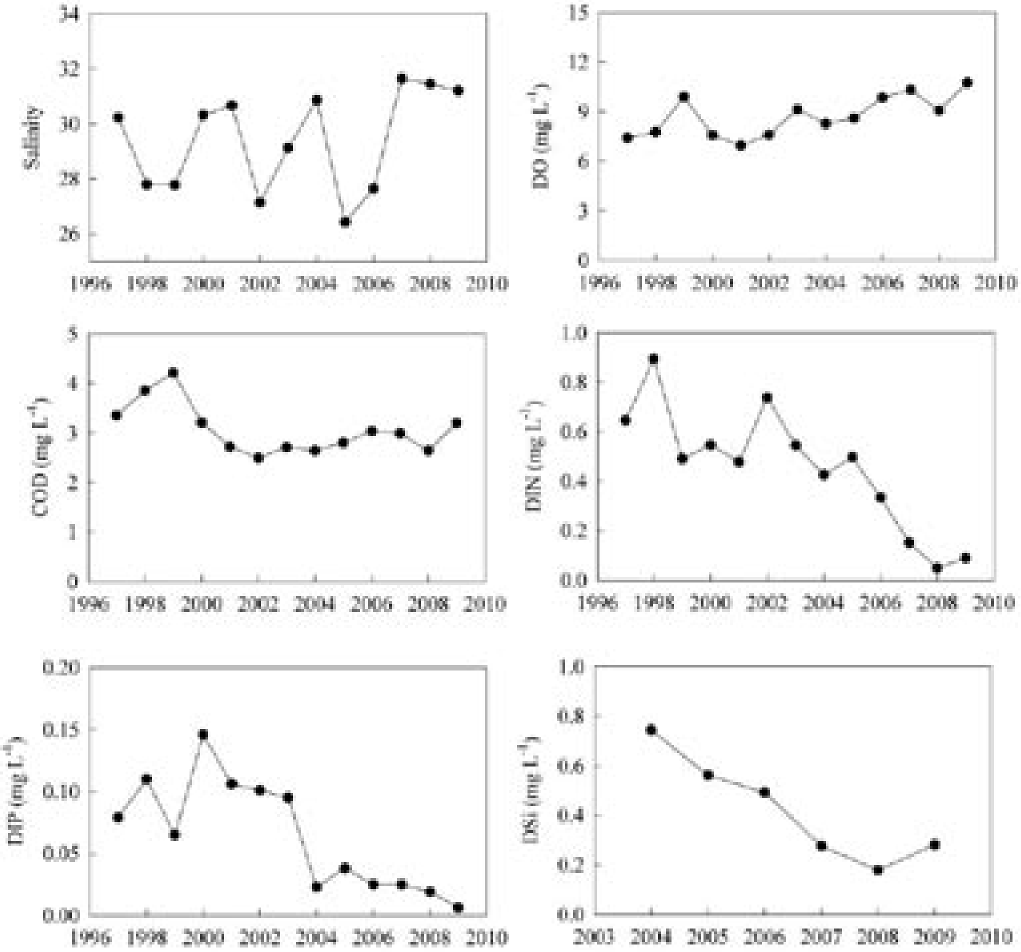

Figure 6.8. The change of annually averaged chemical characteristics in the Masan Bay

For the time being we have data on the trace metals contamination of bottom sediments from the inner part of Masan Bay only (diamonds on Fig. 3.3). The averaged data on the chemical composition of bottom sediments (Table 6.2) demonstrate clearly the contamination of bottom sediments by Zn, Cu, Cd and Pb. Their mean concentrations exceed threshold ecological level established by Canadian government for the assessment of bottom sediments (Interim…, 1995) on 2-4 times. Maximum of observed concentrations of Zn and Cu exceed the probable ecological level (Table 6.2).

Table 6.2. The metal concentration of the bottom sediments in inner part of Masan Bay

	Fe	Cr	Cu	Ni	Zn	Cd	As	Pb	Mn	Hg
Min	3.61	56	28	0.1	131	0.17	4.6	38	503	0.00
Max	5.21	109	115	26.3	492	2.36	16.4	108	978	0.32
Mean	4.53	79	74	16.7	321	1.37	10.5	74	721	0.14
PEL			108	65	271	4.2		112		0.85
TEL			18.7	35	124	0.7		30		0.25

TEL – threshold ecological level, PEL – probable ecological level (Interim…, 1995).

The analysis of the relationships between metal concentrations in the bottom sediments of the inner part of Masan Bay allows separating the group of metals: Zn, Cu, Cd, Pb, and Cr.

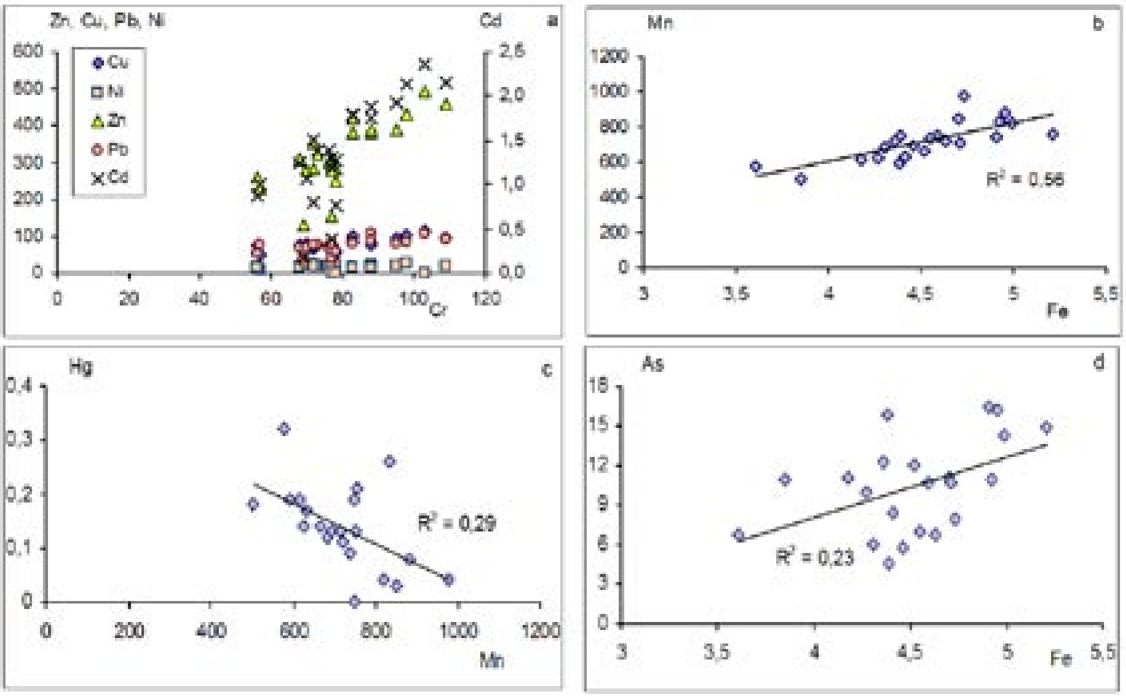

Figure 6.9. The relationships between metal concentrations in the bottom sediments of inner part of Masan Bay

The variability of these metals in the bottom sediments of inner bay is interrelated (Fig. 6.9a) and does not depend on the variability of Fe concentrations which is a proxy of the grain size variation. The excessive anthropogenic runoff is a main reason of the elevated concentration of these metals in bottom sediments. Contrariwise the Mn and possibly As variations could be explained by the variability of sediment grain size (Fig. 6.9b, d). The Hg variability in bottom sediments shows the negative relationship with Mn content (Fig. 6.9c). This special feature of Hg could be explained by the Hg accumulation in the reduced sediments with decreased level of Mn. The release of Mn at the reduced environment in the contaminated coastal sediments is well established (e.g. Santchi et al., 1990).

The distribution of metals along the bottom sediment core at the undisturbed sedimentation allows assessing the dynamic aspect of the contamination. In case of inner part of Masan Bay the obvious increase of Cd, Cr, Zn, Cu, Pb and Hg takes place in the upper 20-60 cm. There is some difference in the distribution of different metals (Fig. 6.10) reflecting the dynamic of their supply during last 50-60 years.

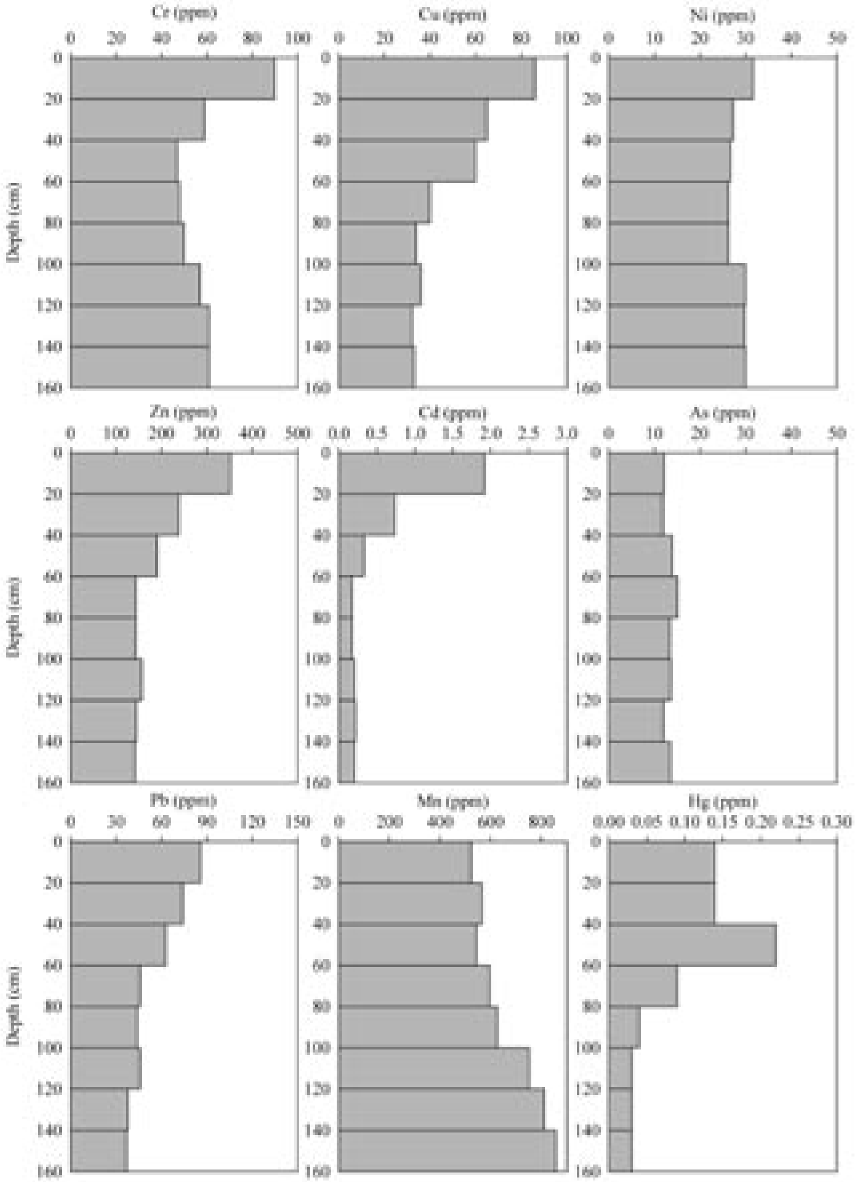

Figure 6.10. The vertical distribution of metals in the upper 1,6 m of sediment core from the inner part of Masan Bay.

Several detailed studies were carried out on the temporal and spatial variability of the contamination of sediments by the persistent organic pollutants (PCBs, DDTs, PBDEs) (e.g. Hong et al., 2003, Hong et al., 2010). The clear decrease trend with distance from the inner parts to the outers was observed for all POPs, though some intermediate increase took place near Duckong WWP outfall (Hong et al., 2010). For example sum of PCBs in sediments decreases from 10-24 ng/g in the inner part to 0.1-1.8 ng/g in the outer ones (Hong et al., 2010). Some years ago concentration of sum of PCBs in the sediments of inner Masan Bay was determined in range 19-41 ng/g with decrease to 1.2-2.2 ng/g in the outer part (Hong et al., 2003). The concentration of DDTs sum was more variable and decreased from 2-89 ng/g in the sediments of inner part to 0.3-3.6 ng/g in outer part (Hong et al., 2003).

The vertical distribution of PCBs, DDTs and PBDEs in the upper 50-60 cm of undisturbed bottom sediments shows (Fig. 6.11) clearly the dynamic of POPs supply to the sediments including the PCBs ban after 1990.

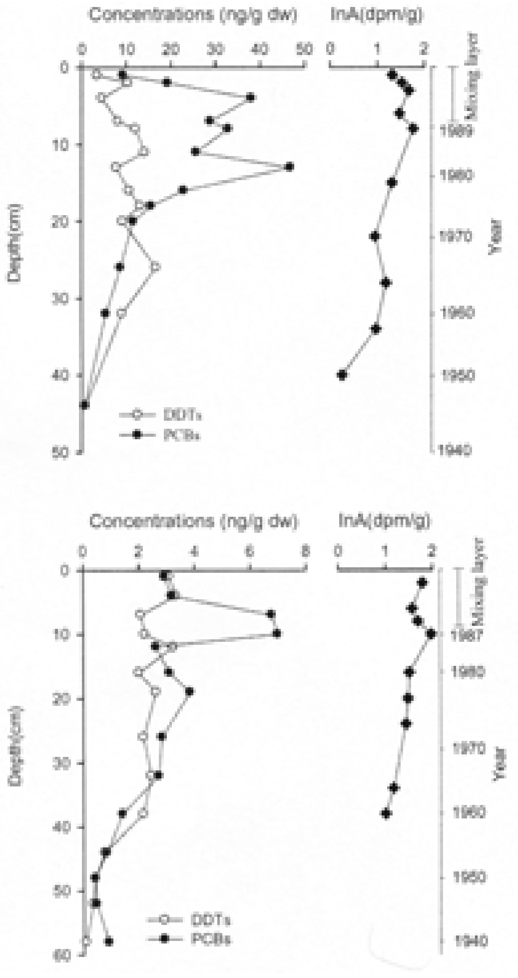

Figure 6.11. Distribution of DDT and PCBs in the dated sediment core of Masan Bay (top) and Jinhae Bay (bottom) (From Hong et al., 2003).

6.2.5. Eutrophication and the changes in the structure of biological communities

The coastal region including Masan Bay with neighboring Jinhae Bay and Haengam Bay was important spawning and breeding area due to ragged coast line and sufficient food supply. This coastal area provided 2/3 of oyster domestic production (Lee, Kim, 2008). After construction of industrial zone in Masan Bay area after 1970s the water quality has deteriorated seriously. The enhanced level of nutrients supply from the land-based sources and correspondent elevated level of nutrients concentration in Masan Bay have led to the eutrophication of this coastal area and adjoining Jinhae Bay as well. After 1980s algal blooms have been observed almost yearly, and sometimes with fish mortality and serious economical damage. The comprehensive assessment of eutrophication of Jinhae Bay is carried out in the integrated report on eutrophication assessment in the selected sea area in the NOWPAP region by NOWPAP CEARAC.

The averaged DIN level in Jinhae Bay after increase period from 1996 till 2000 has shown stable and substantial decrease trend from 0.4 mgN/l to 0.05-0.1 mg/l during last decade. This is coincided with inter annual trend in Masan Bay (Fig. 6.8), though initial concentrations of DIN in Masan Bay were 0.6-0.9 mgN/l that is twice compare with Jinhae Bay. Similar trend was observed for DIP in Jinhae Bay: increase up to 0.08 mgP/l in 2000 and decrease to 0.01-0.02 mgP/l in 2004-2008. And again such trend is coincided with inter annual change of DIP concentration in Masan Bay, with three fold elevated initial level in 2000 – 0.1-0.15 mgP/l (Fig. 6.8).

The registration of red tide events in Masan Bay and Jinhae Bay was carried out since 1979 by NFRDI at the 15 survey points. The number of events varied from 5 to 22 per year with peaks in 1986 and 1999 (Fig. 6.12). The period of 1980s had slightly elevated level of red tide events (10-21), but with diatoms as dominant species. First half of 1990s was characterized by diminish of red tide events (<10), but flagellats began to prevail. Second half of 1990s the number of red tides gradually increased up to 21 per year at flagellats dominance. Since 1999 decrease trend prevails.

Thus the number of red tide events varied without simple relationships with inter annual changes of nutrients level in water. Though some coinciding decrease trends of red tide events and averaged COD content takes place in Masan Bay during last decade (Fig. 6.13). At the same time there is firm trend of red tides size (coverage) increase from 1970s when they were observed within Masan Bay only till 1990s and 2000s when red tides covered all east part of coastal area between mainland and Geoje Is.

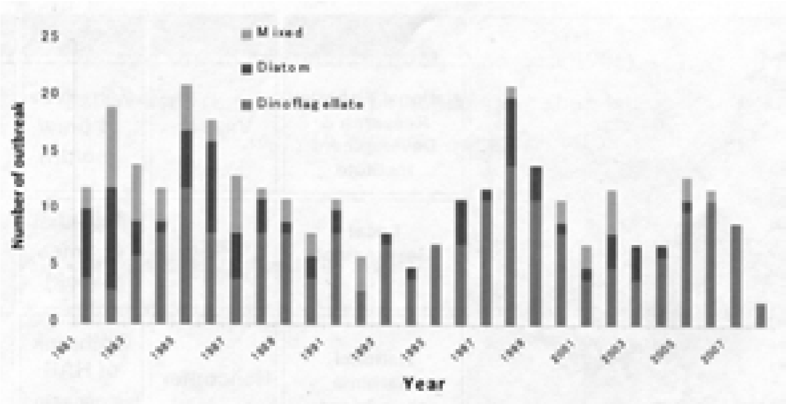

Figure 6.12. The number of red tide events in Jinhae Bay since 1981 (Park, Lee, 2011)

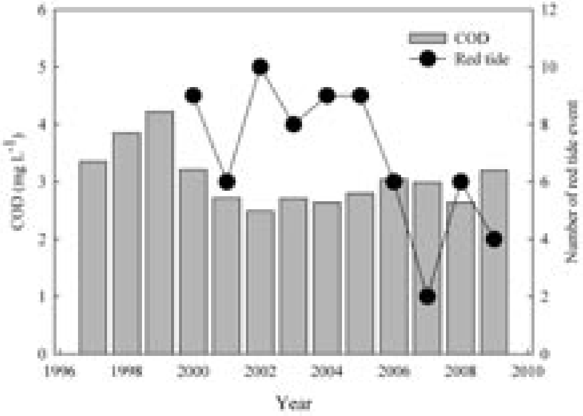

Figure 6.13. The relationship between red tides occurrence and COD level in Masan Bay during last 15 years.

