

A STUDY OF GROUNDWATER CONTAMINATION WITH VARIOUS IONS, METAL AND BACTERIA IN KOREA

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1. Abstract

Regional groundwater contamination with various metals, ions, and bacteria in urban, agricultural, and industrial areas was analysed and compared with Korean criteria for drinking water. Water samples from various groundwater resources were investigated in relation to U.S. EPA guidelines for safe use of groundwater with various parameters. A set of 80 samples from research areas was compared regionally with drinking water criteria for various parameters. The mean concentration of $\text{NO}_3\text{-N}$ satisfied the Korean standard for drinking quality, which is 10 ppm for all areas. However, the concentration of $\text{NO}_3\text{-N}$ in 42.31% of groundwater samples from agricultural areas was higher than 10 ppm. The highest concentration of $\text{NO}_3\text{-N}$ was observed in a water sample from an agricultural area; it was 29.37 ppm, which can cause higher infant mortality by methemoglobinemia. Generally, the mean concentration of various metals was lower than the Korean criteria for drinking water, except in the case of Zinc. The highest concentration of Zn was 1.221 ppm in groundwater from an industrial area; this was the only concentration higher than the Korean standard, which is 1.000 ppm. About 15% and 32.5% of wells were contaminated by general bacteria and *E. coli*, respectively. There were no significant differences among the three areas in the frequency with which wells exceeded the *E. coli* standard. Apparently, there is no adverse effect of acid rain and chemical disposal in the form of pH alteration of groundwater; the mean pH in all areas ranged from 6.5 to 6.7. Generally, industrial groundwater has high concentrations of metals, while agricultural groundwater has high concentrations of $\text{NO}_3\text{-N}$ in Korea.

Table 1 Comparison of various metals (ppm) in groundwater from urban, agricultural, and industrial areas.

Metals:		Fe	Zn	Mn	Cd	Pb	Cu
Area							
Urban	Min	0.005	0.000	0.009	0.000	0.003	0.001
	Max	0.021	0.399	0.424	0.002	0.065	0.008
	Mean	0.011	0.069	0.052	0.001	0.035	0.004
	S.D.	0.005	0.101	0.101	0.000	0.017	0.002
Agricultural	Min	0.003	0.001	0.010	0.001	0.018	0.000
	Max	0.089	0.118	0.737	0.002	0.072	0.017
	Mean	0.015	0.032	0.145	0.001	0.037	0.004
	S.D.	0.024	0.034	0.253	0.001	0.017	0.004
Industrial	Min	0.004	0.006	0.010	0.000	0.001	0.001
	Max	0.077	1.221	5.188	0.002	0.064	0.012
	Mean	0.016	0.251	0.522	0.001	0.026	0.004
	S.D.	0.021	0.390	1.478	0.000	0.021	0.003

Table 2. Comparison of pH and KMnO₄ consumption (ppm) in groundwater from urban, agricultural, and industrial area.

Parameter: Area		pH	KMnO ₄ consumption (ppm)
Urban	Min	6.10	0.03
	Max	7.60	4.64
	Mean	6.70	1.34
	S.D.	0.42	1.07
Agricultural	Min	5.60	0.06
	Max	7.90	7.54
	Mean	6.50	1.77
	S.D.	0.65	1.70
Industrial	Min	5.70	0.06
	Max	8.10	3.64
	Mean	6.50	1.35
	S.D.	0.54	0.85

Table 3. Comparison of various cation concentrations (ppm) and hardness in groundwater from urban, agricultural, and industrial areas.

Cation: Area		Na	K	Mg	Ca	NH ₄	Hardness
Urban	Min	4.60	0.00	1.00	4.40	0.00	16.03
	Max	17.30	12.90	23.09	106.55	5.97	361.53
	Mean	11.33	3.16	9.98	47.77	0.37	161.30
	S.D.	2.96	3.48	6.93	29.95	1.44	100.91
Agri- cultural	Min	7.13	1.00	3.22	10.65	0.00	10.32
	Max	17.28	28.05	21.63	94.09	0.78	318.80
	Mean	11.66	5.78	11.61	48.61	0.07	165.80
	S.D.	2.62	7.00	5.29	22.63	0.22	82.36
Indust- rial	Min	3.04	0.80	2.00	10.06	0.00	33.08
	Max	15.34	16.36	22.03	85.98	0.09	307.21
	Mean	9.77	2.52	8.49	41.34	0.01	134.10
	S.D.	3.51	3.29	6.17	23.17	0.02	85.90

Table 4. Comparison of various anions concentration (ppm) in groundwater from urban, agricultural, and industrial area.

Anion:		F	Cl	NO ₂	NO ₃	Br	SO ₄	PO ₄
Area								
Urban	Min	0.00	3.55	0.00	0.00	0.00	2.12	0.00
	Max	0.61	43.79	1.49	16.65	0.82	155.81	1.22
	Mean	0.16	25.65	0.07	4.73	0.31	40.02	0.03
	S.D.	0.03	11.89	0.30	4.64	0.52	44.22	0.21
Agricultural	Min	0.00	6.31	0.00	0.00	0.00	0.00	0.00
	Max	0.38	65.76	1.80	29.37	0.57	97.50	0.97
	Mean	0.08	29.32	0.06	9.84	0.06	33.57	0.03
	S.D.	0.08	12.65	0.34	9.28	0.11	25.97	0.18
Industrial	Min	0.00	7.83	0.00	0.00	0.00	3.13	0.00
	Max	0.67	60.04	0.19	22.14	0.22	111.50	0.00
	Mean	0.15	29.03	0.01	4.18	0.09	34.95	0.00
	S.D.	0.18	14.65	0.04	5.29	0.08	36.94	0.00

Table 5. Comparison of frequency (%) of samples that exceeded criteria for general bacteria and the *E. coli* group in groundwater from urban, agricultural, and industrial area.

Parameter:	Percentage of samples with concentrations in excess of standards	
	General bacteria (No. in excess/total)	<i>E. coli</i> group (No. in excess/total)
Area		
Urban	8.82 (3/34)	35.29 (12/34)
Agricultural	15.38 (4/26)	30.76 (8/26)
Industrial	25.00 (5/20)	30.00 (6/20)
Average	15.00 (12/80)	32.50 (26/80)

OFFSHORE MARINE AND GROUND WATERS. THEIR RELATIONSHIP AND ZONATION

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Ground waters found on land and those found under the floor of oceans, seas, and major lakes differ distinctly in some features of occurrence. This fact has been debated by K.G. Jamalov, I.S. Zektser, A.V. Meskheteli, V.A. Kiryukhin, A.I. Korotkov, A.N. Pavlov, Yu.G. Yukovsky, N.I. Tolstikhin and others.

Based on the mode of occurrence and discharge pattern of ground (submarine) water, its interaction with sea water, and the horizontal and vertical inhomogeneity of seawater itself (vertical stratification by temperature and salinity), three hydrodynamic zones are recognised: shallow, shelf, and deep.

The shallow zone includes the coast with the areas submerged by high tides, the submarine coastal slope, and the extreme nearshore sections of the shelf. The shallow zone averages a few m to 5 m in depth, with the maximum depth being 10-20 m. The shallows are the first to receive polluted surface and ground waters from extensive catchment areas. The regime of the shallow water zone (circulation, orientation, influx of river and ground water) governs the degree of self-purification capacity and the quality of waters moving seaward into the deeper regions.

The shelf zone, with a maximum depth of 200-300 m, occupies the shelf and part of the continental slope. Not only seasonal thermal fluctuations and wind mixing throughout the whole water column, but also an active interaction with ground water are characteristic of this zone. It is the domain of the principal load of submarine water. Seasonal temperature fluctuation, wind mixing, and submarine water discharge (sometimes reaching the oceanic surface) provide for maximal intensity of convective and advective mixing of the water column. Two subzones, a more active (within 50-100 m depths) and a less active (100-200 m depths), are recognised based on the relationships between sea water and ground water within the shelf zone.

Further offshore, in the deep zone where depths exceed 200-300 m, a hydrodynamic equilibrium between ground and marine waters is usually established. There is little or no ground water discharge into the ocean. The ground water flow under the oceanic floor is retarded, and the periods of water exchange are longer. The constant salt exchange between ground water and sea water may bring about similarity in mineralisation and in the salt composition of waters above and below the ocean floor.

REVIEW OF IMPACT BETWEEN SEA WATER AND FRESH WATER ON THE COASTAL ZONE - A CASE STUDY FROM CHINA

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1. Abstract

The study was undertaken in the eastern shores of Shangdong Province of China. The region lies in the zone of continental monsoon climate and is in the semi-humid warm temperate zone. The annual precipitation is between 500 and 900 mm. However, because of the effects of typical monsoon climate, the seasonal distribution within a year is quite uneven; 50-70% of annual rainfall is concentrated in the period from June to September, frequently causing droughts in spring and wet autumns. The rainfall also varies greatly among the years. All those coastal areas consist mainly of continental deposits. The aquifer has the potential ability to yield large and reliable quantities of water and has been the main water source for domestic, industrial and agricultural utilisation.

There are some important cities in the region. Since 1980s, with rises in people's living standard and rapid economic development, water demand has exceeded water yield in the region. Over-exploitation of groundwater has occurred, especially during series of dry years and dry seasons when the river flow was cut off. Over-exploitation resulted in some area groundwater tables much lower than sea level; sea water as well as coastal salt water intrudes and endangers the fresh water aquifer of the Quaternary system. The intruded area has increased year by year at a high rate and the concentration of chloride ions has reached a high level. The water supply field has become useless.

Sea water intrusion and salt water diffusion not only cause a great danger to industry and agriculture, but also cause problems for the people, worsen the ecosystem in the coastal zone, and change the hydrologic cycle. The occurrence and further development of sea water intrusion have already caused attention by the affected cities and counties in the coastal areas. Some prevention measures have been adopted: water transfer project from outside basins, drilling infiltration wells in the river and canal courses, water resource management, water saving measures, etc. Among the measures, diversion of surface water for groundwater recharge is an effective and economical measure to ease water shortages and to raise water tables to prevent further sea water intrusion.

In spite of many efforts, sea water intrusion and its problems still exist. Understanding of the hydrological regime of coastal aquifers and reasonably planned exploitation of groundwater are essential for the social and economic development and for our living environment.

2. Study Area

The study area is bounded by the Yellow River on its west side and by the seas on the other sides, with an area of 64186 km², and is located in Shangdong Province (Figure 1). The region lies in the zone of continental monsoon climate and belongs to the semi-humid warm temperate zone. The annual precipitation is between 500 and 900 mm, with 50 - 70% of the annual precipitation concentrated in the summer season, from July to September. The potential annual evaporation is 1200 - 1400 mm, frequently causing droughts in spring and wet autumns. The rainfall also varies greatly among the years. The coastal areas consist mainly of continental deposits. The aquifer has the potential ability to yield large and reliable quantities of water and has been the main water source for domestic, industrial and agricultural utilisation.