The decadal succession of red tide causative plankton species is also unambiguous evidence of ecosystem changes in the Masan Bay and Jinhae Bay coastal area. From 1970s till 2000s the gradual decrease of diatoms (*Skeletonema costatum* and *Chaetoceros spp.)* contribution from 66% to 6.8%, and gradual increase of dinoflagellats (*Prorocentrum spp. Heterosigma akashiwo*) contribution from 6.1% to 54% provide major feature of phytoplankton community changes.

7. Peter the Great Bay (Russian Federation)

7.1. Social and economic situation at present time and during last decades

Peter the Great Bay watershed area is the most populated and developed part of the Primorskyi Kray, and Russian Far East as a whole. The contribution of the Peter the Great Bay watershed to the population of Primorskyi Kray reaches up 70% nowadays (Table 7.1), though 45-50 years ago this contribution was 50-55% (Fig. 7.1a). The urban population strongly dominates for the area studied, and Vladivostok with 605000 comprises more than half of all urban population (Fig. 7.1b). Other major cities include Ussuryisk – 152700, Artem – 111200, Nakhodka – 167600, Fokino – 33800, Bolshoi Kamen – 47400, Partizansk – 49600. Such structure of population takes place during last 30 years. 50 years ago the contribution of Vladivostok city was significantly lower (Fig. 7.1b). The population density at the Peter the Great Bay watershed is 5 times higher than for the Primorsky Kray as a whole (Table 7.1). The main reason is high contribution of urban population, the population density at the Khasan, Razdolnaya and Shkotovsky-Partizansky sub-areas off the cities is close to the average level observed for the Primorsky Kray as a whole (Fig. 7.1c). The dynamic of population within Peter the Great Bay watershed is similar to the Primorsky Kray also: increase to the nineteenth of XX century and decrease after that (Fig. 7.1a). The population density has decreased as well (Fig. 7.1c).

Table 7.1. Socio-Economic characteristics of different sub-areas within Peter the Great Bay watershed in 2009

Sub-area	Square, $*10^3$ km^2	Population $*10^3$ person	Population density, per./km^2	Industry, $*10^6$ USD	Agriculture, $*10^6$ USD	GDP $*10^6$ USD	GDP per capita, USD
1	4.13	27	6.5	26.5	5.9	106.5	3916
2	9.42	135.1	14.3	134.1	100.3	420.4	1951
3	7.00	55.1	7.9	237.9	31.0	376.0	6823
4	0.56	605.1	1080.5	2384.5	9.4	6599.8	10835
5	2.74	562.9	205.4	1133.3	197.8	3176.2	7359
6	23.85	1385.2	62.9	3916.3	344.2	10678.8	7709
7	164.67	1984	13.7				

Note: southwestern sub-area (1) includes Khasanskyi district; Razdolnaya area (2) includes Oktober, Mikhailovskyi, Ussuryiskyi, Nadesdinskyi districts; northeastern sub-area (3) includes Shkotovskyi and Partizanskyi districts; (4) – Vladivostok; other cities (5) include Ussuryisk, Artem, Fokino, Bolshoy Kamen, Nakhodka and Partizansk; (6) – all watershed of Peter the Great Bay; (7) – all Primorskyi Krai.

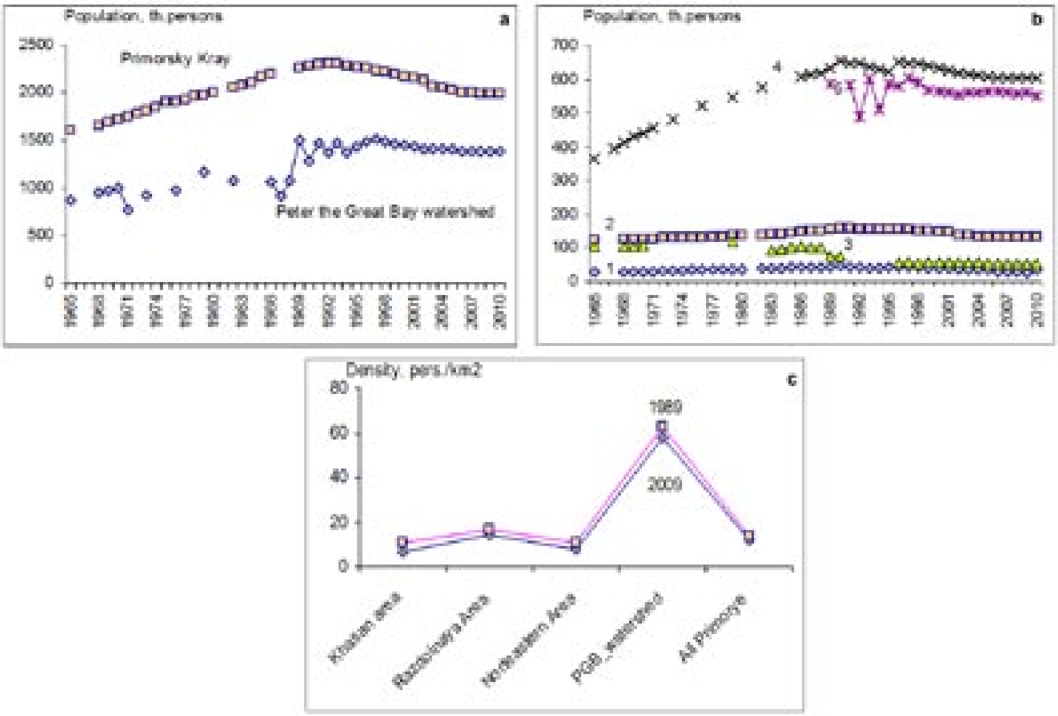

Fig. 7.1. The population dynamic in the Primorsky Krai and Peter the Great Bay watershed as a whole (a), in the different sub areas of watershed (b), and population density for the 1989 and 2009 (c).

Other socio-economic features of the different sub-areas within Peter the Great Bay watershed are also very different (Table 7.1). The relative input of agriculture and industry (with construction) production to the GDP is consistent with distribution of population. The contribution of agriculture input varies depending of district from 1.4% in Vladivostok area to 24% in Razdolnaya area input, but does not exceed 4% for the region as a whole (Table 7.1).

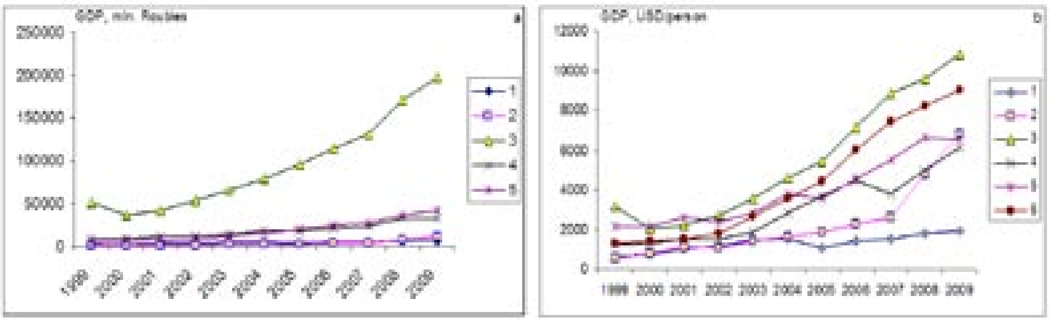

Figure 7.2. The change of the GDP (a) and GDP per capita (b) in the different sub-areas. 1 – Razdolnaya area, 2 – northeastern part, 3 – Vladivostok, 4 – Arteom, 5 – Nakhodka, 6 -Ussuryisk

Service sector employment (service, medicine, education, science, officials) is about 41.5%. At the same time the input of tertiary production accounts for 60% of GDP of the region (Table 7.1). The percentage of people employed in goods manufacture has decreased to 52.5% during last 5 years.

The GDP value of Vladivostok area comprises 61.8% of all GDP (Fig. 7.2a) though Vladivostok population contribution less than 44%. Accordingly the GDP per capita in Vladivostok is maximal (Fig. 7.2b). The lowest GDP per capita is observed within Razdolnaya area where agriculture activity dominates. The trend of GDP per capita for last 10 years shows significant growth, especially in Vladivostok's agglomeration. The growth of GDP is less pronounced for some other sub areas, especially in Razdolnaya area with agricultural specialization (Fig. 7.2b).

The energy production and delivery, machinery, chemicals, timber industry, textiles, construction and food production are the principal fields of the industry activity within Peter the Great Bay watershed. The Artem - Vladivostok sub-area and Nakhodka city are the major food and machinery producers. Districts along the Razdolnaya river ("Razdolnaya area") are the main agricultural areas.

The absolute amount of the wastewaters generated and discharged within the watershed of the Peter the Great Bay decreased from 0.62 bln tons in 1990 to 0.33 bln in 2007 along with the same decrease has been observed last two decades for all Primorye region. The main reason of the wastewaters decrease is fall down of industrial activity in Russia during 90s . The more distinct decline of the fresh water usage during this period confirms it (Fig. 7.3a). The contribution of the Peter the Great Bay watershed to the waste water pool of the region reached up 73% in 1994 and elevated to 82-83% last 5 years according with the population contribution and enhanced economical activity.

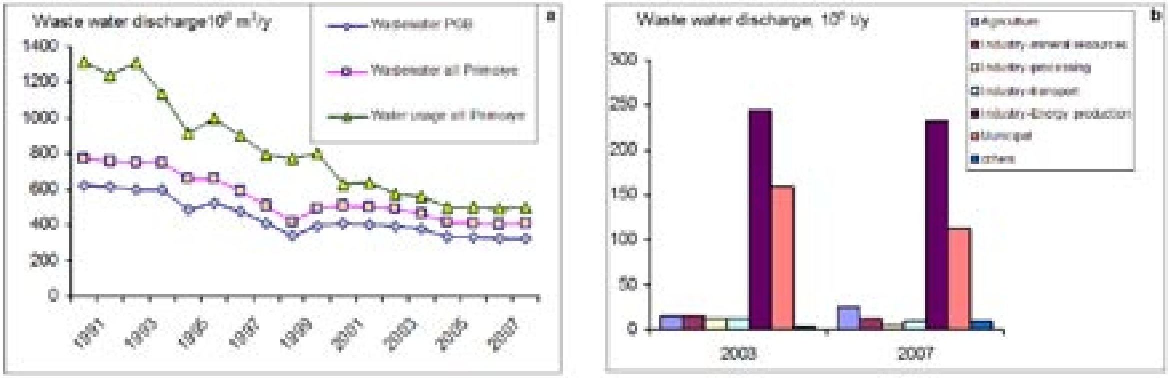

Figure 7.3. The water usage and waste water discharge (10^6 t/y) within Peter the Great Bay watershed and all Primorye region (a), and the contribution of different economical activities to the production and discharge of waste waters (10^6 t/y) in all Primorye region in 2003 and 2007 (b).

This volume of wastewaters looks not so big in the according with relatively low absolute population. But amount of waste waters generated by capita within Peter the Great Bay area was 235-238 tons/person.year that is twice comparing with Korea and China. It means that local hot spots are likely possible within this area despite the not very dense population.

The structure of the waste water pool within Primorye region is characterized by the domination of the industrial waste waters generated at the energy production (Fig. 7.3b). This is rather uncontaminated cooling waters mainly. The contribution of contaminated industrial waste waters generated at the processing enterprises does not exceed 1-3% of all wastewaters. Municipal (domestic) wastewaters are the second major part in the wastewaters pool (28-35%). Municipal (domestic) wastewater runoff in Russia is assessed by water supply data without distinction between night soil and gray water. The annual discharge of domestic wastewater in Primorskii Krai in 2007 was about 0.132 bln. tons, and about 41% of this amount is discharged untreated and 19% is only partially treated. The Vladivostok agglomeration is a major source of the domestic wastewaters discharge. Two new wastewater treatment plants each for 160,000 m^3/day are under construction now in Vladivostok, and it will improve the situation significantly in 2011-2012 when these plants will be on work.

7.2. Environmental problems in the coastal zone, including rivers and coastal sea areas

7.2.1 Chemical pollution and temporal changes in composition of river runoff

The chemical composition of the river waters is controlled by natural factors like climate, relief, vegetation, and lithology, and by socio-economic drivers, such as population, urbanization, industrialization, and water management. In many regions the river chemistry is more controlled by anthropogenic press than by natural drivers. The negative alteration of water quality is one of the best studied consequences of anthropogenic press.

Among problems of the water quality caused by economic activities, it is possible to allocate several most important: 1) salinization due to industrial/mining wastewaters and poor irrigation practice; 2) acidification due to acid rains influence on the rivers with small buffering capacity; 3) eutrophication due to excessive inputs of nutrients (N, P, Si, C) which leads to enhanced plankton production, consumption of oxygen, hypoxia and degradation of water ecosystem; 2) receiving of potentially toxic chemical compounds like heavy metals, pesticides, phenols, surfactants which can render negative influence on biota and reduce quality of water as resource; and 3) changes of a chemical composition of water, caused by alteration of physical characteristics of water systems (construction of water reservoirs and dams).

All these problems are worldwide, but have different significance within different regions and sub-regions. For the rivers of the Peter the Great Bay watershed the excessive inputs of nutrients and potentially toxic chemical substances are the most important environmental issues. The salinization of the fresh waters i.e. increases of mineralization takes place as well. Even initial stages of salinization are very indicative and useful for the assessment of the anthropogenic press, but observed increase of salt contents does not deteriorate the water quality significantly. All river waters at the Peter the Great watershed outside direct sea influence have mineralization less than 200 mg/l.

The recent situation with chemical parameters reflecting fresh water quality at the Peter the Great Bay watershed is presented in Table 7.2.

Chemical oxygen demand (COD) parameter in many Russian rivers is significantly higher than in Japanese rivers and even in Korean ones. COD reflects the amount of substances (organic mainly) could be oxidized by chemicals ($KMnO_4$ or $K_2Cr_2O_7$). The use of stronger oxidant $K_2Cr_2O_7$ for the determination of COD in Russia is a first reason of difference. Among Russian rivers the low COD is observed in the most pristine small mountainous streams of southwestern subarea. The high COD exceeding MPC (maximum permissible concentration) take place in Razdolnaya River and severely polluted streams like Knevichanka river, draining Arteom city and inputting to the low reach of Arteomovka river (Table 7.2)

Biological oxygen demand (BOD_5) values exceed MPC 2 mg/l in all rivers draining moderately populated and economically developed watersheds, namely in Razdolnaya and Knevichanka (tributary of Arteomovka). The only exception is down stream of the Tumen River with rather low BOD but with elevated COD that exceeds MPC 15 mg/l. The enlarged COD was observed also in the rivers Razdolnaya and Knevichanka where clear pollution by BOD_5 took place.

NH_4 and NO_2 as well as PO_4 ions in river water equal or exceed MPC in the most anthropogenically loaded Razdolnaya and Knevichanka rivers only. At the same time there is distinct difference between rivers by NH_4 and PO_4 contents reflecting the level of the anthropogenic load. Down stream of the Tumen River in China, NH_4 content is also elevated, but near the Tumen River mouth in Russia NH_4 decreases while NO_3 increase due to natural oxidation and biological uptake.

Phenol and oil (petroleum hydrocarbons – PHs) concentrations exceed MPC in the most anthropogenically loaded rivers like Razdolnaya and Knevichanka, though MPC for phenol in Russia is nearly equal to MDL and improvement of the method used for the determination of phenol is needed.

Table 7.2 Some chemical characteristic (mg/l) of major rivers at the Peter the Great watershed (2001-2007 averaged data)

River	COD_{Cr}	BOD_5	$N_{NH4}+$	$N_{NO3}-$	P_{PO4}^{3-}	PHs	v-phenols	SS
Tumen	18.8	1.93	0.24	0.63	0.017	0.02	0.003	86.5
Rivers of south – western part*	3.4	1.5	0.08	0.20	0.003	0.02	0.001	6.0
Razdolnaya	21.2	11.6	0.87	0.20	0.071	0.11	0.003	29.2
Knevichanka	26.1	6.1	2.25	0.22	0.24	0.06	0.002	29.9
Artemovka	10.7	2.14	0.14	0.09	0.010	0.05	0.001	9.6
Partizanskaya	10.8	2.53	0.05	0.12	0.009	0.05	0.0003	12.1
MPC	**15.0**	**2.0**	**0.40**	**9.1**	**0.05**	**0.05**	**0.001**	**-**

* - Tsukanovka, Brusya, Narva, Barabashevka, Amba; Nutrients are determined in the filtered (0.45 mkm)

Dissolved oxygen (DO) and pH (not shown) of river inputting to Peter the Great Bay do not indicate any deterioration in water quality.

The concentrations of chlorine organic pesticides DDTs (sum of DDT and its metabolites DDD and DDE) were less than 35 ng/l, and HCHs (sum of hexachlorcyclohexan isomers: Eldrin etc.) were less than 4 ng/l in the rivers studied.

The observation on the down reach of Tumen River are carried out by China specialists (40 km up stream of river mouth), and Russia specialists (15 km up stream of river mouth) as well. Taking in mind differences in sampling places and methods, data for down stream reaches of the Tumen River gathered by Russia and China show good concordance.

The use of trace metal (heavy metal) concentrations for water quality assessment as part of routine monitoring procedures in Russia meets with the same problems as encountered in other countries. The main reasons are analytical problems in obtaining reliable “contamination-free” results and the need to use filtered samples for analysis given an affinity of most metals to suspended particles. Analytical monitoring procedures in China, Japan and Korea are, as a rule, carried out with unfiltered samples. At the same time, the usefulness of metal concentrations in rivers for assessing anthropogenic influence on the surface waters is obvious.

Existing reliable data on dissolved forms of some metals in Russian rivers within the NOWPAP region are presented in Table 7.3. These data have been borrowed from the published scientific research of Pacific Geographical Institute RAS (Shulkin et al., 2007, Shulkin et al., 2009).

The concentrations of most potentially hazardous dissolved forms for heavy metals Cd and Pb are far below MPC as well as for Zn and Ni. The dissolved Cu concentration exceeds MPC 1 μg/l (0.001 mg/l) in many rivers, but is explained by unsupportable low MPC established for exclusively ionic dissolved forms of Cu, though in natural water the major part of dissolved Cu is presented by less toxic organic complexes.

Dissolved Mn and Fe are not very toxic, but in some rivers concentrations of these metals exceed MPC. This is explained by prevalence of colloidal forms for Fe and mobilization from swampy and/or polluted landscapes for Mn.

Inter annual change of chemical composition of Russian rivers inputting to the Peter the Great Bay is different for different parameters (Fig. 7.4, 7.5). The suspended solids and COD do not demonstrate any clear trend except the continuously elevated COD in the polluted rivers. The high COD values in the Russian rivers compare with lower COD in the rivers of other NOWPAP countries are explained partly by the use in Russia more strong oxidative at the COD determination.

Table 7.3. Concentration of dissolved forms of metals in rivers inputting to Peter the Great Bay (2001-2007 averaged data).

Rivers	n	Pb d (μg/l)	Cu d (μg/l)	Mn d (μg/l)	Fe d (μg/l)	Cd d (μg/l)	Zn d (μg/l)	Ni d (μg/l)
Tumen	13	0.166	**1.57**	**97.7**	81.5	0.022	0.93	0.72
Southwestern rivers*	41	0.026	0.46	5.1	22.1	0.005	0.39	0.31
Razdolnaya	23	0.061	**1.05**	**54.8**	82.2	0.006	1.03	0.84
Artemovka	2	0.058	0.43	**27.2**	**145.1**	0.005	0.51	0.57
Shkotovka	9	0.053	0.38	8.1	20.2	0.002	0.41	0.27
Partizanskaya	8	0.019	0.50	**25.4**	38.4	0.003	1.11	0.53
MPC		***6***	***1***	***10***	***100***	***5***	***10***	***10***

The BOD shows distinct decrease trend in the rather polluted Razdolnaya River, but in other polluted stream – Knevichanka River BOD increase 1.5-2 times last years. Less polluted rivers do not show any clear trend for BOD (Fig. 7.4).

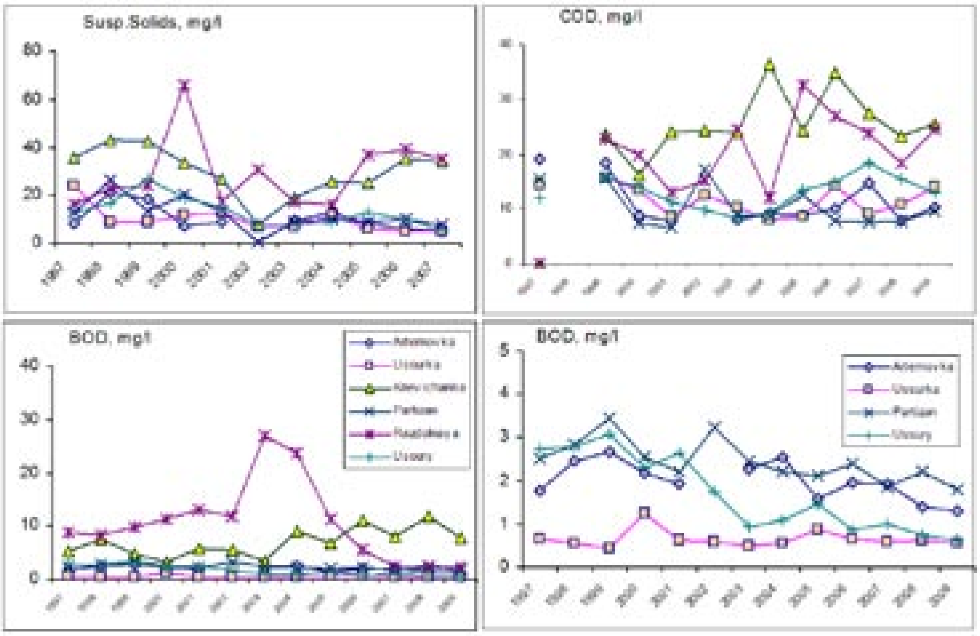

Figure 7.4. Annually averaged concentration of suspended solids, COD and BOD in the Artemovka and Razdolnaya rivers of the Peter the Great Bay basin, and two big rivers of the Amur River basin: Ussury and Ussurka.

Annual means of phosphate show trend of increase during last 5-6 years in the polluted rivers, and that is more important, in the less contaminated ones (Fig. 7.5c, 7.5d). Increased level in the pristine Russian rivers continue to be lower than in many Korean and Japanese rivers, but trend itself is alerted. The somewhat similar trend of rising is observed for the concentration of ammonia nitrogen and DIN (sum of ammonia and nitrate nitrogen) in the contaminated Razdolnaya and polluted

Knevichanka rivers at least, but in the more clean rivers there was stabilization or even decrease of ammonia nitrogen and DIN concentration last 5-6 years (Fig. 7.5).

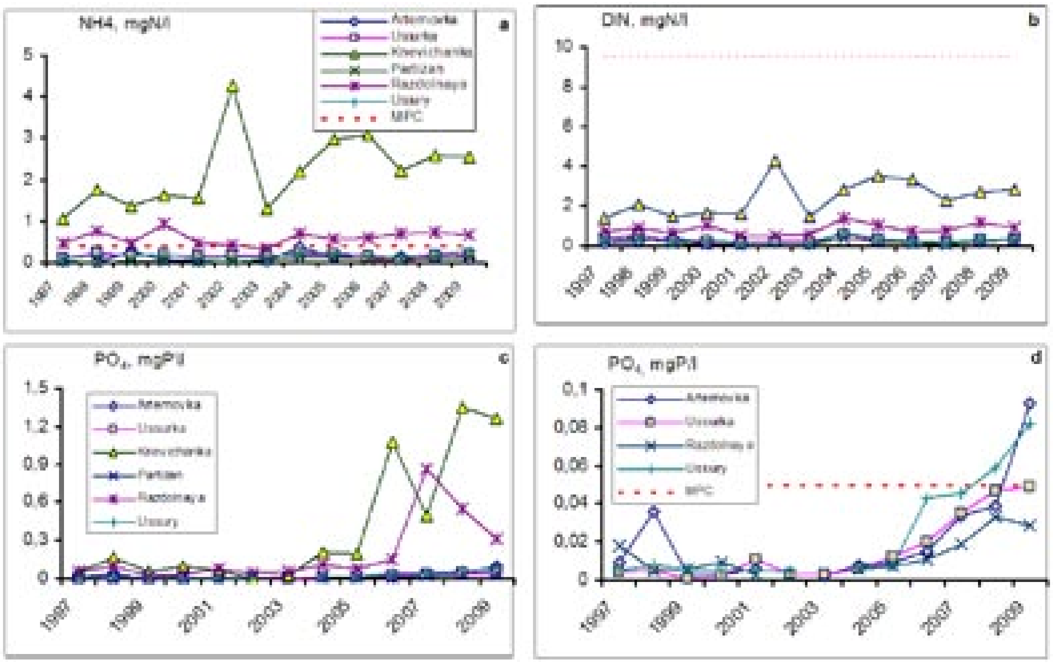

Figure 7.5. Annually averaged concentration of ammonia nitrogen (a), dissolved inorganic nitrogen (b) and phosphate (c, d) in the Artemovka and Razdolnaya rivers of the Peter the Great Bay basin, and two big rivers of the Amur River basin: Ussury and Ussurka.

The most extended and reliable time series (more than 30 years) of the chemical composition is available for the Razdolnaya River. This river provides 47% of the summary accounted river discharge to the Peter the Great Bay, and drains the most populated part of the watershed.

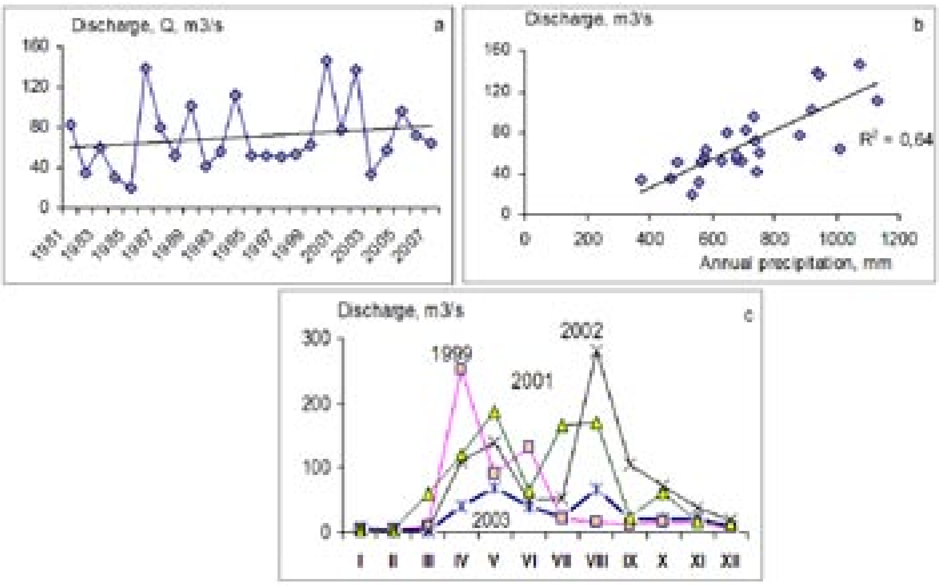

Figure 7.6. The time series of annual average of water discharge (a), relationship between annual average discharge and precipitation (b) for the Razdolnaya River for the last 30 years, and seasonal average discharge for the years with different wateriness (c).

The analysis of hydrological time series for Razdolnaya River (Fig. 7.6a) has shown following features:

1. Inter annual variations of river discharge reach up 6-7 times, and are controlled by 2-3 times inter annual variations of atmospheric precipitation. There is significant correlation between annually averaged discharge and precipitation;
2. Seasonal variations of monthly discharge for April-November period vary from 2-3 times at the "dry" years to the 10-15 times at the years with plenty of rains. The discharge is stable and extremely low during the winter when river is covered by ice;
3. Seasonal variations of rains amount for the warm period (April-November), when 90% of precipitation takes place, reach up 18-25 times;
4. There is no correlation between monthly averaged water discharge and monthly averaged amount of precipitation regardless the season. It is obviously for winter, but points out the complicated relationships between river discharge and atmospheric precipitation for summer period.
5. We do not observe any significant trends in Razdolnaya River discharge and atmospheric precipitation amount for the last 30 years.

The last feature allows looking at the time series of chemical characteristics of Razdolnaya River as a proxy for the assessment of chemical pollution of river waters during last 30 years.

The analysis of the reliable time series of the chemical characteristics at the down stream of Razdolnaya River has shown:

1. The inter annual variability of the annually averaged mineralization of river water reaches up 2-2.5 times without distinct trend.
2. The annually averaged COD and BOD parameters have significant inter annual variability, but there is some trend of COD decrease and BOD rise during last 25 years (Fig. 7.7). It means increase trend of easy oxidizable organic substances in the river run off. The period after 2004 is exception due to construction of wastewater treatment plant near Ussuryisk city. The operation of treatment plant has led to the decrease of BOD in the river receiving the effluents.

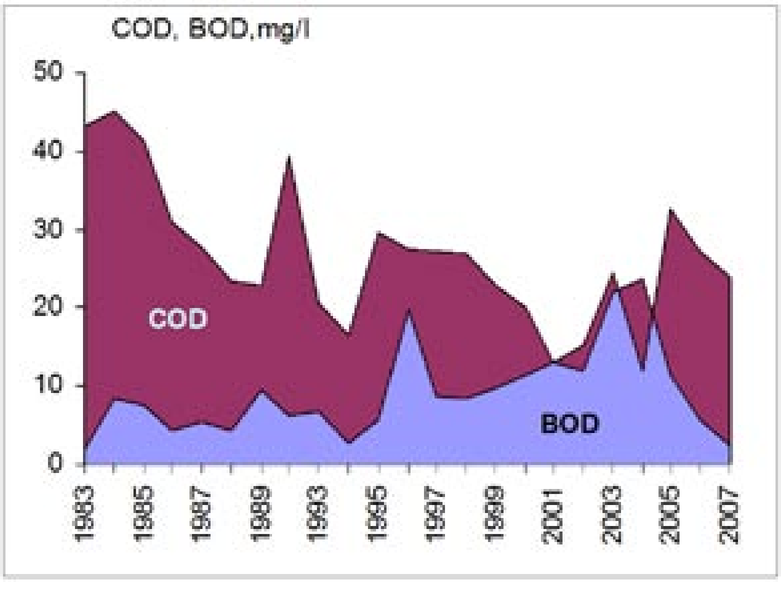

Figure 7.7. The inter annual variability of COD and BOD at the down stream of Razdolnaya river during last 25 years.

7.2.2. Loads of contaminants through rivers and by direct inputs

7.2.2.1 The contribution of rivers, wastewaters and storm waters to the loads of contaminants

Besides river quality issues determined by the concentration of chemical substances, the flux (input) of these substances to the coastal sea is very important as well. First reason is an influence of river input on the sea water quality of the adjacent coastal areas. Another interest to the assessment of river fluxes is appeared when we want to compare the natural inputs with anthropogenic wastewaters, sewages and exhausts generation and discharge. These negative consequences of human activities are expressed as fluxes usually (amount per time unit).

The estimation of river flux of the chemical substances is based on multiplication of water discharge and the concentration of the substance, and subsequent summation on the annual or other time basis. The uncertainties of such estimation have several reasons connected with different reasons. First one is an incomplete observation on the water discharge, and chemical composition of the rivers. For the Peter the Great Bay watershed the volume of non counted river discharge reaches 36% of counted discharge (Table 7.4). This assessment is carried out without taking into account the runoff of the large Tumen river, because the mouth of this river is situated at the south border of the Peter the Great Bay. This is very important area due to location of the State Marine Reserve nearby. Rather intensive studies have been carried out in this area (The State of Environment, v.1, 2, 3, 2001) and have shown that Tumen river runoff can affect on the southwestern corner of the Peter the Great Bay: south of Posyet Bay only (Fig. 3.4). The domination of the southward water currents along the outer border of Peter the Great Bay is a main feasible reason of restricted influence of Tumen river on the Bay. At the same time the watershed square and water discharge of Tuman river are very large, and exceed the watersheds and discharge of all rivers together inputting to the Peter the Great Bay (Table 7.4). The taking Tumen river into account will bias the averaged estimations of river inputs for the Peter the Great Bay from the point of investigation of relationships between river inputs and characteristic of coastal sea waters.

The widespread of the urban territories with special features of fresh water runoff is another peculiarity of the Peter the Great Bay coast, especially within its inner parts. The elevated specific discharge of storm water with increased concentration of pollutants (Gavrilevski et al, 1998) is a typical characteristic of urban area. The outputs of treated and untreated wastewaters even more contaminated are situated within urban territories as well. The storm water and wastewater runoff of the cities situated inland (e.g. Ussuriysk or cities of the Tumen river watershed) is realized and accounted through river runoff. The storm water runoff in Table 7.4 refers to the coastal urban areas only.

The contribution of the non-river input of fresh water to the Peter the Great Bay for the time being does not exceed 5% of the overall runoff by volume. This is provided by urban area which is about 0.7% of watershed land. If urban area will grow up to 3% (in Korea urban areas reach up 5.9% of territory) the contribution of the urban derived water runoff will be 20%.

The concentration of pollutants in the wastewater outputs and especially in the storm waters is very variable, and all assessments are inevitably rather approximate. Such estimates (Gavrilevsky et al., 1998) for Vladivostok area by the chemical parameters often used as water quality indices are presented in Table 7.5. These data coupled with fresh water runoff data (Table 7.4) and information on the chemical composition of river discharge (Table 7.2) allow to evaluate the contribution of rivers, storm waters and wastewaters runoffs to the total input of water and some chemical substances to the Peter the Great Bay (Fig. 7.8).

Table 7.4. The elements of fresh water runoff from the Peter the Great Bay watershed

	Watershed square, km^2	Runoff, km^3/y	Specific discharge, $l/s/km^2$
River runoff			
Tumen River	33200	9.05	8.6
Tsukanovka	170	0.12	10.4
Brusya	160	0.04	12.4
Narva	332	0.13	12.4
Barabashevka	576	0.32	17.6
Amba	242	0.19	13.4
Razdolnaya	16800	2.46	4.6
Artemovka	1460	0.29	3.1
Shkotovka	714	0.22	8.9
Suhodol	443	0.14	10.4
Partizanskaya	4140	1.32	10.1
Accounted watershed*	25037	5.23	6.6
Non counted watershed*	6498	1.89	9.2
All watershed*	31535	7.12	7.2
Storm water runoff			
all urban area	237	0.171**	22.9
Vladivostok only	171	0.055***	10.2
Direct wastewater discharge			
Vladivostok		0.11-0.14****	
Vladivostok		0.41-0.44*****	
Nakhodka		0.02	

* - estimations for Peter The Great Bay as a whole are carried out without Tumen river runoff; ** - assessment based on the atmospheric precipitation without evapotranspiration;
*** - from Gavrilevsky et al., 1998; **** - without sea water cooling the electricity and heat generation stations in Vladivostok; ***** - total discharge of industrial and municipal wastewaters from Vladivostok

Table 7.5. Concentrations (mg/l) of Substances in the Wastewaters and Storm Waters of Vladivostok (Gavrilevski et al., 1998)

	BOD_5	**NH_4**	**PO_4**	**Sufr***	**PHs****	**Phenols**	**SS**
Wastewater	32.6	4.2	1.9	0.11	0.92	0.015	39.2
Storm Water wastes	17.8	3.5	0.25	0.17	1.09	0.011	85.9

*- surfactants (detergents); ** - PHs petroleum hydrocarbons

These assessments are rather rough due to high seasonal and spatial variability of the volume and chemical composition of the end-members. But such estimations show clearly insignificant contribution of storm and wastewaters in terms of water volume input. The contribution of storm and wastewaters increases up to 15% for the degradable organic substances load (BOD), and up to

40-46% for the NH_4^- and petroleum hydrocarbons (PHC). The contribution of storm and especially wastewaters to the phosphorus load exceeds the contribution of river runoff.