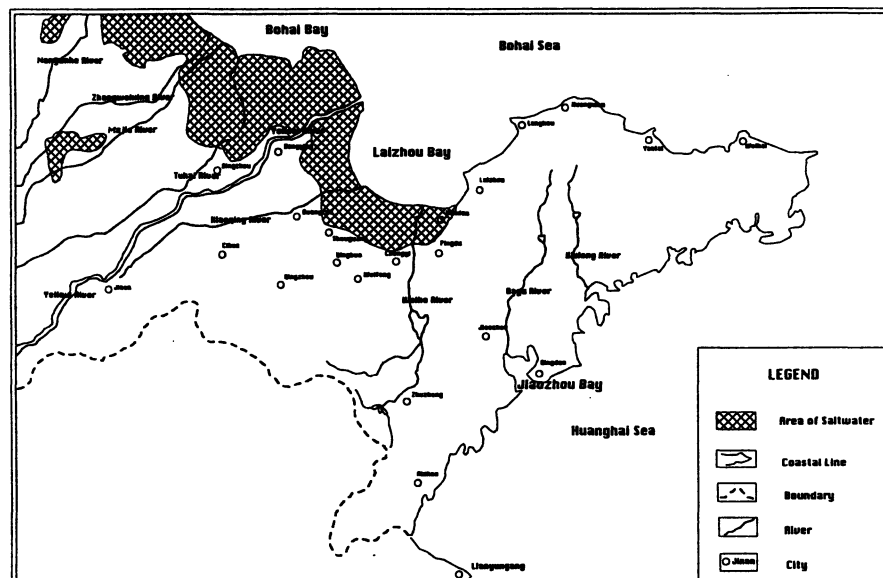


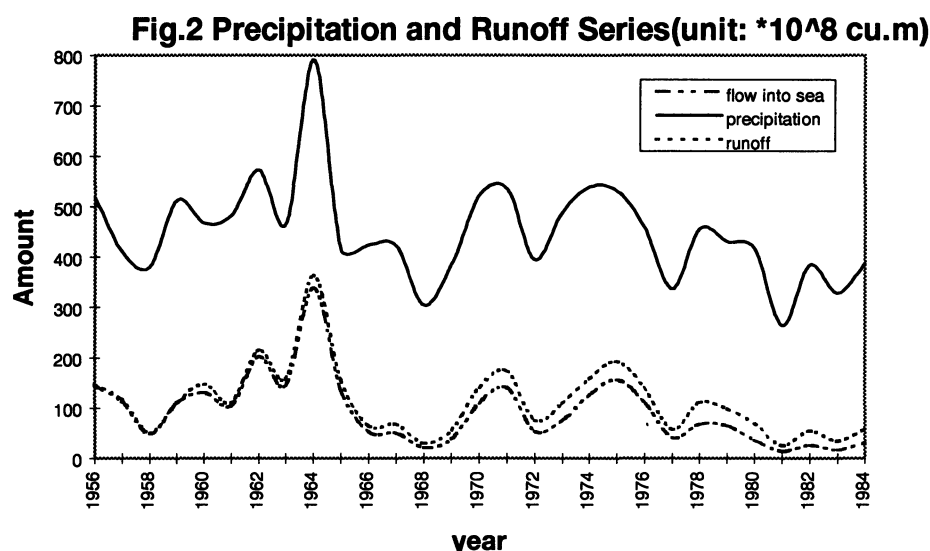
Figure 1 Geographic Location Of the Study Area

3. Description of Sea Water Intrusion and Reduction of Available Water

With the expansion of industry, agriculture and urbanisation, as well as the rising in people's living standard, the amount of water use has increased year by year.

Since 1970s, lack of good management, groundwater recharge reduction, a series of dry years, reduction of runoff into the seas (Figure 2), and over-exploitation of groundwater, have resulted in the phenomenon of sea water intrusion into the aquifer of the Quaternary system. Salt-water diffusion to different degrees has affected the counties and urban districts in the study area. The total area of sea water intrusion into fresh aquifer reached 397 km² in June 1984, with a concentration of chloride ions of more than 250 mg/L (the highest concentration is up to 6900 mg/L). In Hanting, Shouguang, Changyi and Guangrao counties, the area of sea water intrusion is 137 km², with an intrusion rate of 100 m annually.

Upstream of this area is piedmont alluvial plain. There is a sharp boundary between fresh and salt water in the coastal areas of Pingdu, Changyi, Shouguang, and Guangrao Counties. South of boundary region, there is fresh water whose mineralisation is less than 1 - 2 g/L. In the northern boundary region, salt water with mineralisation greater than 2 - 5 g/L is found. During the continuously dry years, the amount of water consumption increased (Figure 2), and groundwater over-exploitation caused different degrees of coastal salt water diffusion, intruding toward the south and polluting the fresh water aquifer. It appears that there is a sharp fresh - salt interface in the mentioned areas. According to incomplete statistics, the affected area is up to 100 km².



Due to the long-term over-exploitation of groundwater in the study area, there was not only sea water intrusion in coastal areas, but also larger areas with a water-table cone of depression. To June 1986, the total area of depression was up to 9600 km² in the coastal zone. The groundwater table is generally 10 meters lower than sea level. The motor-pumped wells and equipment to lift water were almost unusable in the area of water-table depression, so the wells and machine-pumps had to be replaced, which greatly increased the cost of irrigation. Taking Yantai as an example, there existed an area of 40 km², where the water table was lower than sea level. The deepest water table reached 13 meters below sea level. It caused springs to dry up, rivers to stop flowing, and even sewage water permeation polluted the groundwater. The water source field was becoming useless.

As a result of over-exploitation of groundwater, the speed of surface water seeping into the ground is accelerated and surface water levels declined; some rivers, lakes and ponds have dried up in dry years or dry seasons. The regional environment and ecosystem was been damaged; some aquatic plants and animals could not live, some fish and birds disappeared, and biodiversity has been reduced. Drawing down the groundwater table changed the condition of horizontal and vertical infiltration, and led to shallow water pollution.

4. Problems

It is not an exaggeration to say that water supply is the most critical local problem. The sea water intrusion, salt water diffusion, and groundwater depletion has limited the local economic development and threatened the environment where people live.

4.1. Restriction of Industrial Development

Due to the groundwater reduction and sea water intrusion, water supply has been sharply reduced, so industrial water use has been affected. Some factories, construction, and projects have had to stop or partially to stop production due to the lack of water supply. In 1979, the industrial output was reduced by about 90 million Yuan in Yie County.

4.2. Hindrance of Agricultural Production Development

Due to the shortage of irrigation water, the effective irrigation area decreased year by year. In Yenta, effective irrigation area decreased to 1896 million mu in 1989, which was 62% of the cultivated area. From 1980 to 1989, there were 910 million mu per year suffering water shortage due to sea water intrusion and drought, and the food oil production was reduced 1675 million tons. Yie County lost 250 million kilograms compared with 1979. Moreover, 34 villages with a total population of 44900 persons lacked adequate drinkable water. Due to the salinity of groundwater the vegetation of the coastal region is diminishing, which also affects future life in the coastal zone.

4.3. Problems for People's Normal Living

Water is part of everyday human life. Freshwater shortage greatly troubles people's normal living, making it difficult to supply water for both urban and rural people. In Yie County, for example, based on statistics of early 1985, the water quality of 1078 wells in 12 villages and towns became salt because of sea water intrusion.

In some cities during the dry period, water supplies are often managed by putting a limit on quantity time of use. In 1989, for example, in Yenta City, the limit on water quantity use per person was 50 L per day. This not only affected the people's normal living, but also obstructed the development of the tourist industry.

5. Counter-measures

The occurrence and further development of sea water intrusion have already caused attention by affected cities and counties to the need for defining water problems and working out equitable solutions in coastal areas. Some prevention measures have been adopted and good results have been achieved.

Water transfer projects from outside river basins and tide-control gates have been built. This was done to regulate the runoff in the flood period and to divert runoff for groundwater recharge in the groundwater depression cone areas near coastal areas. The purpose was also to build up some projects of diverting water from water source areas to solve the difficulty of water supply for the area near the towns, and to reduce the rate of sea water intrusion.

In Huang county, infiltration wells were drilled in the river and canal courses for increase the amount of groundwater recharge. Water resources management was strengthened. Industrial and agricultural water saving measures widely were taken. In this way, conditions were improved to some degree.

However, the river systems in the study area belong to the same climatic region, so that the wet and drought cycle occurs synchronously in all of the river basins. So, there is no excess water available to be diverted from one river to another. Therefore, the measures taken are still unable to fully solve the problems. In addition, groundwater abstraction is still not strictly controlled, and the water saving measures and regulation on the plantation structure have not been carried out everywhere. So, the sea water intrusion is still not under control.

Diversion of surface water for groundwater recharge is an important measure to solve the water shortage. Along the coastal zone, some water recharge measures have been adopted. For example, building some gates across rivers and excavating water transmission canals; transferring flood water to water shortage areas for recharging groundwater sources; drilling wells in river course and canal bottom and filling them with sand to make the flood water permeate downward; excavating canals and ponds to save surface water for water recharge.

Generally, irrigation is one of the measures for recharge. The methods of over irrigation as well as infiltration of ditches and ponds are used to recharge the groundwater. The results are satisfactory, with the water levels in the cone area raised rapidly. In Huang County, 5000 infiltration wells were drilled and filled with sand along the canal and river bank (each one with a diameter of 1 meter, and a depth of 5 meters) in the western part. The amount of infiltration increase in rainy season is quite obvious, the water table rose rapidly. The results show that diversion of water to recharge groundwater will have a high efficiency if the basins do not have the same wet and drought cycles. However, diverting water or retarding floods in the flood season to recharge the cone of depression areas in the neighbouring basins, has poor results when the wet and drought cycles occur synchronously, especially in long continuous droughts. The problem of the cone of depression in such areas is still not solved.

The types of water recharge projects are well-recharge, ditches, canals, puddle and pond infiltration, field surface irrigation instead of recharge, etc. According to experimental data for the silt and fine sand aquifer, well recharge would require much more investment, while yielding poor results. Usually, the amount of recharge in a well is less than 5 - 10 m³/h and decreases with duration of the recharge. But by utilising ditches, canals and puddles for recharge, good results were achieved. The daily infiltration depth from the water surface of ditches and canals is 0.05 to 0.1 meter or so. The daily infiltration depth from puddles and ponds is 0.02 to 0.07 meter or so. The effect of recharge is better in new puddles and ponds than that in old ones. In the area where the stream water was used as the source of irrigation water, the recharge effect was better, since the rate of infiltration that can be reached is 25% to 35% of the total diverted water. In addition, by using canals instead of wells, the amount of pumped groundwater will be reduced. So if there is a high probability of water sources in such area, then groundwater level can be raised rapidly.

Moreover, when carrying out groundwater recharge, clean water should be used in order to protect the groundwater from pollution.

6. Conclusion

Although many efforts have been made, sea water intrusion problems still exist. A good understanding of the hydrologic regime in the coastal zone is essential for social and economic development, and for preservation of our living environment.

GROUNDWATER DEVELOPMENT AND SIDE EFFECTS IN MAIN CITIES ALONG THE COASTAL ZONE OF CHINA

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1. Abstract

China has a coast line of about 18000 km. Along the coast, there are more than 20 metropolitan areas and cities, such as Tianjin, Shanghai, Xiamen, Guangzhou, Zhanjiang, Zhuhai, and Shenzhen, which are the developed areas in China. As a result of rapid economic development, construction, and of population increase, agricultural, industrial, and domestic water usage are speedily increasing. The conflict between water demand and water supply becomes more prominent day by day in the above cities.

2. The Situation of groundwater development in typical cities along the coastal zone

(1) Shanghai is the biggest economic center in China. The total area is 6200 km² with 12 million population (P=1141 mm, E=1427 mm, T=13-16 °C).

In Shanghai, the main source of water supply is surface water with a small amount of groundwater coming from deep aquifers.

In 1980 (a rainy year), more than 80 hundred million m³ of total water was used; 58 per cent for industries, 36% for agriculture, and 6% for domestic.

The total surface water is about 120 hundred million m³. Because the local runoff and the water from upper reaches are small, per capita quantity of water resources is 1000 m³, only 1/2 of that in the country.

However, Shanghai has plentiful tide water resources (about 470 hundred million m³) that makes up the deficit of local runoff and water from upper reaches.