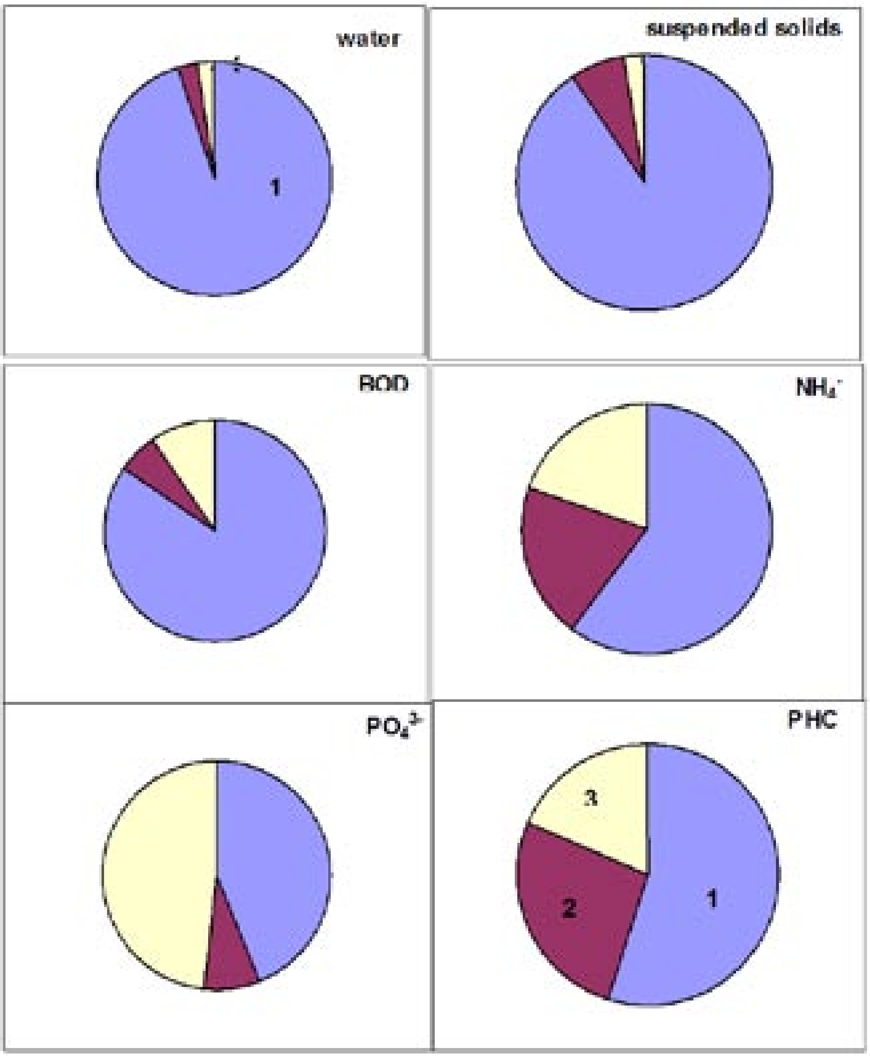

Figure 7.8. The contribution of river runoff (1), storm waters (2) and waste waters (3) for the inputs of water, suspended solids, BOD, ammonia nitrogen, phosphate and petroleum hydrocarbons (PHC) to the Peter the Great Bay area as a whole.

Taking into account the obvious spatial heterogeneity of Peter the Great Bay (Fig. 3.4) there is necessity to carry out similar assessment for the different parts of the Peter the Great Bay.

Amursky Bay, Ussuriysky Bay, northeastern part including Nakhodka Bay with Vostok Bay and adjacent coastal area, and southwestern part of the Peter the Great Bay are the main conventionally recognized 4 subareas. The outer part northward of the Bay sea border is 5th subareas (Fig. 3.4). The space of these sub-areas varies from 921 to 3616 km^2 (Table 3.2). The estimation of the fresh water and contaminant inputs has shown that contribution of river and other sources of contaminants to these subareas vary greatly (Fig. 7.9). At the same time the prevalence of river contribution for water and suspended solids has been observed for all subareas as well as increase of stormwater and wastewater contribution for the inputs of nutrients and pollutants (oil).

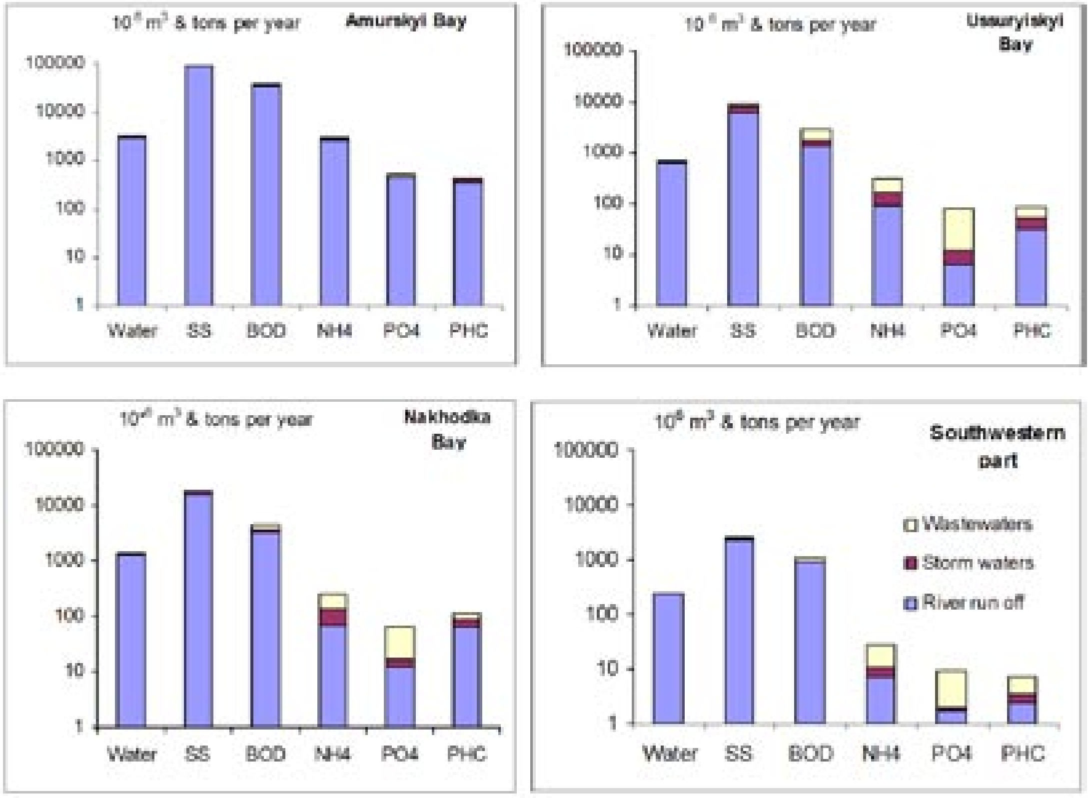

Figure 7.9. The contribution of river runoff (1), storm waters (2) and waste waters (3) inputs of water, suspended solids (SS) and some chemical substances to the different sub-areas of Peter the Great Bay.

There are two nontrivial features reflected on Fig. 7.9. First one is an enhanced anthropogenic wastewater and stormwater contributions of nutrients for the southwestern and northeastern part of Peter the Great Bay, that is for subareas with less pronounced ecological problems. The low background concentration of nutrients in the pristine rivers of these subareas, and relatively small river run off is a reason. And this circumstance makes southwestern and northeastern parts more vulnerable to the excessive inputs of contaminants.

Second feature is an enhanced contribution of wastewaters/stormwaters input of nutrients for the Ussuryisky Bay. The reason is an accounting of the wastewater discharges to the most contaminated Golden Horn Harbor as inputting to the Ussuryisky Bay. There is scientific background for this due to eastward main water flux from Golden Horn Harbor. At the same time the main property of Ussuryisky Bay is rather clean except for southwest coast receiving the wastes and stormwaters from the Vladivostok, and north coast receiving the Artemovka and Shkotovka rivers runoff with associated wastewaters of Artem city. This feature shows the natural heterogeneity of some coastal areas, and inevitable limitation of the usage of the averaged balance estimation to the heterogeneous coastal areas. We can not avoid the averaged balance approach at the assessment of the inputs of the matter from land to sea, because data on the wastewater inputs and other land based sources are presented on the averaged basis mainly. The complementary usage of remote sensing methods for the characteristics of spatial-temporal heterogeneity can help to designate subareas where contribution of different sources of inputs is changed significantly.

7.2.2.2 Dumping of dredged sediments as a source of contaminants

There is no official data on the waste dumping within Russian part of the NOWPAP area. At the same time the dredging operation at the port activities inevitably took place in the past and continues now. Accordingly the dredged sediments are the main component of the dumped wastes in

Russia. The contamination of dredged sediments can lead to the deterioration of the environmental quality at the dumping sites and nearby.

There are three areas within Peter the Great Bay with large scale dredging operation. The southeastern part of Amursky Bay is the locality where dredged sediments from the Vladivostok Harbor have been dumped from 1970 to 1983. The overall volume of dumped sediments during this period was 2,563,000 m3. After that the southwestern part of Ussuriysky Bays was used as a dumping site. The southwestern part of Nakhodka Bay is the place where dredged sediments from the Nakhodka and Vostochniy harbors have dumped.

The detailed study of the dumping in southeastern Amursky Bay has been carried out (Mishukov et al., 2009). There was significant inter annual variability of the dredged sediment dumping in this locality (Table 7.6), but averaged annual input in 1970-1983 period was 214,000 m3, that is 107,000 t (at the sediment density 2 t/m3, and the water content in the dumped pulp 75%). The averaged annual input of suspended solids through Razdolnaya river is 111,136 t. Thus during 1970-1980s the input of suspended solids with dumped sediments and with river discharge was the same order.

Table 7.6 Input of dredged sediments from the Vladivostok Harbor to the Amursky Bay, 103 m3 and 103 t

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1981	1982	1983
Volume	449	319	267	136	160	356	23	141	36	290	42	344
Mass	225	160	134	68	80	178	12	71	18	145	21	172

The contamination of bottom sediments within Vladivostok Harbor (especially inner part of Golden Horn Bight) is very severe (Tkalin et al., 1996, Shulkin, 2004, Naumov, 2006). Concentration of potentially toxic trace metals Pb, Cd, Hg, Zn and Cu exceed the background level 10 times and more. Accordingly the contribution of the dumped sediments to the trace metals input in solid phase to the Amursky Bay ecosystem during the end of last century was higher than river input.

Besides trace metals, the oil pollution is also harmful consequence of the dumping of contaminated dredging sediments to the Amursky Bay (Tkalin, Shapovalov, 1985).

Unfortunately the volume of the dredged sediments dumping in the southwestern part of Ussuriysky Bay was not assessed. We can assume that during 90th the activity of dredging decreased due to economic depression. But according to the model computation (Mishukov et al., 2009) even 10,000 m3 of dumped sediments in this locality will lead to the significant increase of suspended solids and pollutants contents at the coastal waters near Russkiy Is.

The third main place of the dumping in the Peter the Great Bay is a locality near Lisiy Is. in Nakhodka Bay. The volume of the sediments dumped here during last 30 years could be assessed in 2,500,000 m3 by the change of the underwater relief (Preobrazhensky, pers.com.). Besides regular dredging of the Nakhodka and Vostochniy ports area, the large scale dredging took place here for the construction of the offshore drilling platform in the artificial pool within Vostochniy Port. The volume of dredged sediments here reached up 1,000,000 m3. The dynamic of the dumping is unknown, and assuming the even input, the averaged annual volume of dumped sediments would be about 80,000 m3, that is 40,000 t. The annual solid discharge of Partizanskaya River – the biggest river inputting to the Nakhodka Bay varies from 10,600 to 35,760 tons. Thus in the eastern part of the Peter the Great Bay the input of suspended solids with river runoff and with dumped sediments are the same order, and latter could not be ignored. Fortunately unlike western part of the Peter the Great Bay the contamination of bottom sediments is not so severe in the Nakhodka Bay.

Thus the dumping of dredged sediments in the west part of Nakhodka Bay and especially in the southeast part of Amursky Bay during the last 30 years could be comparable with the solid matter discharge of the Partizanskaya and Razdolnaya rivers respectively. The severe contamination of the sediments dumped in the Amursky Bay made them the major source of trace metals and oil pollution of the bottom sediments within southeast part of Amursky Bay.

7.2.3. Degradation, changes and loss of coastal habitats

Degradation, changes and loss of coastal habitats can be occurred due to natural, natural, but induced by anthropogenic, and direct anthropogenic reasons. The decrease of the suspended solids (sediments) discharge of the rivers due to dam construction and consequent erosion of coastal areas is an example of such complex natural/anthropogenic processes. The reclamation of shore line and nearby coastal areas for the port facilities construction is an example of the direct anthropogenic reason. The construction of berths and shipyards is inevitably accompanied by the elimination of coastal habitats. The physical destruction of the bottom habitats takes place due to siltation at dumping of dredged sediments, or at the dredging itself. The improper fishing practice (trawling) and sand/gravel extraction are the next examples of anthropogenic activities in the coastal waters leading to the physical destruction of habitats.

The physical destruction of habitats along with necessity to manage municipal wastewaters, nutrient over-enrichment, and marine litter has been noted as the problems for the priority actions by GPA (UNEP/GPA, 2006). Physical alteration and destruction of coastal ecosystems has continued to increase as a direct result of population growth and associated growth in economic and development activities, in particular those associated with infrastructure and tourism. Average population density in the coastal zone worldwide increased from 77 persons/ km^2 in 1990 to 87 p/km^2 in 2000. The forecast is 99 p/km^2 in 2010, 115 p/km^2 in 2025 and 134 p/km^2 in 2050 (www.gpa.unep.org/padg). This growth has a clear bearing on the amount of physical alterations and consequent destruction of coastal areas. Coastal ecosystems and habitats, particularly wetlands, are fast disappearing; this in turn affects biota, with negative consequences for bio-diversity and food supplies. While deterioration is worst in regions with the fastest rates of population growth, no area is spared. An emerging factor is the growing incidence of catastrophic natural events, sometimes exacerbated by previous weakening of nature al systems brought about by human action.

The significance at the regional scale of the habitat degradation due to anthropogenic influence is proportional to the population, and Russian Far East with average population density 12 persons per square kilometers has low level of these problems compare with highly populated areas of Korea, Japan or northeastern Chinese provinces. For example the length of the port facilities within Peter the Great Bay does not exceed 16.6 km (6.2 km for Vladivostok; 5,8 km for Nakhodka; 3.5 km for Vostochny; 1.1 km for Posyet and Zarubino), that is less than 0.01% of the mainland shore line. But habitat destruction problem can be very significant at the local scale. For example, Vladivostok and Nakhodka seaports are characterized by much stressed ecological conditions, but this is a consequence of improper treatment of wastewaters, not the port operation itself. The Vostochny Port is a major seaport of Peter the Great Bay with cargo 15-16 million tons, has properly operating wastewater treatment facilities and gives an example of coexistence the rather intensive port activity and well-being of habitats just near the port facilities (Gulbin et al., 2005). There are lots of similar good examples in the more ecologically advanced countries like Sweden, Norway, USA, Japan, ROK. At the same time it is clear that each coastal area especially semi-enclosed one has some limit on the port facilities construction, even at the properly operated waste and wastewaters treatment. The most damaging actions are: changes in land use, including draining wetlands for use in agriculture or settlements, building dams, ports, seawalls and aquaculture installations as well. The most important effects are imbalances in ecosystems, complete habitat destruction and damages to wildlife and fisheries.

7.2.4. Pollution of the marine ecosystems

Pollution of the marine ecosystems is understood usually as an increase of concentration of some chemical substances in the different ecosystem components (water, suspended solids, biota, bottom sediments). Though for some chemical parameters (e.g. dissolved oxygen) the decrease is a sign of pollution.

The assessment of the long term (years to decades) change of concentrations of contaminants in coastal waters is complicated due to continuous improvement and change of the sampling and analytical procedures, and therefore incompatibility of the data existing. The nutrients with unified analytical methods during last 50-60 years are the only exception. For other contaminants: trace metals, persistence organic pollutants (POPs) and petroleum hydrocarbons we can carry out at the best case the assessment of the present contamination level of the water and biota.

The determination of contaminant concentrations in the tissues of marine organisms for the evaluation of ecosystem pollution has some advantages. The relatively high concentration is one of them. An important advantage underlying biomonitoring is that contaminant concentrations in the organisms are directly proportional to the bioavailable concentrations in the environment (water or sediments). Besides, the use of rather long lived organisms provides integrative measure of the ecotoxicologically significant fraction of contaminants. Mollusks and macroalgae are the most often used as biomonitors of metals and POPs contamination in many coastal waters. These organisms are abundant in coastal and estuarine systems and can be relatively easily collected for chemical analysis.

Analysis of bottom sediments gives the most integrative measure of the ecosystem contamination. Moreover the distribution of contaminants across the upper layer of sediments at their undisturbed deposition allows assessing the history aspects of pollution. The use of sediments has own limitations: the concentration of contaminants depends, amongst other factors, on rates of deposition and the nature of particles and does not reflect bioavailability.

Therefore the comprehensive assessment of the contamination of coastal areas requests the use of different ecosystem components.