The allowable withdrawal of groundwater is 10 hundred million m³ (including 4.3 hundred million m³ water from the unconfined aquifer and 5.7 hundred million m³ water from the deep confined aquifer), which is insufficient for water demands of the city because of the small permeability of aquifer, poor water recharge, waste water disposal, and sea water intrusion. According to statistical data for the year 1987, waste water disposal was 5 million tons per day, which was mostly drained directly into the Huangpu river and its branches without waste water treatment. The pollution of surface water and groundwater makes the quantity of water available much smaller.

There is a need to pay more attention to water exploitation and utilisation due to the flat landform, frequent typhoons, rainstorms, and water body contamination. The calamities of flooding, tides, and soil salinization are still not effected with a radical cure in the city.

(2) Tianjin is an another typical example of a water-importing city among cities of Dalian, Xiamen, Shenzhen and Qingdao etc..

Tianjin is the third biggest city in China with 11300 km² and 7.5 million populations. It is in a semi-moist to semi-arid area (P=550-800 mm, E=1000-1200 mm, T=11.7 °C). It is located in the Hai River and Ruan River Basins, where it is one of rainfall-shortage cities along the east of the coastal zone.

In the past, surface runoff mostly passed Tianjin into the sea even during the successive dry years of 1980-1985. The average water flow to the sea was 144 hundred million m³ in the 1950s and 4.66 hundred million m³ during the dry years 1980-1985, and the water quantity could satisfy the demands of agriculture, industrial and domestic use before 1980. Since the end of 1950s, a water crisis has emerged because of large quantities of diversion works constructed in the upper reaches of Hai River, waste disposal, and successive dry years. The water crisis was only alleviated by importing water from the Ruan River into Tianjin city for use after 1983.

In Tianjin, the hydrogeological conditions are similar to Shanghai. The shallow aquifer is the main exploitation aquifer due to high salinity water in deep aquifer. The allowable yield of groundwater is 0.1 hundred million m³ within the downtown of the city. Because of groundwater overpumping (1.1-1.2 hundred million m³/year), land subsidence and sea water intrusion have occurred.

For solving the problems of water shortage, water has been imported from Ruan River. Works for importing water from the Yellow River and the Yangzi River are being planned.

(3) Qinhuangdao city is more than 3000 years old. The area is about 7790 km² with 124 km coast line and more than 2 million population (P=690 m, T=10.1°C).

It has a continental climate, in the semi-moist monsoon region of the warm temperate zone.

There are more than 100 rivers passing through the city. The precipitation is mostly concentrated in the flooding season that makes up 1/3 of total annual rainfall. In January, the precipitation only accounts for 2% of the total.

The rivers along the coast have short courses and rapid flow with poor water regulation because 70-80% of the annual water flow occurs during the flood season.

The main reservoirs (such as Shihe reservoir) are small for water supply to the city in a dry season. In rainy years, a large quantity of water is drained away directly into the sea.

The total groundwater quantity is about 6.1 hundred million m³ that is mainly distributed in the plain of alluvial fans of the Ruan River and the Yang River. The aquifer is thinner (depth of bed rock is 10-20 metres), so the allowable withdrawal of groundwater is only 0.12-0.18 hundred million m³. As a result of lack of surface water, sea water has invaded inland due to groundwater overpumping, which has made water quality worse along the coast area.

The city is one of the water-deficient cities in China, where water-importation works and conservation constructions are urgently needed to meet the water demands of Qinhuangdao city.

(4) Guangzhou is the biggest city in the south part of China with 16631.7 km² area and more than 7.1 million population in 1987. It is in the tropical monsoon climate of south Asia, (P=1600-2000 mm, T=21°C). It is situated in the south-central plain of Guangzhou province, where the Zhu River delta is the north boundary, near Hong kong and Macao in the confluence of the East River, West River and North River. The Zhu River passes through the city.

Guangzhou is rich in shallow groundwater. The annual quantity of groundwater was 54.45 hundred million m³, accounting for 26.7% of surface runoff in 1987. The natural water quality is good with the exception of the river mouth area where the total dissolved solids and hardness are high due to tidal influence. At present, groundwater is mainly supplied for sanitary use.

The surface water is abundant including transit water (about 500 hundred million m³) and flood tide water (4.6 hundred million m³ and good quality in flooding season). The average river flow per year is 203.6 hundred million m³ (Per capita quantity of water is 2866 m³), 70-80% of which occurs in the flooding season that is the same as maximum rainfall distribution.

Even so, people are still facing a future water crisis in Guangzhou city because of the areal expansion of the city, rapid development of industries, deforestation and decrease in grass land, water pollution, waste disposal and low rate of waste water treatment, etc..

For solving the problem of lack of water, importing water from the North River and West River into Guangzhou city is essential.

3. The side effects induced by groundwater overdevelopment

When water resources bring benefit to mankind, they also give various ecological and environmental problems as side effects in the process of development and utilisation.

Especially because the cities along the coastal area of China are economically developed areas, the water demands there are much bigger. Groundwater is one of main sources in these cities. Many environmental side effects have taken place and are taking place due to groundwater overpumping.

The main side effects can be described as follows:

(a) Sea water intrusion

Since 1970s, because of overpumping of karst water, the groundwater level dropped by 10-40 metres in comparison with that in 1964, which led to sea water intrusion and chloride ion increase to 1.3 g/l in the wells of some water works along the coastal area of Dalian City of Liaoning province.

The area of sea water intrusion was 360 km² and involved 10 counties of this city. The groundwater level was 10 metres lower than sea level, causing 2000 wells to be abandoned and 266.4 km² of farmland to become saline in Longkou and Laizhou cities of Shandong province in 1981.

Since the 1950s, because of groundwater overpumping in some water works of Beidaihe City, the sea water intrusion has invaded inland with a speed of 8 m/year which caused water deterioration and drops in crop production.

At present, with rapid economic development, similar incidents have occurred along almost the whole coastal area of China, from Dalian, Yinkou, Beidaihe of Laizhou bay in the North, to Shanghai, Ningbo, Dongshan island of Fujian province in the East, and to Zhangjiang, and Beihai in the South. The distance of sea water intrusion inland has been more than 10 km along coastal area of Bohai Bay.

(b) The problems of environmental geology

Groundwater is an important factor for maintaining the natural stress balance of strata. Large-scale abstraction of groundwater will lower water head pressure in the aquifer and destroy the stress balance of strata, which will cause some geological problems, such as land subsidence, ground fissures and collapse, etc.

Land subsidence has occurred in the cities of Shanghai, Tianjin, and Suzhou along the coastal area. The biggest depth of land subsidence is 2.37 and 2.70 metres in Shanghai and Tianjin respectively, which has destroyed building foundations and caused disastrous sea tides.

Moreover, in Tianjin city, the flood control dike on banks of Hai River has subsided 1-2 metres. The capacity of flood discharge of Hai River was decreased from 1200 m³/s to 400 m³/s. Many sluice gates of the river were damaged due to land subsidence.

Now, the altitude of the land surface is less than 2 metres higher than sea level along coastal areas of Tanggu, Hangu, Dagang and the downtown of Tianjin, which will be inundated with sea water if the land surface continues to subside.

Land collapse is the greatest problem of environmental geology in buried karst pumping areas. Usually, the fillings and water escape from karst caves, and latent corrosive action is aggravated due to groundwater pumping; then land collapse occurs as a result of disruption of the stratum.

Generally speaking, the land collapse often happens so suddenly in karst areas that control measures are usually very difficult to adopt in time. For example, when a 50000 m³/d water supply work was built in Liujiang basin of Qinhuandao city of Hebei province, after a half year, 1700 buildings in 16 villages were damaged because of 286 land subsidence and collapse **occurrences within an area of 28.32x10⁴ m².**

Similar incidents occurred in Guanghua basin on the north of the Zhu River Delta. It is a syncline basin of carbonate rock covered by Quaternary loose deposits where more than 100 wells were distributed with 75000 m³/d of total pumping quantity in 1987. Because of overpumping, 140 land collapses and ground fissures have happened in the basin and 73 buildings have cracked to various degrees.

(c) Water quality deterioration and human health

Some important environmental side effects insidiously emerged due to unreasonable groundwater development. For instance, the regional groundwater level continuously dropping down has resulted in a percentage decrement of total surface water cover from 27.8% in the 1950s to 7.7% in the 1980s which made land desertification and salinization increase, while the precipitation and moisture were decreasing and temperature rising slowly (The average temperature increase was 1°C in the 1970s and 0.4-0.6°C in the 1980s).

The incidence of fluorosis and liver cancer has risen in the past few years along the coastal area, which has a close relationship with the bad quality of drinking water. Because of lack of fresh surface water and shallow groundwater, some residents have endemic disease of fluorosis and goitre resulting from drinking water with high fluoride or iodine content from the deep aquifer.

Along the coastal area, Guangxi, Guangdong, Jiangdshu, Fujian, Zhejiang, Yangzi Delta and the Zhu River Delta are areas of high incidence of liver cancer because of bad drinking water quality.

According to the statistical data at the end of 1980s, waste disposal was 340 hundred million m³/year, more than 75% of which came from industrial waste in China.

The Yangzi River Delta and the Zhu River Delta are the main industrial developed areas where a large quantity of waste disposal without waste water treatment is the primary cause of water pollution. This area is the heavy endemic disease area.

In sum, groundwater resources are precious for mankind, but they also give many kinds of ecological and environmental problems under unreasonable groundwater exploitation.

Making full use of water resources while controlling the side effects is the pressing task for hydrogeologists. Some measures, such as water resource regulation, water level control under optimal condition, artificial recharge and comprehensive development of groundwater and surface water must be adopted under different conditions in different places.

The prefect water management organisation and water law are also required for solving the problems mentioned above.

*QUANTIFICATION OF GROUNDWATER INPUTS TO THE COASTAL OCEAN AND RESIDENCE TIMES OF COASTAL WATER USING RADIUM ISOTOPES

MOORE, W.S.

Submarine discharge of groundwater may be as important as river discharge for the supply of some elements to the ocean. Because of the diffuse nature of this source and the difficulty in recognising and quantifying its importance, few investigators have attempted to assess the impact of submarine groundwater discharge (SGWD) on ocean chemistry. Evidence is mounting that SGWD must be considered in the mass balance equation for the supply of some elements to the ocean (Moore 1996; Moore and Church 1996, Rama and Moore, in press). New methods are needed to assess the magnitude and impact of this process.

To assess the impact of SGWD, it is critical to know the total dissolved flux of components of interest from coastal regions to the ocean. Short lived Ra isotopes, ^{223}Ra (half life = 11.3 days) and ^{224}Ra (half life = 3.6 days), constrain the mixing time across the coastal ocean. Therefore, offshore gradients of dissolved components in coastal waters coupled with these exchange rates provide an estimate of fluxes to the ocean. These fluxes must be sustained by input from rivers, SGWD, or other sources.

Submarine groundwater is a mixture of fresh groundwater and sea water; chemically, it is very different from either component because of reactions with aquifer solids. For example submarine groundwater entering the Bay of Bengal during low river discharge is at least a factor of 3 supersaturated with respect to barite, and more likely a factor of 10 supersaturated (Moore, submitted). Groundwater entering the South Atlantic Bight contains at least 100 times more ^{226}Ra and 10 times more Ba than local rivers (Moore 1996; Shaw *et al.* submitted).

Estuarine processes sequester many of the trace elements and nutrients delivered by rivers through processes such as flocculation, adsorption and intense biological productivity. Consequently, estuarine processes (rather than river water chemistry) determine the net flux of many elements to the coastal ocean. Because SGWD largely bypasses the estuary filter, the elements delivered by this route are more likely to be mixed into the ocean interior rather than removed into estuarine and coastal sediments. Thus groundwaters represent an input flux of trace elements and nutrients for which the magnitudes and the chemical processes are virtually unknown. New methods are needed to assess this input.