7.2.4.1. The contamination of the water of the Peter the Great Bay by the trace metals.

Concentrations of dissolved and suspended forms of many trace metals (Fe, Mn, Zn, Cu, Pb, Cd, Ni) in the rivers, streams and wastewater outputs inputting to the Peter the Great Bay are much higher than in the sea water (Table 7.3). As a result the increase of concentration of these metals in the adjacent sea waters takes place. The scale of this increase is determined by the fresh water discharge and therefore is a subject of significant seasonal variability. The distribution of salinity is a key parameter for the determination of riverine influence. Moreover sorption on particles and uptake of dissolved forms by plankton, and sedimentation of suspended forms of metals lead to accelerated metals scavenging from sea water. From other side, desorption at the salinity increase, and flux from the reduced or contaminated bottom sediments are accompanied by the additional input of dissolved metals. The input of metals with atmospheric deposition could not be ignored in some cases as well. The overall decrease of the metals in sea waters compare with riverine ones means that scavenging prevails. The detailed researches are needed for the investigation of trace metals distribution in each selected sub areas of Peter the Great Bay. Moreover the evaluation of the degree of contamination in any sea area by water analysis has a number of disadvantages. The low concentration of trace metals in seawater increases the risk of contamination during handling of samples and makes necessary the use of complicated analytical techniques. There is also a high degree of variability in the levels of trace metal in coastal areas, and therefore a large number of samples must be collected to obtain reliable results. The averaged level of trace metal concentrations in some parts of Peter the Great

Bay is the best result for the time being (Table 7.7). It is obviously that observed concentrations of dissolved trace metals, especially most potentially toxic Cd, Pb, Cu are far below maximum permissible level (MPC).

Table 7.7. Concentration (µg/l) of dissolved metals in the Peter the Great Bay sub-areas

Sub area	Fe	Mn	Zn	Cu	Pb	Cd	Ni
Southwestern part	-	-	0.08-0.48	0.20-0.32	0.02-0.03	0.02-0.03	-
Outer part of Amursky Bay	1.1	1.4	0.2	0.2	0.01	0.01	0.2
Inner part of Amursky Bay	3.5 - 21.6	4.5 – 41.7	0.8	1.2	0.2	0.04	0.6
Inner part of Ussuryisky Bay	2.5	3.8-10.5	0.5- 1.85	0.8- 2.7	0.2-0.96	0.03-0.13	0.5
Vostok Bay	1.7	2.2	0.2	0.2-0.3	0.004-0.01	0.01-0.02	0.2-0.4
Nakhodka Bay, west part	-	-	0.04-0.52	0.32-1.17	0.03-0.11	0.002-0.04	-
Nakhodka Bay, east part	-	-	0.15-0.22	0.19-0.23	0.06-0.10	0.009-0.013	-
MPC	**50**	**50**	**50**	**5**	**10**	**5**	**50**

Source: Shulkin, 2004.

5.2.4.2. The variability of the nutrients concentrations in the Peter the Great Bay

There are 2 major sources of information on the nutrients concentrations in Peter the Great Bay. First one is data base obtained by regional branch of ROSHYDROMET mainly. These data joined with some data of TINRO were compiled as united data base and analyzed by (Luchin et al., 2005).

This data base includes 25,062 oceanographic stations for 1925-2001 period. The data are distributed by 10`x10` squares and grouped for 5 sub-areas, namely Amursky Bay, Ussuryisky Bay, Posyet Bay, Nakhodka-Vostok Bay and open part, that is pretty close to the division used in this overview. There are reliable data sets for such parameters as temperature, salinity, phosphates and silicates. The data are analyzed as multiyear averaged charts for the depth 0, 20, 30 and 50 m.

The salinity distribution is rather stable and reasonable, and shows clearly the maximum fresh water input in July-August, and maximum influence of fresh water input on the surface layer. Compare the different sub-areas by the influence of fresh water, the following order by increase could be noted: open part-Posyet Bay-Ussuryisky Bay-Nakhodka Bay-Amursky Bay (Fig. 7.10). The seasonal changes of salinity are significant within surface layer only. At the 10 m and below the salinity variations do not exceed 0.5-1.0‰ at the different sub-areas of Peter the Great Bay.

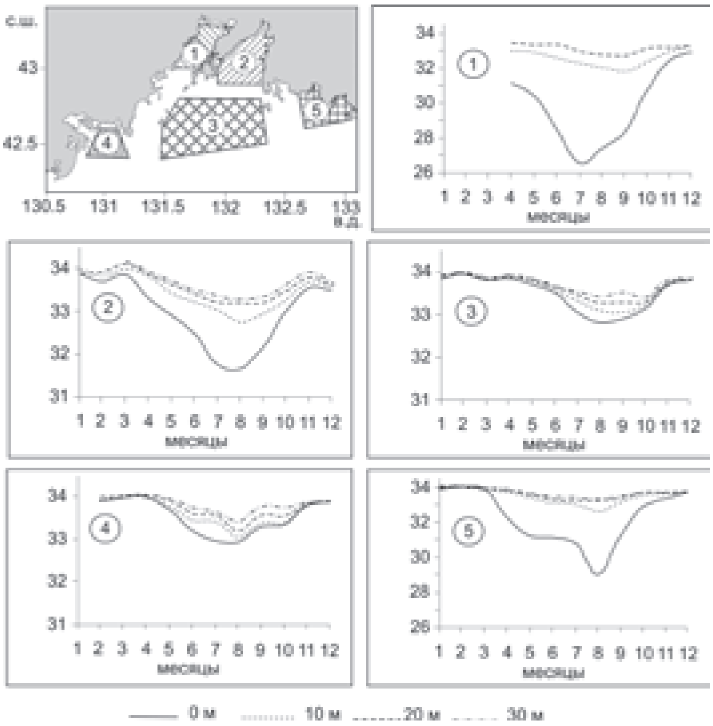

Figure 7.10. The seasonal variability of salinity (‰) in the different sub-areas of Peter the Great Bay (from Luchin et al., 2005).

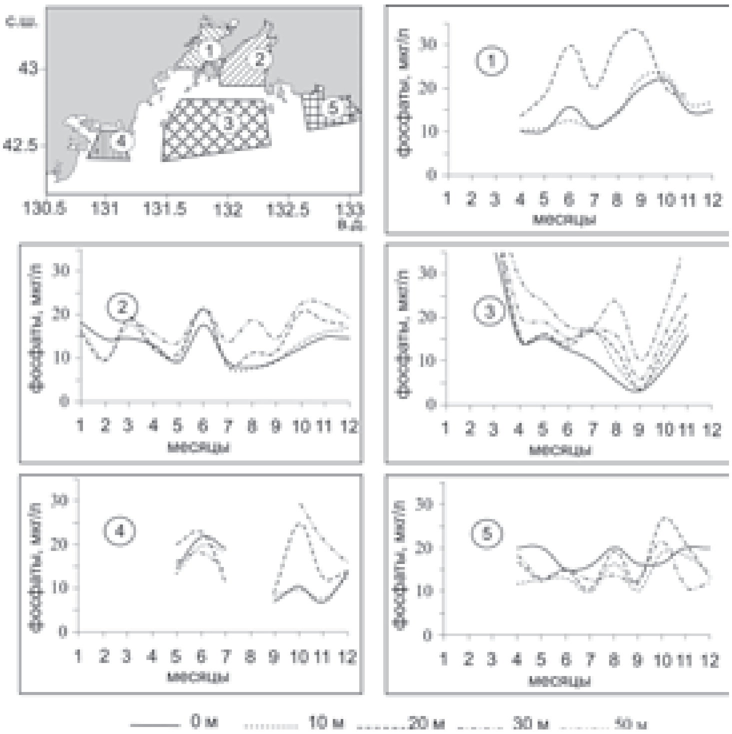

Figure 7.11. The seasonal variability of phosphate (ugP/l) in the different sub-areas of Peter the Great Bay (from Luchin et al., 2005).

The most distinct feature of the phosphate distribution in Peter the Great Bay is enhanced and more variable concentration in the bottom waters than in surface ones (Fig. 7.11). The significant increase of phosphates during warm season takes place in the Amursky Bay only which is under maximal river influence. Contrariwise in the most open outer part of the Peter the Great Bay the maximum phosphate concentration is observed during winter season, reflecting the open sea source of phosphate for this sub-area.

7.2.4.3. The contamination of the biota of the Peter the Great Bay by the trace metals and POPs.

The difficulties of the obtaining reliable information on the concentration of trace metals and POPs in the water led to the search of parameters which could be a suitable proxy of environmental pollution by these substances. The concentration of the metals and POPs in the some species of water organisms and plants are used successfully for this purpose more than 30 years. Moreover the accumulation of contaminants in the organisms reflects the ecological significance of the elevated concentration of contaminants in the environment.

The sedentary long-lived mussels *C. grayanus* and oysters *C. gigas* are the most studied mollusks in Peter the Great Bay in terms of their chemical composition (Shulkin et al., 2003, Tkalin et al., 1997).

The comparison of metal concentrations in mussels and oysters with those in ambient sediments has been made because some fraction of the sediment-bound metals should be available to suspension feeding mollusks. Significant increases in Cd, Cu and Zn in *C. grayanus* were found at the concentrations of easily leachable metals in ambient sediments higher than 2, 100, and 800 ug/g, respectively. This corresponds to bulk concentrations of 2.2–3.2, 145–180, and 1200–1400 ug/g for Cd, Cu, and Zn, respectively. Therefore, mussels could be used as bioindicator of metal contamination for heavily polluted habitats. Fortunately there are only few such localities within Peter the Great Bay: Vladivostok and Nakhodka harbors, and some points at the west coast of Ussuryiskyi Bay. Pb was accumulated by mussels without a distinct threshold in the easily leachable Pb contamination of sediments. Regulation of metal accumulation puts limitations on the use of *C. grayanus* for monitoring habitats with slightly or moderately contaminated sediments.

The oyster *C. gigas* showed definite accumulation of all metals, except Ni, with moderate contamination of ambient sediments. With a further increase of Zn, Pb and Cu concentrations in sediments, concentrations of these metals in oysters increased slowly, and seemed to reach saturation, probably due to physiological control. Thus, the mussel *C. grayanus* should be used mainly for monitoring of heavy contaminated localities, and oyster *C. gigas* is more suitable as an indicator of initial or moderate contamination (Shulkin et al., 2003).

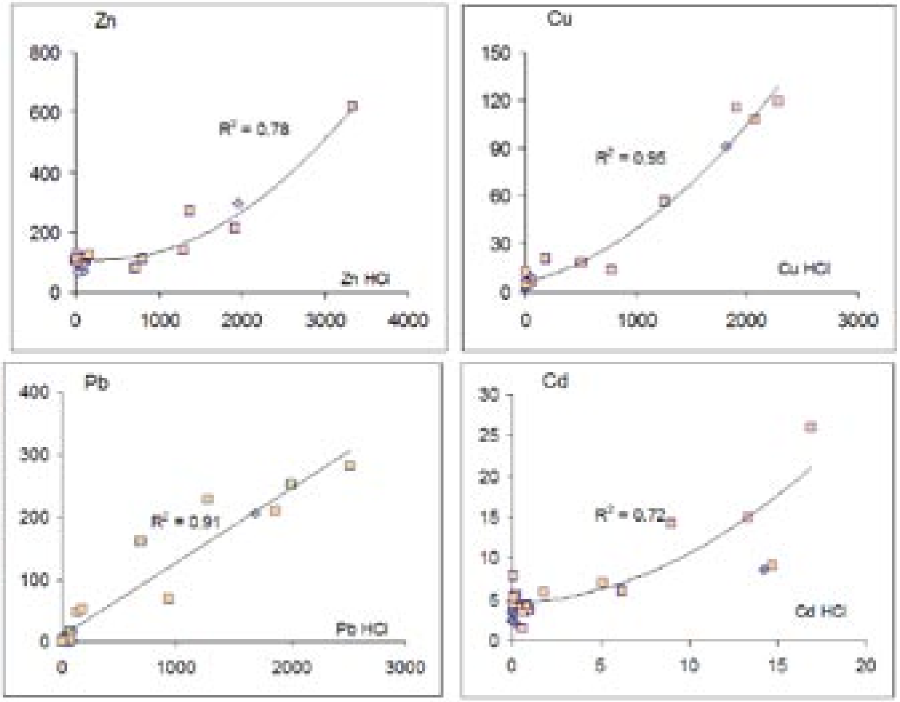

Figure 7.12. The relationships between metal concentration in the mussel tissues (ug/g, ordinate axis) and acid-leachable forms of metals in the ambient sediments (ug/g, abscissa)

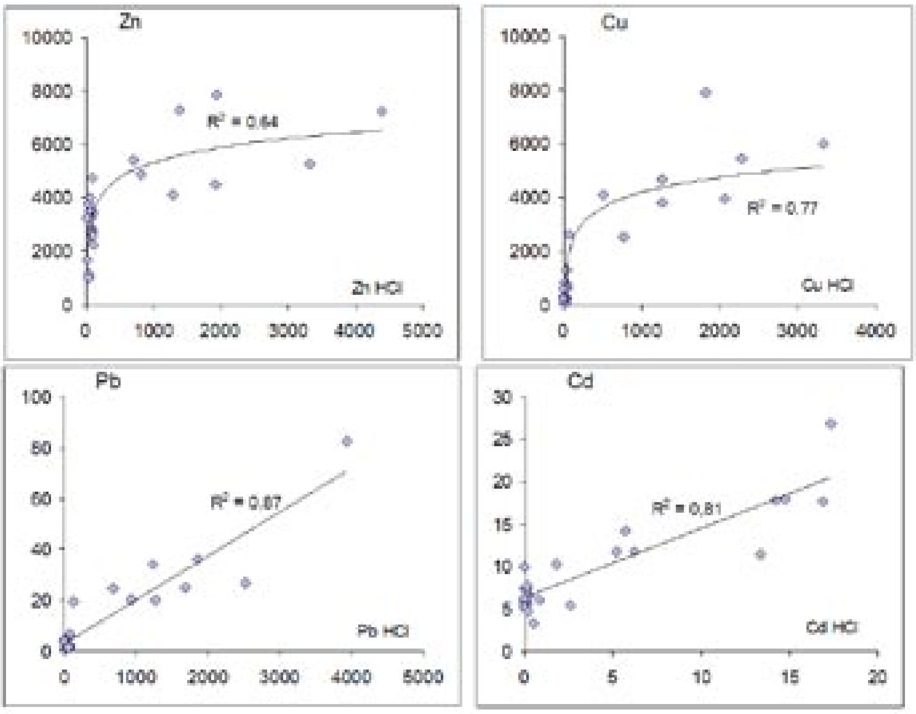

Figure 7.13. The relationships between metal concentration in the oyster tissues (ug/g, ordinate axis) and acid-leachable forms of metals in the ambient sediments (ug/g, abscissa).

Some species of macro algae have been studied and used successfully as indicator of additional metal inputs to the some coastal areas Peter the Great Bay. Namely *Sargassum spp*. from the east coast of Amursky Bay with distinct anthropogenic press have Zn and Pb contents 2-10 times higher than algae sampled from the southwest coast of the bay (Khristoforova, Kozhenkova, 2002).

Within southwestern part of Peter the Great Bay the significant (2-4 times) increase of Fe, Mn and Cu has been observed in the brown algae (*C. costata, L. japonica* and *S. pallidum*) around Furugelm Is. compare with localities near Big Pelis Is. due to the influence of Tumen River runoff. Moreover the 1.5-2.0 times increase of Zn, Cd and Ni in the same algae was obtained during the period 1987-1996 attributing to the increase of anthropogenic press from different sources (Kozhenkova, Khristoforova, 2001).

The contamination of the water organisms living in Peter the Great Bay by persistent organic pollutants (POPs) has been studied sporadically. The data on such POPs as organotin compounds, dioxins, PBDE are practically absent. There are some data on DDTs and HCHs isomers in mussels, and scallops. These results demonstrated (Tkalin et al., 1997) that the concentrations of both DDTs and HCHs in mussels were quite high at some locations (up to 37.6 and 15.9 ng/g dry weight, respectively). Elevated concentrations of DDTs were found in mussels around the Muravyev-Amursky peninsula where Vladivostok city is situated with maximum (2-3 times) in mussels from the south end of peninsula. The DDTs concentrations in mussels sampled southward near the Reineke Is. is similar to values registered in the rather clean US coastal zone within the National Status and Trends (NS&T) Program (Tkalin et al., 1997).

The concentration of DDTs and HCHs in the marine organisms from some enclosed bights of southwestern part of Peter the Great Bay has reached up 446 and 170 ng/g, respectively (Lukyanova et al., 2006) showing the significant pollution similar to the Baltic Sea and some polluted coastal areas of Yellow Sea (Kim et al., 2002). It is clear that many research in Peter the Great Bay should be done for the clarification the status and trends of the organisms contamination by POPs.

7.2.4.4. The contamination of the bottom sediments of Peter the Great Bay by the trace metals and POPs as integrative indicator of pollution in present and in the past.

The bottom sediments are one of the most often used ecosystem component for the assessment of the coastal areas contamination. The high integrative capability and relatively simple sampling and analysis techniques are the major advantages using recent sediments for the evaluation of ongoing pollution. But the most prominent peculiarity of bottom sediments is their potential to reflect and to save the contamination level of the past in the chemical composition of the down layers of the sediment cores. Of course, the sedimentation should be undisturbed, or disturbance degree should be known. Correct use of sediments for the assessment of ecosystem contamination needs taking into account the natural heterogeneity of chemical composition of sediments due to variations of grain size and mineralogical features.

The contamination of recent sediments within Peter the Great Bay by trace metals has been assessed by some surveys during last 30 years (Anikiev et al., 1993, Polyakov, 2008, Aksentov, 2008). The contamination of bottom sediments by some POPs (DDT and HCH isomers) was studied as well (Tkalin et al., 2000). The Amursky Bay and west part of Ussryisky Bay are the most investigated areas.

It was found the elevated concentrations of some trace metals (Zn, Pb, Cu, Cd, Hg) in the bottom sediments of eastern part of Amursky Bay and western part of Ussuryisky Bay, that is around the Muravyev-Amursky peninsula where Vladivostok city is situated. The maximum concentrations were observed in the middle of the west coast of Ussuryisky Bay, where city landfill was located. Sediments of the Golden Horn Bight and other small inlets at the south pert of peninsula are also severe polluted. At the same time the sediments of northwestern coast of Ussuryisky Bay have near background concentrations of metals as well as sediments of northeastern and south parts of Amursky Bay.

To assess the anthropogenic contribution in the metal content in bottom sediments some normalization procedures are used. The normalization against Fe (or Sc) allows taking into account the variability of metal concentrations in sediments due to grain size variations. Such relationships for the Amursky Bay are presented on Fig. 7.14.

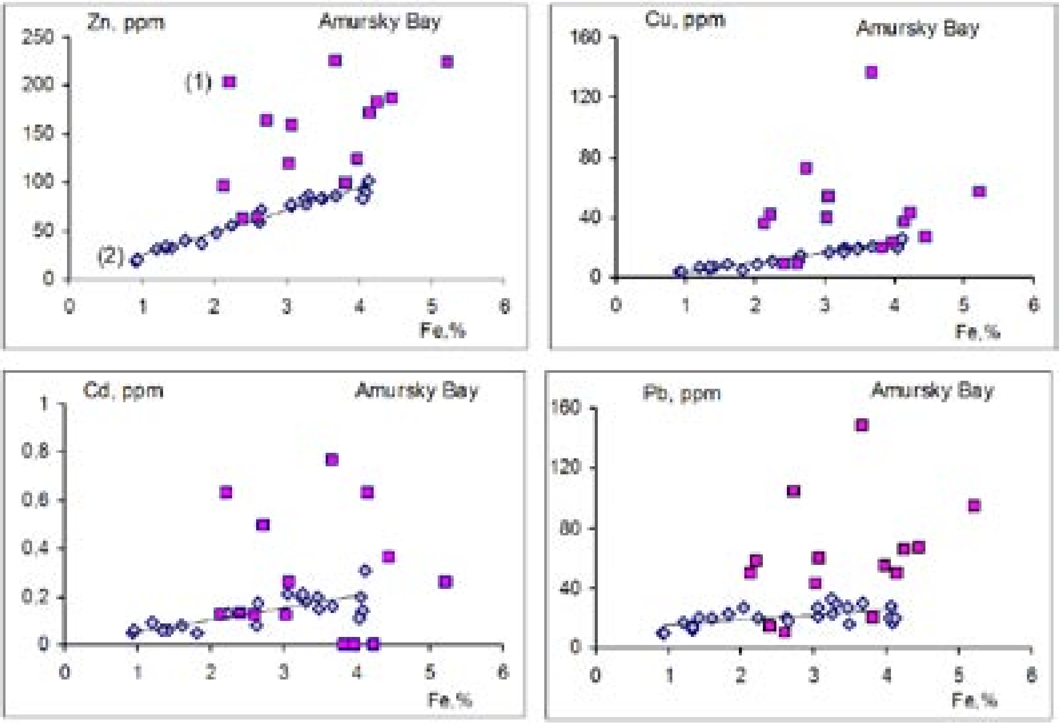

Figure 7.14. The dependence of metal concentrations vs. Fe contents in bottom sediments of Amursky Bay. (1) – contaminated southeastern part, (2) – uncontaminated sediments of the southwestern part of the Bay.

The similar relationships are observed for the Nakhodka Bay and other sub-areas of Peter the Great Bay with distinct anthropogenic influence.

Thus, anthropogenic influence has led to the formation of the zone of elevated concentration of some trace metals in the bottom sediments around the Muravyev-Amursky peninsula. The rather vast area is formed within southeastern part of Amursky Bay with total concentration of Pb, Zn, Cu, Cd elevated 1.5-3 times above background. The enrichment by the easy-leachable forms reaches up 3-10 times in 0.5 km coastal zone and 2-4 times off shore. The similar contamination is observed in the bottom sediments of Bosphor Strait. The bottom sediments of the semi enclosed bights: Golden Horn and Diomid where Vladivostok sea port facilities are situated have much higher metal concentration: the enrichment reaches up 10-30 times.

The sediments of the southwestern coast of Ussuryisky Bay have Zn, Cu, Pb concentration 2-3 times above background but unlike Amursky Bay the strip with contaminated sediments does not exceed 0.5-0.7 km. The “hot spot” with very high metal concentration in sediments is situated in the middle of the west coast of Ussuryisky Bay. The inputs of debris and leakage from the city landfill situated on the coast are the main reason of this hot spot.

The spatial distribution of the trace metals in the upper layer of bottom sediments is rather similar, though degree of enrichment is different for different element (Fig 7.15 and 7.16).

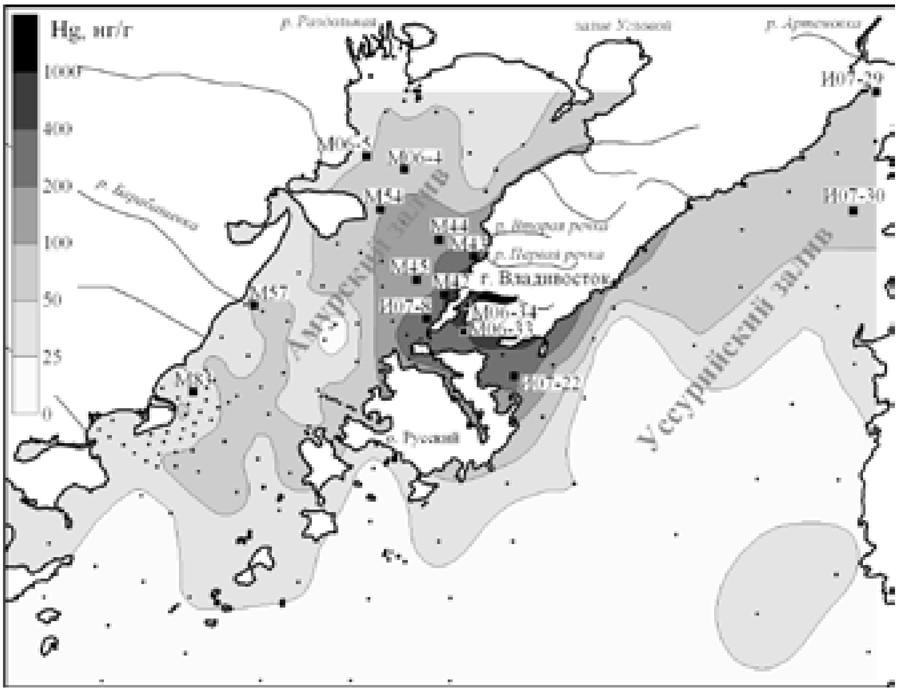

Figure 7.15. Distribution of Hg in the bottom sediments of Amursky and Ussuryisky Bays (from Aksentov, 2008).

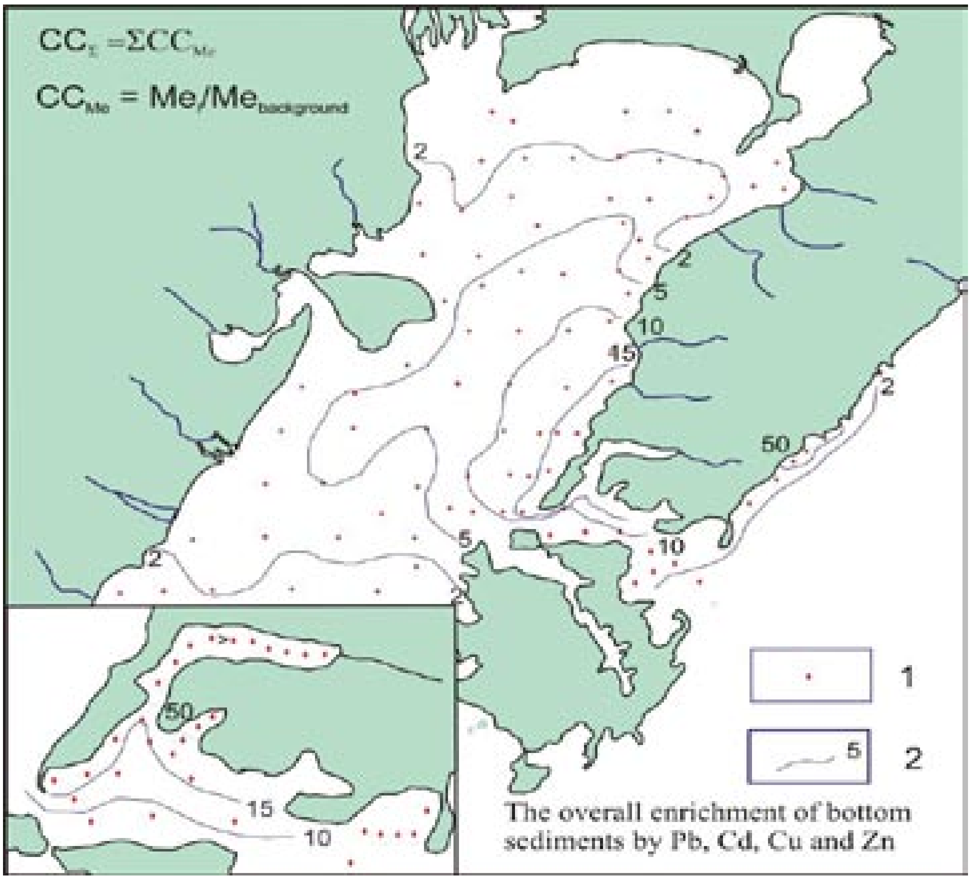

Figure 7.16. Distribution of the summary enrichment coefficient (CC_{Σ}) by Pb, Cd, Cu and Zn in the bottom sediments of Amursky Bay and west part of Ussuryisky Bay (Shulkin, 2004).

According to (Tkalin et. al., 2000) the concentrations of DDTs and HCHs in bottom sediments of Amursky Bay varied between <0.10±4.78 and <0.20±4.47 ng/g dry weight, respectively, without any influence of river discharge on POPs distributions in Peter the Great Bay. Near Vladivostok the total DDTs concentration reaches up 27.7 ng/g. No significant correlation was found between concentrations of these POPs in the bottom sediments and mussels (Tkalin et al., 2000).

At the absence of reliable time-series data on the concentration of contaminants in the river and coastal waters, the distribution of contaminants across the upper layer of sediments is the most suitable and often used proxy for the history of pollution during last decades/centuries. There are some published data on the trace metals distribution across the upper layer of the bottom sediments in the different part Bay (Tkalin et al., 1996, Shulkin, 2004, Polyakov, 2008, Aksentov, 2008). Some of studied sediment cores are dated by Pb^{210}. These data (Fig. 7.17a) allow testifying the beginning of 50s last century as a start of significant additional input of Hg to the southeastern part of the Amursky Bay. Gradual increase of anthropogenic press took place until maximum in the middle of 70s with support of high level after that. The anthropogenic input of Pb started 100 years earlier, and reached up maximum in 30s of last century (Fig. 7.17b).

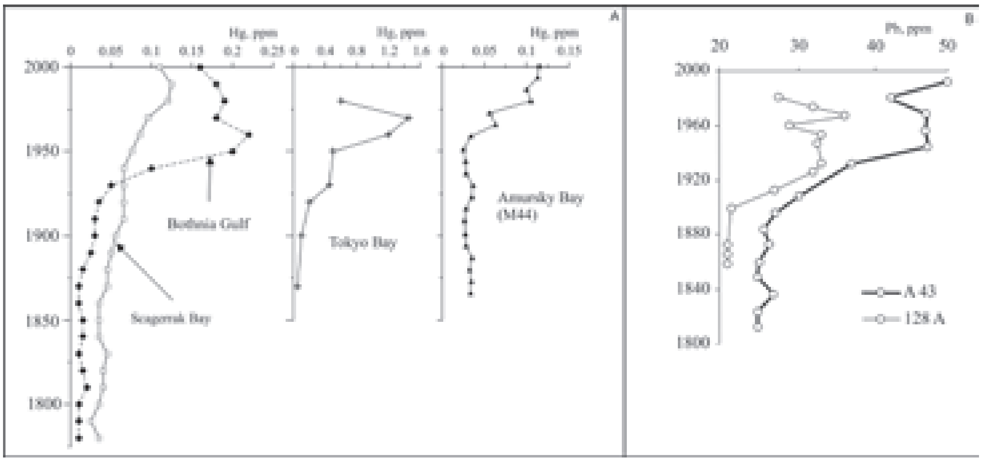

Figure 7.17. Distribution of Hg (a, Aksentov, 2008) and Pb (b, Polyakov, 2008) in the upper 50 cm bottom sediments in the middle of Amursky Bay and some other areas.

7.2.5. Eutrophication and the changes in the structure of biological communities

The eutrophication as a phenomenon is characterized by the chlorophyll “a” concentration 8-25 ug/L and TP concentration 35-100 ug/L. At the chlorophyll”a” content >25 ug/L the water status is classified as hypertrophic (Treatise in Geochemistry, 2005). According these criterions only some inner parts of Peter the Great Bay could be identified as eutrophic. This eutrophicated status is observed during the rather restricted periods (1-2 weeks) at the phytoplankton blooms. Most frequently bloom events in Amursky Bay are registered in July and August (Fig. 7.18) (Orlova et al.,CEARAC Report, 2005). The duration of blooms is around one week. Only blooms caused by *Noctiluca scintillans* and *Oxyrrhis marina* lasted more than 20 days. The area occupied by red tides varies extremely depending on oceanographic, meteorological, and biological conditions. The red tides area rarely exceeds 1 km^2. Only *Noctiluca scintillans* blooms spread areas that exceeded 10-20 km^2.

Thus, for the time being the eutrophication itself is not a problem for the Peter the Great Bay as a whole. At the same time there are some signs of excessive inputs of nutrients to the inner parts of Peter the Great Bay. As a result the phytioplankton blooms have been observed in the inner part of Peter the Great Bay, namely in the Amursky Bay. The late summer depletion of DO takes place in the bottom layer of Amursky Bay as a consequence of phytoplankton destruction. This feature can be indicated as a symptom of local eutrophication and was studied in current CEARAC report. Moreover the toxin producing species of phytoplankton are observed within Peter the Great Bay, and the absence of damage is explained by the low level of aquaculture development for the moment.

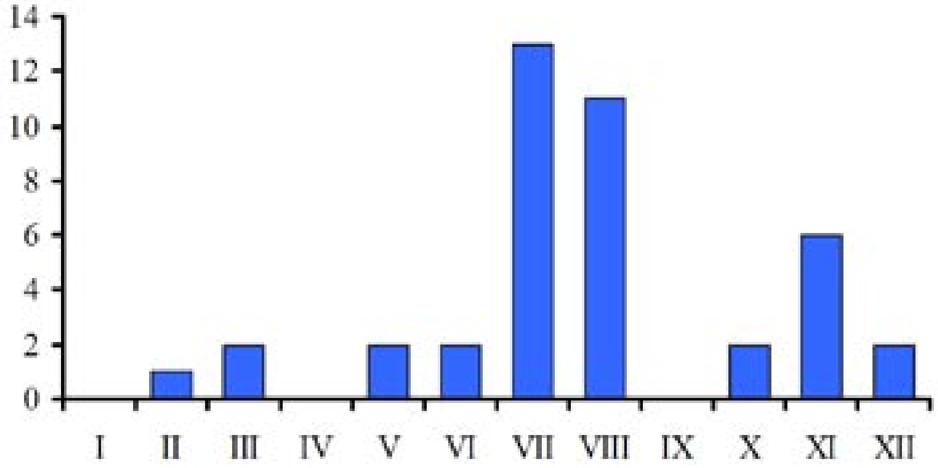

Figure 7.18. The seasonal distribution of "red tides" (phytoplankton bloom) events in Amursky Bay during the 1991-2007 period (Orlova et al., from CEARAC Report, 2005).

The changes in the structure and distribution of benthos communities have been studied within the Amursky Bay in detail. The polychet *Maldane sarsi* and ophiur *Ophiura sarsi* community was discovered within sandy silts of the north Amursky Bay in 1931-1933 (Deryugin & Somova, 1941). In 1957 the prevailing of *O. sarsi vadicola* and *M. sarsi*, continue to be registered in the central part of Amursky Bay, though siltation took place in the northern end of the Bay. In 1973-1975 the community of *O. sarsi vadicola* has occupied the silty habitats, and bivalves and echinoderms communities have occupied the sandy coastal zone.

The change of the macrozoobenthos from 1931-1933 till 1973-1975 has expressed in the decrease of ophiures and in the shift of the trophic structure: the prevailing of surfer deposit feeders had been changed to the domination of borrow deposit feeders (Klimova, 1981). But the main features of the benthos structure were the same: the central and south part were occupied by *O. sarsi vadicola* and *M. sarsi* community, surrounded by sea star *L. quinaria bispinosa* community.

The dramatic change of the benthos structure has been observed in 1970-1989 period (Tkalin et al., 1993, Belan, 2003). The communities of *L. quinaria bispinosa* and *O. sarsi vadicola* have been disappeared. The community of tolerant to the pollution *Th. pacifica* and *Ph. harmeri* has been observed instead. The quantitative assessment during the end of 80s shown the catastrophically low level of bivalves in the benthos communities of the Amursky Bay (Moschchenko, Belan, 2006).

In 2001 north part of Amursky Bay was occupied by communities of polychaete *L. longifolia, Th. pacifica* and *S.inflatum,* and bivalves *Makoma tokyoensis.* The averaged biomass of the macrozoobenthos communities elevated from 1986-1989 till 2001.

In 2005 polychaete *L. longifolia* and bivalve *Pomatocarbicula amurensis* prevailed in the north part of the Amursky Bay with depth less than 20m. The polychaete *Th. pacifica* and phoronides *Ph. harmeri* resistant to the pollution dominated southward.

Thus, during 1986-2005 the significant variability of the species composition was observed for the macrozoobenthos of Amursky Bay. The biomass of the benthos in the north part of Amursky Bay increased at this period. The change of the ratio between species tolerant and sensitive to the pollution indicated that situation was rather stable before 1975. The degradation was prevailed in

1975-1989, and some symptoms of recovery were observed from 2001. The decrease of abundance of pollution tolerant species and increase of bivalve mollusks typical for this area earlier have been observed in 2001 (Belan, MPB, 2003, 49, 9, 1111-1119). But repeated increase of species – positive indicators of pollution has been noted again in 2005.