Ra based mixing rates coupled with solute concentrations yield a transport flux for dissolved constituents from the coastal zone into the ocean. In order to understand the process that control these fluxes, the transport studies must be coupled with a detailed evaluation of groundwater input processes. Groundwaters are distinctly different from river waters and as such contribute a very different chemical flux to the ocean.

Most of our work has been along the southeastern coast of the US. Here we find ^{226}Ra activities greatly exceeding the amount that can be supported by river input (Moore 1996). The source of this extra ^{226}Ra must be the discharge of salty groundwater. Intrusion of salt water into coastal aquifers facilitates the desorption of Ra from the sediments. Flushing of this chemically altered groundwater into the ocean explains the high ^{226}Ra activities. Sizeable contributions of Ba, P and N are also provided by the groundwater discharge.

This paper explores the use of short-lived Ra isotopes, ^{223}Ra and ^{224}Ra , to establish residence times of coastal waters and uses the residence times to estimate fluxes of elements to the ocean. I apply these concepts to evaluate the importance of groundwater as a source of ^{226}Ra and Ba to near-shore waters.

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ASSESSMENT OF SALTS DISCHARGE WITH GROUNDWATER TO SEAS

SAFRONOVA, T. I

1. Abstract

The submarine groundwater runoff is often the main cause of formation of large geochemical anomalies in the bottom and sea sediments. In turn, anomalies in geochemical fields at sea bottom are indicators of submarine groundwater discharge. Subsurface dissolved solids discharge to seas is governed by the rate of submarine groundwater discharge, washing of water-bearing rocks, paleohydrogeological and present conditions of groundwater formation, as well as human activities in the coastal zones. The total discharge of salts with groundwater to oceans amounts to 52% of salt discharge with river inflow. Therefore, the estimates show that submarine discharge of groundwater can have substantial effect on the salt and hydrobiological regime of seas and oceans, biogenic sedimentation, and formation of mineral deposits in bottom sediments.

2. Introduction

Oceans, marginal and inland seas are the main base of drainage of surface and groundwater runoff. In this connection, their salt balance is generated under the influence of salt transport by river and ground waters. Of these two main sources of dissolved solids supply to seas, river dissolved solids transport has been studied sufficiently. Estimation of the contribution of groundwater runoff to dissolved solids transport has been complicated until recently by lack of data on regional groundwater discharge directly to seas.

As result of studies carried out in separate regions show, direct groundwater discharge to sea bypassing the river network in respect of the total river runoff is usually expressed by a small value. At the same time, the contribution of subsurface dissolved solids discharge to the salt balance of inland seas is appreciable and accounts for tens of per cent of the surface dissolved solids transport by rivers. For example, the transport of salt by groundwater to the Caspian Sea accounts for 27% of dissolved solids transport by rivers, while the groundwater discharge to the sea does not exceed 1% of river inflow (Dzhamalov *et al.*, 1977).

In the distribution of the groundwater and subsurface dissolved solids discharge to seas, the general vertical hydrodynamic and hydrochemical zonality for the groundwater is observed; this zonality governs the increase in the total transport of salts with depth despite the general reduction in groundwater discharge. This general law is sometimes disrupted by the effect of local hydrogeological conditions (wide occurrence of karst, presence of salt-bearing rocks, and processes of continental salinization). For instance, the largest values of subsurface dissolved solids discharge to the Baltic Sea ($48.5 \text{ t yr}^{-1} \text{ km}^{-2}$) are characteristic for the coastal portion of the Silurian-Ordovician plateau, where submarine groundwater flow is mainly generated in aquifer systems composed of karstified limestones and dolomites.

3. Main results and discussion

It should be noticed that the contribution of subsurface dissolved solids discharge to generation of the salt regime of seas may appreciably increase with a decrease in total river runoff under the action of natural factors and the human impact. Salinization of the deep portion of the sea would occur more intensively since there water-exchange periods are longer. The salinization of some deep hollows in inland seas, being observed at present, may be caused in addition to other factors, by the increasing influence of subsurface dissolved solids discharge from deep aquifers. Apart from the effect of groundwater runoff on the total salt balance of seas, it is often the main cause of formation of large geochemical anomalies in the bottom water layer and sea sediments. In turn, anomalies in geochemical fields at sea bottom are indicators of submarine groundwater discharge.

The salt transport by groundwater to the Atlantic Ocean amounts to 470 million t/yr, and to the Arctic Ocean (from estimated drainage areas) 7 million t/yr. The total supply of salts with groundwater to oceans amounts to 1300 million t/yr that is 52% of salt supply by river runoff amounting to 2480 million t/yr (this last figure does not include the dissolved solids transport by river from major islands). The proportion between surface and subsurface dissolved solids discharge amounts for continents is presented in the following Table 1.

Table 1. Estimated continental surface and subsurface dissolved solids discharge.

Continent	Surface dissolved solids discharge (Mt/yr)	Average salinity of river water (g/l)	Subsurface dissolved solids discharge (Mt/yr)	Average total groundwater dissolved solids content (g/l)
Europe	240	0.077	60	0.4
Asia	850	0.065	296	0.9
Africa	310	0.072	288	1.0
North America	410	0.069	149	0.4
South America	550	0.053	113	0.3
Australia (including Tasmania, New Guinea, New Zealand)	120	0.060	199	0.5
World's total	2480	0.063	1045	0.6

Note: Data on surface dissolved solids discharge and average river water salinity are taken from the book by M.I. Lvovich (1974). The value 1045 Mt/yr does not include discharge from major islands.

Subsurface dissolved solids discharge to seas is governed by the rate of submarine groundwater discharge, washing of water-bearing rocks, paleohydrogeological and present conditions of formation of groundwater dissolved solids content and composition, presence of evaporites and development of continental salinization processes in arid regions.

The tabulated data show that the average total dissolved solids content of groundwater discharging directly to oceans from the area of Asia is equal to 0.9 g/l. However, in arid and semi-arid regions, a decrease in submarine groundwater discharge is attended by an increase in total and specific values of subsurface dissolved solids discharge.