The eutrophication and siltation are the most probable obstacles for the full recovery of benthos community. The abundance of *C. capitata*, *Ph. harmeri*, *T. fragilis*, *R. pulchella*, *E. japonica* at the different parts of the Amursky Bay and appearance of *U. fenestrata* at the south border of the area are the evidences of the eutrophication of the northern part of Amursky bay.

The long term trends of the macrobenthos characteristics for Peter the Great Bay as a whole is not so unambiguous. Thus analysis of macrobenthos communities in different parts of Peter the Great Bay in 2003 compare with the 1970 has shown the significant increase of the macrobenthos biomass (Nadtochi et al., 2005). This increase was provided by bivalves and cirripedias in the inner parts of the Peter the Great Bay, and by holothurians in the outer parts. The variability of the quantitative estimation of the biomass due to grid density and natural unevenness of the macrobenthos spatial distribution is a clue reason of the differences of benthos community characteristics during last 50 years.

Another coastal area where the distinct change of the benthos community has been recorded during last 20 years is the Vrangel Bights – small (about 6 km^2) water basin in the eastern part of Nakhodka Bay. The port facilities with freight turnover about 20 mln. tons have been constructed in Vrangel Bight. The large scale dredging of bottom sediments was taken place during last 35 years. According with three surveys in 1989, 1995 and 2001, it leads to the decrease of macrobenthos biomass and to the change of trophic structure: disappearance of the sestonophagous and prevailing of the deposit and sediment feeders. The status of benthos community is characterized as unstable: at the not stop pollution and destruction of bottom biotopes the benthos will degrade readily. From other hand the remediation measures could be rather successful (Gulbin et al., 2003).

8. The influence of different human activities on the marine and coastal environment within selected case study areas

Data on typical coastal waters of NOWPAP indicate clear link between of the majority of natural and anthropogenic processes occurring in the coastal zone. Therefore, to solve many environmental problems in coastal zones, they should be treated as single systems that include coastal watersheds and coastal sea areas connected by the river and direct flows of matter from adjacent land, and by the atmospheric deposition as well.

Among various environmental problems of the coastal zone caused by economic activities and land use, there are inevitable problems related to the development and exploitation of the territory. These include, among others, physical alteration of habitats associated with development: land filling, dumping and other transformations of both land and underwater landscapes. If significant socio-economic development takes place, transformation and loss of natural habitats are inescapable and sometimes irreversible. Population density, type and intensity of economic activity, and land-use practices are the main socio-economic factors that control this process. It is clear that the scale of transformation of landscapes and biotopes must be quantitatively linked to population density and economic activities. Therefore, among the areas studied, the scale of loss of natural habitats is at a minimum in the Peter the Great Bay (Russia), due to its low population density and is at a maximum in Masan Bay (Korea) and Dokai Bay (Japan), due to intense economic activities and high population density. The environmental activities (proper discharge and dumping of waters and solids, protection of neighboring localities, remediation measures), accompanying processes of land reclamation are also important.

Natural factors controlling the transformation and loss of biotopes are geological and geomorphologic features of a particular section of the coastal zone, limiting its commercial development due to natural hazards (flooding, exposure to storm surges and tsunamis, etc.). Given the unique combination of natural constraints for each of the sites, it is practically impossible to identify quantitatively the regularities between loss of biotopes and the intensity of economic activity common for all sites.

The only way to mitigate the negative impact of the physical destruction of habitats is to develop a network of specially protected areas and to implement proper spatial zoning taking into account uniqueness and/or specific habitats even at the stage of planning of economic activities.

The invasion of biological organisms in ballast waters and in fouling assemblages on ship hulls is probably the inevitable environmental problem for the coastal waters. Under certain conditions, invasive species can displace the native organisms, and lead to undesirable changes in aquatic ecosystems. To forecast this issue is even more difficult, in terms of ascertaining its quantitative links with intensity of shipping and geography of the vessel routes.

However, many environmental problems in coastal areas are not irreversible and could be more or less managed. A necessary step in this management process is to assess the effectiveness of environmental measures, which, in turn, must be based on an analysis of the quantitative relationships between socio-economical factors and ecosystem quality indicators. From this perspective, the joint consideration of the situation in such diverse areas as Jiaozhou Bay, Masan Bay, Dokai Bay and Peter the Great Bay could be useful.

Chemical composition of river water and its seasonal and inter-annual variability is an integral measure of natural processes occurring on watersheds as well as anthropogenic load. Sufficiently unified chemical parameters used in different countries to characterize the quality of river waters, allow to compare heterogeneous catchment areas in different climatic and landscape settings. At the same time, it is necessary to take into account the peculiarities at the determination of certain chemical parameters in selected countries (COD_{Cr} in Russia and

COD_{Mn} in other NOWPAP countries, analyzing different forms of nitrogen, etc.). Determination of the background chemical composition of river waters is also very important for the proper accounting of natural features. By COD and BOD values, concentrations of dissolved nutrients (nitrogen and phosphorus), many rivers on the west coast of the Japanese islands and several rivers of Primorsky Krai of Russia can be considered as “clean”. For the rivers of Primorye it is due to the very low population density, and for rivers in Japan due to well developed and efficient wastewater treatment systems.

If we consider the rivers flowing into the case study areas, there is a clear sequence of increasing concentrations of BOD, COD, DIN, DIP: Partizanskaya River → Razdolnaya R., Dagu River → Masan’s Bay rivers → rivers draining Qingdao city (Fig. 8.1). Average BOD (the only parameter available for the rivers feeding the Dokai Bay and its vicinity), classifies these rivers since 1997 as almost unpolluted, although the same watercourses in 1980 had BOD 7.5-18.4 mgO/l, i.e. rivers were significantly contaminated.

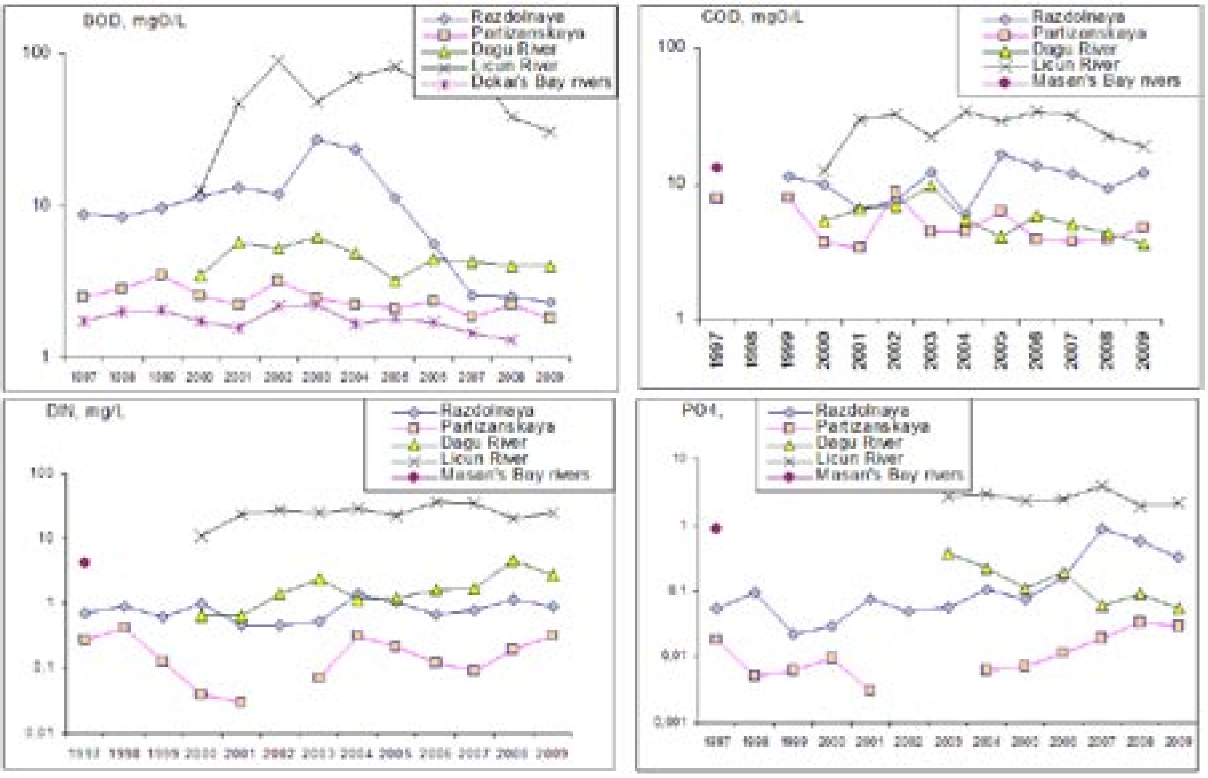

Figure 8.1. The changes of some chemical parameters of the typical rivers within case study areas during the last decade (note the log scale on the vertical axis).

The observed sequence looks quite logical in terms of population density on watersheds: minimum for Partizanskaya R. and maximum for Licun R., draining Qingdao city. However, similar level of pollution for Razdolnaya R. (Russia) and Dagu R. (China), despite substantially greater density of population in the catchment area of the latter, indicates that the efficiency of wastewater treatment is equally important. Almost background values of BOD in rivers of north-western part of Kyushu which feed the Dokai Bay and drain the territory of the city of Kitakyushu (Fig. 8.1) confirms the possibility of almost complete cleaning of urban waste water at least from organic matter with proper cleaning efficiency.

Water runoff and its seasonal variation are the natural factors affecting the vulnerability of the chemical composition of river waters to anthropogenic load. The larger river, the less effect will have an additional anthropogenic influence on the chemical composition of its water. The exception is the initial periods of floods when flushing away material accumulated during the previous period of small flow rate can be accompanied by an increase in the concentration of many chemicals in river flow (e.g. Rember, Trefry, 2004).

Thus, the degree of transformation of the chemical composition of river waters (R) is a direct function of the population density on watersheds (D), the intensity and type of business (r), and inverse function of the efficiency of sewage treatment (1/t) and river water (1/Q):

River runoff is often the main source of pollutants for coastal marine waters. Unlike quality of river waters, which is determined only by the concentration of chemical compounds, the influence of river runoff on the contamination of coastal waters depends both on the volume of runoff and their chemical composition.

Average river runoff shows significant inter annual variation due to alternating years with different amounts of precipitation. In addition to inter annual variability in the NOWPAP region there is a significant seasonal variability of runoff caused by monsoon climate. However, significant trend in river runoff was not observed within coastal study areas over the past 10-20 years. Thus the inter-annual trend of pollutants load in coastal waters will be determined by the trends in their concentrations in river waters. Therefore, the observed trend of increasing supply of nutrients N and P in water Jiaozhou Bay from 1995 to 2004 (Fig. 4.12, 4.13) reflect the likely increase in the anthropogenic load on the rivers flowing into the Jiaozhou Bay. This in turn leads to an upward trend in the average annual concentration of dissolved nitrogen estimations in the waters of the Jiaozhou Bay, although very large variability takes place (Fig. 4.17). For the average annual concentration of phosphate and COD values the increasing trend is not observed, probably due to more efficient uptake by plankton and removal in the sediments. The effective environmental actions at the Dokai Bay watershed from 1971 to 1990 resulted in significantly reduced concentrations of nitrogen, phosphorus and COD in the Bay itself. However, already at a distance of 2-3 km off the Dokai Bay mouth no trend over the past 10 years was observed (Fig. 5.6, 5.7, 5.8). Thus, if for river ecosystems the links between anthropogenic load and water chemistry are clear enough, when considering processes in coastal marine waters the influence of river runoff cannot be established so easy.

When comparing data on concentration of nutrients and COD in the Jiaozhou Bay and different parts of Dokai Bay (Fig. 8.2), it is obvious that the level of pollution in the Jiaozhou Bay is similar to the environmentally safe sea area adjoining to the mouth of the Dokai Bay from the west.

This indicates that there is no simple relationship between anthropogenic load and chemical parameters of coastal water quality. The internal properties of water systems – rate of water exchange, types of sediments and living resources (plankton first of all) – become more dominant.

In the waters of Masan Bay after a maximum observed in 2000, there has been a significant reduction in DIN: from 0.6-0.9 to 0.08-0.1 mgN/l and in DIP: from 0.11-0.15 to 0.01-0.02 mgP/l in 2008. There is similar decrease DIN from 0.4 to 0.05-0.10 mgN/l and DIP from 0.08 to 0.02 mgP/l within Jinhae Bay – a seaward continuation of Masan Bay (Park, Lee, CEARAC, 2010). These clear trends could be explained by wastewaters treatment efforts, though additional data on the river inputs have to be discussed.

Thus, the level of pollution of coastal waters is controlled by the concentration of pollutants in river flow and the water runoff, i.e. the quantity of pollutants entering the area. On the other hand the hydrodynamic conditions (rate of water exchange) and other internal factors (interaction with sediments and organisms) determine the distribution and transport of contaminants within the coastal waters, as well as their removal and dispersal. The dominance of internal factors makes questionable the possibility of developing quantitative relationships between the anthropogenic load on the watershed and the dynamics of the concentration of contaminants in coastal waters which will be suitable for the all coastal study areas.

The distribution of pollutants in the recent coastal sediments is very informative in terms

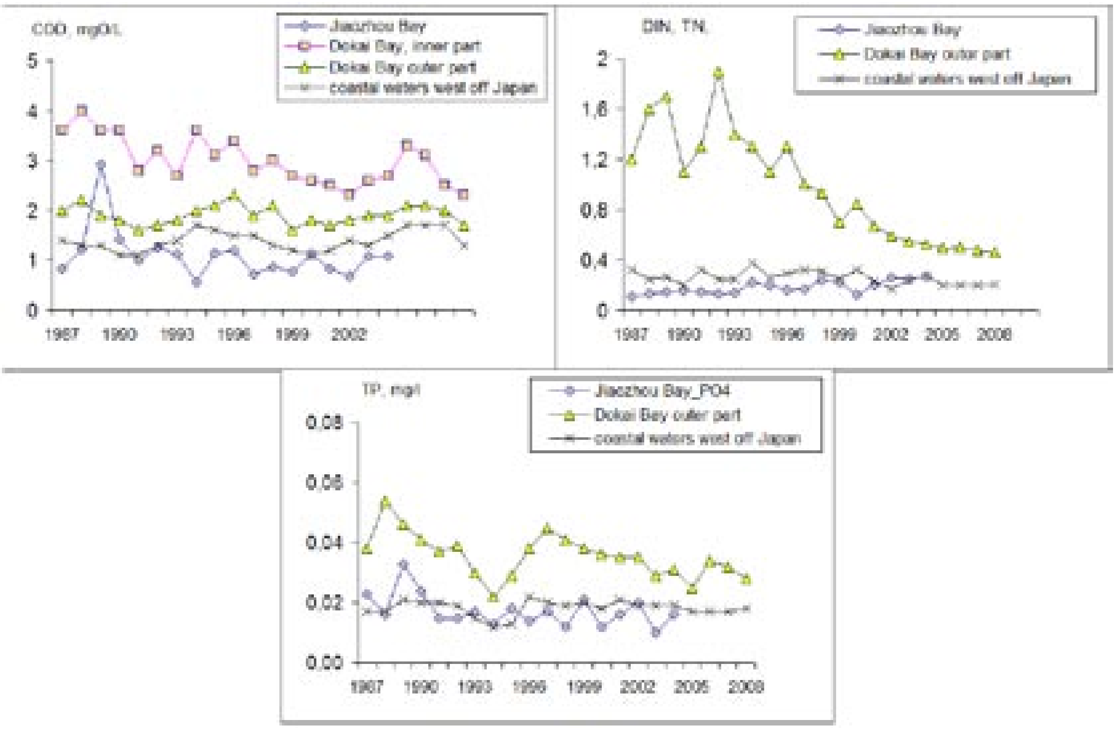

Figure 8.2. The changes of annually averaged COD, TN (DIN) and TP (PO$_4$) in the waters of Jiaozhou Bay and different parts of Dokai Bay.

of assessing human impacts. Variability of pollutant concentrations in sediment core allows to estimate the intensity of their input in the bottom sediments, and to characterize the history of pollution in the case of determining the rate of sedimentation.

The best results of the sediment investigation are obtained for the assessment of pollution with trace metals and POPs – persistent organic pollutants (DDTs, PCBs). Grain size distribution and behavior at the diagenesis must be taken into account for the metals. For example, sub-surface maximum concentration of Cd in sediments Jiaozhou Bay (Fig. 4.20) is probably caused by the diagenetic processes, and the general trend of reducing metal concentrations down the column (Fig. 4.20, 8.3) is explained by coarser grain size of the material supplied up to 1950-1960.

In contrast to the Jiaozhou Bay, bottom sediments of Amurskiy Bay and Masan Bay show a clear increase in the concentration of heavy metals such as Pb in the upper layer of sediment accumulated over the past 50 years (Fig. 8.3). The higher concentrations reflect more intensive anthropogenic load.

A detailed study of the distribution of exclusively anthropogenic persistent organic pollutants (DDTs and PCBs) in the upper 50 cm layer of Masan Bay sediments accumulated since 1940 clearly shows an increase in use of these substances. At the same time, a ban on the use of DDTs and PCBs in the 1960s and in 1989, respectively, is also reflected in the distribution of these compounds in the upper layer of Masan Bay sediments (Fig. 8.3).

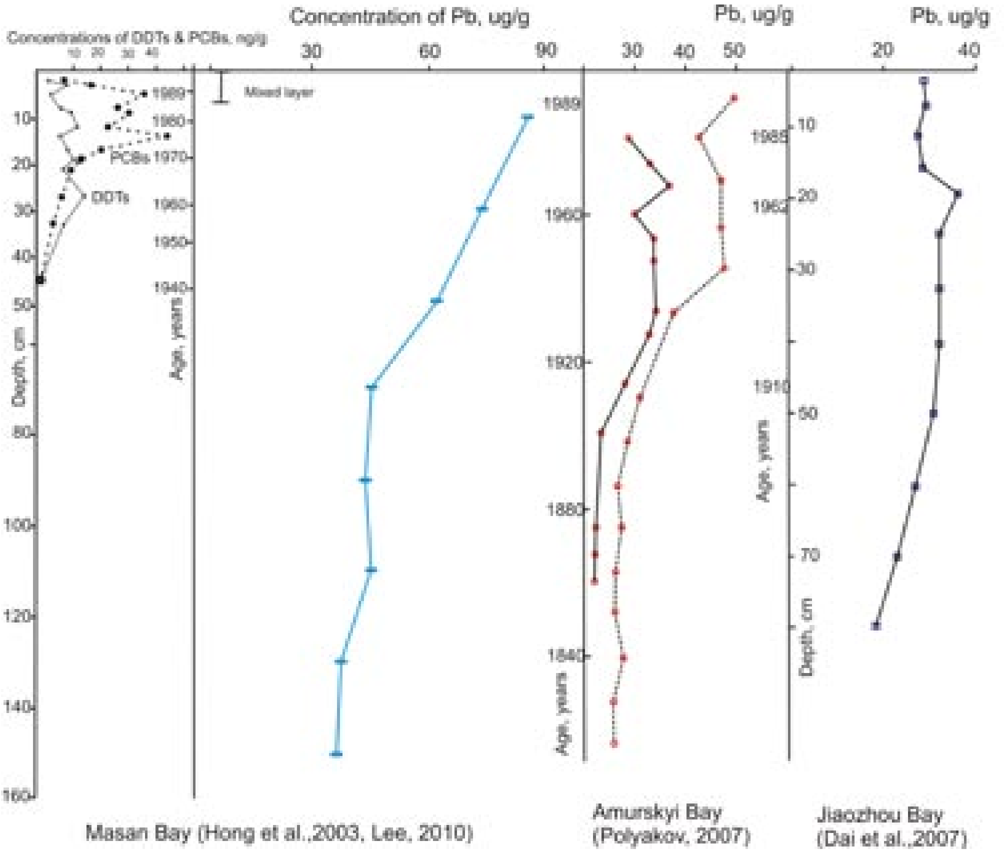

Figure 8.3. The distribution of POPs and Pb in the upper layer of recent bottom sediments.

The main limitation of the recent sediments use to assess the variability of the pollution of coastal ecosystems during last 10-15 decades is the necessity of a stable regime of sedimentation. In addition, changes in content in the water column nutrients, eutrophication and related ecological problems are not reflected in the chemical composition of the sediments so clearly as trace metals and POPs. Though detailed micropaleontological research of bottom sediment cores could help in such case. For example, a sharp decrease in diatoms frustules and the change of the dominant species in the upper 30 cm layer of bottom sediments of Jiaozhou Bay collected since 1981 clearly reflects increased eutrophication in the last 30 years (Liu et al., 2008).

Thus, the study of modern sediments of coastal areas is a powerful tool for assessing anthropogenic stress, pollution and changes in environmental conditions over the past 100-150 years. In addition, the use of sediment allows comparing coastal areas with significantly different internal characteristics.

9. Conclusions

The following concluding remarks could be drawn for the coastal study areas in the NOWPAP region in terms of existing environmental problems and their links with anthropogenic activities.

Jiaozhou Bay. The trends in nutrients (DIN, DIP) and COD concentrations in Jiaozhou Bay seawater are in accordance with the changes of nutrient inputs from land-based sources (from Qingdao city). It indicates that the discharge of nutrients from land-based sources into Jiaozhou Bay have affected the nutrient concentrations in Jiaozhou Bay seawater.

The data analysis indicates that due to the pressure from Qingdao economy and society and especially the discharges from land-based sourced into Jiaozhou Bay, the nutrient structure of Jiaozhou Bay seawater is far beyond the Redfield ratio, and the structure of phytoplankton communities also changed to some extent. Basically, the diatom species became most predominant with the dinoflagellate species second in the structure of phytoplankton communities. From the 1980s, the abundance of bigger diatom and chain-shaped diatom species decreased, while the abundance of smaller diatom and dinoflagellate species increased. The average concentration of SiO_3-Si in Jiaozhou Bay seawater has decreased, and the SiO_3-Si/DIN ratio has dropped from 0.6 to 0.4. These changes obviously affected the diatom species which need SiO_3-Si for their cells.

These results clearly show that significant long-term environmental changes have affected the structure of phytoplankton community of Jiaozhou Bay since the 1980s.

Dokai Bay. The amounts of organic pollutants discharged from Kitakyushu City region dramatically decreased after 1970s, after countermeasures were taken against wastewater effluents and wastewater treatment systems were built. Nitrogen concentrations in 2005 fell to one-fourth of those in 1990 as a result of introducing environmental quality standards for nitrogen in Dokai Bay. Phosphorus concentrations in Dokai Bay also gradually decreased. However, a large amount of organic matter and non-regulated chemical substances are still discharged into the sea even now. In particular, a large amount of pollutants discharged from factories and the sewage treatment facilities flows into the enclosed Dokai Bay, and those pollutants eventually accumulate in bottom sediments. Consequently, Dokai Bay is still suffering from eutrophication, and red tides occur every summer. Although the diversity of aquatic organisms has been recovering, current conditions seem to be far from the original natural conditions.

Since most of the seashore facing the sea has been reclaimed, wildlife habitation has declined. However, since there are no further reclamation plans for this area, further declines in habitats are not expected to occur. Since 80% of the coastline in Kitakyushu City region has been transformed into artificial coast over the past 50 years, many habitats have been lost. The remaining natural coastline is also exposed to the threat of development activities.

The diversity of organisms in the seashore facing the Seto Inland Sea is rich when compared with Dokai Bay and eastern part of NOWPAP sea area, mainly because natural seashores, such as the tidal flats, remain. Still, catches of shellfish and benthic organisms have decreased greatly due to construction of an artificial island and the reduction of shallow sea areas. Since there is a plan to construct a new reclaimed island as a disposal site for sediment dredged from the strait between eastern part of NOWPAP sea area and Seto Inland Sea, the effects of the reclamation should be minimized.

In Kitakyushu area, organic pollutant loads via rivers are estimated to have decreased by about 90% since the early 1970's, mainly due to installation of a sewer system. Organic pollutant loads from factories also decreased by more than 40%, and were accompanied by a 75% decrease in the total nitrogen load and a 15% decrease in the total phosphorus load (including those of domestic-waste origin).

Since pollutant loads from the land to the sea greatly decreased, the marine environment which was once called the "Sea of Death" improved significantly, and many aquatic organisms have actually returned.

Masan Bay. The large scale and fast economic development of the Masan Bay watershed during the last 50 years was accompanied by the obvious environmental problems at the coastal areas. The significant loss of the habitats is one of them. Chemical composition of the rivers inputting to the Masan Bay is seriously affected by anthropogenic pressure. Concentrations of nutrients and COD values in some rivers often exceeds WQS. Additional data are needed to evaluate the trends of river input trends. At the same time, due to continuous efforts on wastewater treatment, the annually averaged concentrations of DIN, DIP and DSi significantly decreased and dissolved oxygen increased during the last decade. This trend is coincided with the trend of nutrients concentration observed in Jinhae Bay – seaward continuation of Masan Bay. Actually these two coastal areas are the two parts of the single ecosystem. However, clear trend of nutrients decrease in the coastal sea waters in Masan Bay-Jinhae Bay area was not accompanied by similar tendency in the red tide occurrence or eutrophication status. There is some weak trend of red tides occurrence decrease, but at the same time annually averaged concentration of chlorophyll "a" shows variable increase, and area suffering from the red tides is increasing as well.

Bottom sediments within Masan Bay have been contaminated by trace metals and POPs during the last 50-60 years. Detailed research shows some decline of POPs in sediments during the last decade due to the ban for using PCBs and DDTs, though additional data are needed to assess the dispersion of pollutants outside the Masan Bay.

Peter the Great Bay. The big size and wide connection with open sea areas provide excellent water exchange and significant dilution capacity for the Peter the Great Bay. The inner parts of the Peter the Great Bay, namely Amursky, Ussuriysky, Nakhodka and Posyet bays are the areas with possible environmental problems due to anthropogenic (mostly land based) activities. For the time being, the northern part of Amursky Bay, and some internal parts of Ussuriysky and Nakhodka bays have severe environmental problems.

Despite the relatively low population density compared with other NOWPAP countries, many rivers draining the Peter the Great Bay watershed, including biggest one - Razdolnaya River, have rather elevated BOD values, exceeding the MPC of 2 mgO_2/l. The inefficient treatment of municipal and agricultural wastewaters is the most probable reason. The increasing trend for the phosphate concentration in the river runoff was also observed during recent years.

The river input of contaminants dominates for the Peter the Great Bay as a whole, but for some parts of the Bay, the wastewater and storm water discharges become the prevailing source of phosphates, ammonia nitrogen and petroleum hydrocarbons. Coastal waters adjacent to Vladivostok city is the most obvious example, but due to significant pollution load from Razdolnaya River Amursky Bay as a whole is under prevailing river input influence. At the same time, rather pristine coastal localities with clean rivers and low population density are vulnerable to the untreated wastewater inputs.

There is no clearly observed increasing trend for the nutrients and COD values in the Peter the Great Bay during the last decades. In recent years, signs of eutrophication, reflected in oxygen depletion and nutrients enrichment, were observed in the near bottom waters of Amursky Bay in late summer. The obvious reason is seasonal phytoplankton blooms initiated by the Razdolnaya River discharge peak in July-August with subsequent fast decay of produced organic matter in the Amursky Bay, although dispersion and long lasting effects of the contaminated bottom sediments dumped in southeastern part of the Bay 20-30 years ago could not be ignored as well.

The distribution of trace metals in bottom sediments of the Amurskiy Bay is a superposition of inputs from the Vladivostok city, dumped contaminated sediments, and Razdolnaya River solid discharge. Former two are the main sources for such metals as Pb, Cd, Zn, Cu and Hg. The vertical distribution of these metals in sediment cores allows to reveal the history of anthropogenic influence on the Amursky Bay during the last 10-15 decades.

Besides long-term changes in the concentrations of metals in bottom sediments and seasonal changes in the hydrochemical properties of sea water, significant long-term alterations were observed in the benthos communities within Amursky Bay during the last 30-40 years. Bottom sediments siltation seems to be a major reasone of these changes in benthos communities, though direct contamination of bottom sediments could be also a reason at the some localities. The invasive species have been registered as well.

References

China

1. “China Bay Records”, China Ocean Press, 1993
2. http://www.stats-qd.gov.cn
3. Marine Environment Quality Bulletin of Qingdao, Qingdao Marine Fisheries Service
4. http://www.soa.gov.cn/chichao/ccd/1933-1999b.htm
5. China Sea water quality standard, GB3097-1997,
6. Han Xiaotian, Zou Jingzhong, et al. Red tide in Jiaozhou Bay and their ecological distribution of species, Marine Science, 2004.
7. Wang Xiulin, Li Keqiang, Shi Xiaoyong, et al. Capacity of main chemical pollutants in Jiaozhou Bay. The marine environment
8. Environment Quality Report of Qingdao, Qingdao Environmental Protection Bureau, 2000-2009.
9. Yao Peng, Zhigang Yu, Chunmei Deng et al. Spatial temporal distribution of phytoplankton pigments in relation to nutrient status in Jiaozhou Bay, China / Estuarine, Coastal and Shelf Science 89 (2010) 234-244.
10. Dai Jicui, Jinming Song, Xuegang Li, Huamao Yuan et al. Environmental changes reflected by sedimentary geochemistry in recent hundred Years of Jiaozhou Bay, North China. 2007. Environmental Pollution, 145, 656-667.
11. Shen, Z.L., 2001. Historical changes in nutrient structure and its influences on phytoplankton composition in Jiaozhou Bay. Estuarine, Coastal and Shelf Science 52, 211-224.
12. “Qingdao City Chronicles”, Qingdao Press, 2000~2009
13. Liu Dongyan, Jun Sun, Jing Zhang, Guangshan Liu. 2008. Response of the diatom flora in Jiaozhou Bay, China to environmental changes during the last century. Marine Micropaleontology, 66, 279–290.
14. “Qingdao Statistical Yearbook” 1980~2009, Qingdao Municipal Statistics Bureau.
15. Jiaozhou Bay pollution survey report, Marine Bulletin, Chen Xianfen,1991
16. Jiaozhou Bay and its coastal environmental profiles, Marine Bulletin, Chen Xianfen, 1992
17. “Qingdao Environmental Statistics Yearbook”,1995~2009
18. Jiaozhou Bay and adjacent coastal joint function zoning, 1996
19. Qingdao Environmental Quality Report, Qingdao Environmental Protection Bureau, 1980-2009.
20. Qingdao Environmental status Bulletin, Qingdao Environmental Protection Bureau, 1980-2009.

Japan

21. Agricultural report of Fukuoka prefecture
22. Annual report on sewerage in Kitakyushu City
23. Chemical pollution in coastal waters around Kitakyushu City and their origins; K. Kadokami, et al, J. Environ Chem, pp435-453, 1998.
24. Environment of Kitakyushu City
25. Kadokami K., et al. Occurrence of 888 chemicals in sediments and their effects on benthic animals in an enclosed sea in Kitakyushu, Japan. In Persistent Organic Pollutants Research in Asia, 2008, 205-212.
26. Statistical yearbook of Kitakyushu City
27. Statistical yearbook on agriculture, forestry and fisheries in Fukuoka prefecture

Korea

28. Hong S.H., Kannan N., Jin Y., Won J.H., G.M.Han, W.J.Shim. 2010.Temporal trend, spatial distribution and terrestrial sources of PBDEs and PCBs in Masan Bay, Korea. Mar.Poll.Bull. 60. 1836-1841.
29. Hong S.H., U.H.Yim, W.J.Shim, J.R.Oh, I.S.Lee. 2003.Horizontal and vertical distribution of PCBs

and chlorinated pesticides in sediments from Masan Bay, Korea. Mar.Poll.Bull. 46.244-253.

30. Santschi P.H., Hoehener G., Benoit, and M. Buchholtz-Ten Brink. 1990. Chemical processes at the sediment-water interface. Mar Chem., 30: 269-315.

Russia

31. Aksentov K.I. Mercury in abiotic components of the Peter the Great Bay ecosystem. In *Current environmental condition and tendencies of its change in the Peter the Great Bay, Sea of Japan*. Moscow. GEOS, 2008. P. 173-183 (In Russian).
32. Integrated report on harmful algal blooms (HABs) for the NOWPAP region. NOWPAP CEARAC. 2005. 67 p.
33. Khristoforova N.K, Kozhenkova S.I. 2002. The use of the brown algae *Sargassum spp.* in heavy metal monitoring of the marine Environment near Vladivostok, Russia. *Ocean and Polar Research*. 24(4). 325-329.
34. Kim S.K., J.R.Oh, W.J. Shim et al., 2002. Geographical distribution and accumulation features of organochlorine residues in bivalves from coastal areas of South Korea. Marine Pollution Bullettin. 45. 268-279.
35. Kozhenkova S.I., Khristoforova N.K. Biomonitoring of heavy metal content in the coastal waters of southwestern Peter the Great Bay using brown algae. In The State of Environment and Biota of the Southwestern part of Peter the Great Bay and Tumen River mouth. Vol. 3. Vladivostok 2001, 30-37.
36. Millenium Ecosystem Assessment. 2006. www.millenniumassessment.org/. National Research Council. 2000. Clean Coastal Waters. Understanding and Reducing the Effects of Nutrient Pollution. National Academy Press, Washington, D.C.
37. Polyakov D.M. Accumulation of heavy metals in the bottom sediments of the Amursky Bay. In *Current environmental condition and tendencies of its change in the Peter the Great Bay, Sea of Japan.* Moscow. GEOS, 2008. P. 163-172 (in Russian).
38. Prepas E.E., Charette T. (2005). Worldwide eutrophication of water bodies: causes, concerns, controls. P. 311-332. In *Environmental Geochemistry*. Vol.9. *Treatise on Geochemistry.* Elsevier-Pergamon. Oxford.
39. Rember R., Trefry J.H. 2004. Increased concentrations of dissolved trace metals and organic carbon during snowmelt in the rivers of Alaskan Arctic // Geochim. Cosmochim. Acta. V. 68. № 3. P. 477 – 489.
40. Shulkin V.M., Kavun V.Ya, Presly B.J. 2003. Metal concentrations in mussel *Crenomytilus grayanus* and oyster *Crassostrea gigas* inrelation to contamination of ambient sediments. Environ.Intern. 29: 493-502.
41. The State of the Marine Environment: Trends and processes. UNEP/GPA, The Hague, 2006, 43 p.
42. Tkalin A.V., Lishavskaya, T. S. and Hills, J. W. 1997. Persistent organic pollutants in mussels and bottom sediments from Peter the Great Bay near Vladivostok. Ocean Research 19. 115-119.
43. Tkalin A.V., Samsonov D.P.., Lishavskaya T.S. and Chernik G.V. 2000. New Data on Organochlorine Distributions in the Marine Environment near Vladivostok. Marine Pollution Bulletin , Vol. 40, No. 10, pp. 879-881.
44. Tkalin AV, Presley BJ, Boothe PN (1996). Spatial and temporal variations of trace metals in bottom sediments of Peter the Great Bay, the Sea of Japan. Environ. Pollut., 92: 73-78.
45. Ткалин А.В., Шаповалов Е.Н. 1985. Поступление нефтяных углеводородов в морскую среду при взмучивании загрязненных донных отложений // Океанология. Т. 25, вып. 5. С. 775-779.

Научно-справочное издание

Regional Overview: Case studies of river and direct inputs of contaminants with focus on the anthropogenic and natural changes in the selected areas of the NOWPAP region

Региональный обзор: Поступление загрязняющих веществ в типичные прибрежные акватории региона Северо-Западной Пацифики с акцентом на антропогенные и природные изменения

На английском языке

Автор В.М.Шулькин
Отв.редактор А.Н.Качур

Отпечатано с оригинал-макета, поготовленного Центром защиты дикой природы «Зов тайги»,
минуя редподготовку
Компьютерный дизайн, верстка Л.М.Кабалик

Формат 60x80,8. Усл.п.л. 4,28. Уч.изд.л. 4.
Тираж 200 экз. Заказ 000

Тихоокеанский институт географии Дальневосточного отделения Российской академии наук
690041, Владивосток, ул. Радио, 7

Отпечатано в типографии Издательство «Дальнаука» ДВО РАН