An anomalously high salt evacuation by groundwater is observed in areas with evaporite deposits where they contact water-bearing rocks (the Red Sea and the Persian Gulf). It is a determining azonal factor of dissolved solids discharge formation.

The Red Sea basin is noted for very peculiar groundwater runoff conditions. As to tectonics, the region is located in a rift zone whose sites are a system of grabens of different age. The grabens are filled mainly with sedimentary rocks with large inclusions of evaporites. In this connection, discharge sites of thermal water having a high dissolved solids content are observed largely in the deeps of the Red Sea. Unfavourable recharge conditions are responsible for very insignificant regional submarine groundwater discharge values commonly not exceeding $0.1 \text{ l s}^{-1} \text{ km}^{-2}$. At the same time, the high dissolved solids content of groundwater is the cause of a substantial salt discharge to the sea (its total amount equals 22.2 million t/yr and the discharge rate is up to $150 \text{ t yr}^{-1} \text{ km}^{-2}$).

The values of specific submarine groundwater discharge to the Mediterranean Sea from the area of the Near East and Asia Minor are usually no more than $3 \text{ l s}^{-1} \text{ km}^{-2}$. The groundwater dissolved solids content is diverse and commonly increases southward (up to 12 g/l) where gypsums, limestones, and terrigenous deposits occur among other rocks. The higher salinity of groundwater is responsible for the fairly appreciable subsurface dissolved solids discharge to the Mediterranean Sea from the Asian continent, the specific discharge rates gradually rise from north to south from 46 to $140 \text{ t yr}^{-1} \text{ km}^{-2}$.

The broad development of karstified carbonate rocks and fissured sandstone on the Florida Peninsula results in an azonally high submarine groundwater discharge whose specific rates sometimes exceed 6 l/s per sq. km. A tongue of fresh and brackish groundwater, formed inland in Paleogene and Cretaceous limestones, is traced under the floor of the Atlantic Ocean 120 km off shore down to a depth of over 600 m. Submarine groundwater is commonly freshened in the influence zone of coastal artesian basins. At the same time, the existence of submarine water with a salinity of over 35 g/l is indicative of the occurrence of salt-bearing rocks at some depths in the majority of cases.

On the whole, the wide distribution of fresh groundwater all over the Atlantic coast of the USA is responsible for the insignificant subsurface dissolved solids discharge here, its specific discharge rates gradually increase from 10 to $40 \text{ t yr}^{-1} \text{ km}^{-2}$ in the direction of the Florida Peninsula.

The Eucla basin is a typical example of artesian basin of arid desert regions in Australia. In this artesian basin, water-bearing Paleogene cavernous limestones are not practically recharged now because annual precipitation here does not exceed 180 mm. In this connection, the groundwater discharge to the oceans from the Eucla basin is as small as $0.1 \text{ l s}^{-1} \text{ km}^{-2}$, while the subsurface dissolved solids discharge amounts to $75 \text{ t yr}^{-1} \text{ km}^{-2}$ is due to the high salinity of groundwater.

In the distribution of submarine dissolved solids discharge values, their dependence on latitudinal physiographic zonality may be observed since salt transport with groundwater primarily depends on submarine groundwater discharge (Zektser *et al.*, 1984). Fresh and weakly mineralised groundwater flows to seas largely from the upper hydrodynamic zone. The dissolved solids content of groundwater increases largely due to the presence of salt-bearing rocks, processes of continental salinization, stagnant flow regimes, or weak flushing of aquifers. These conditions of formation of the chemical composition of groundwater are often encountered within African and Australian coasts, which leads to azonally high values of submarine dissolved solids discharge in some areas there. The complicated character of dissolved solids discharge distribution indicates that this natural process is greatly governed by paleo- and recent geological and hydrogeological conditions of groundwater discharge generation. In other words, the regional effect of the latitudinal physiographic zonality on the distribution of principle runoff-forming factors is levelled or complicated in separate coastal areas by local conditions of the generation of the chemical groundwater composition.

4. Conclusion

Thus, submarine groundwater discharge may exert a considerable influence on the salt and hydrobiological regimes of seas and oceans, on processes of biogenic sedimentation and on formation of mineral deposits on sea floor. The significant role established for salt transport by groundwater discharging to seas (52% of surface dissolved solids transport) should drastically modify existing concepts in which the primary biological products of seas and the scale of biogenic sedimentation are considered to be limited only by the amount of salt transported by rivers to the seas (Zektser *et al.*, 1984).

5. Acknowledgements: This research has been carried out with support of Russian Foundation for Fundamental Investigations (Project 95-05-64107).

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SOVERI, J.

All Nordic countries have operative national groundwater observation networks, which were established during the International Hydrological Decade (1965-1974). The networks provide several types of data to be utilized both in research projects and as reference material. It should also be performed to provide good information for integrated management of environmental sectors. A better understanding the complex interaction between groundwater, terrestrial and coastal systems requires more detailed studies on chemical and physical processes in catchment areas and long-term monitoring of groundwater quality and quantity.

This presentation is an outline of a joint project proposal including participants from Denmark, Estonia, Finland, Latvia, Lithuania, Norway and Sweden. The main aim of the project is to develop a compatible groundwater monitoring system in the Nordic and Baltic Countries, i.e. to establish joint databases, exchange information for the regional planning of groundwater abstraction, evaluate the changes and trends in groundwater quality and prepare and implement common groundwater protection measures. The overall objective of the project is to establish the necessary basis for a common, comparable groundwater monitoring programme in the Baltic Drainage Basin as a part of the entire monitoring of the Baltic Region.

The Baltic Sea is a semi-enclosed sea of about 370 000 km² of brackish water, and its volume about 21,000 km³. The watershed is more than four times as large, inhabited by 80 million people. From the watershed area with all ongoing human activities, waste production, leaching of agricultural chemicals etc., the fresh water is discharged into the sea from hundreds of rivers and water courses. The annual fresh water input totals is estimated to be approximately 450 km³.

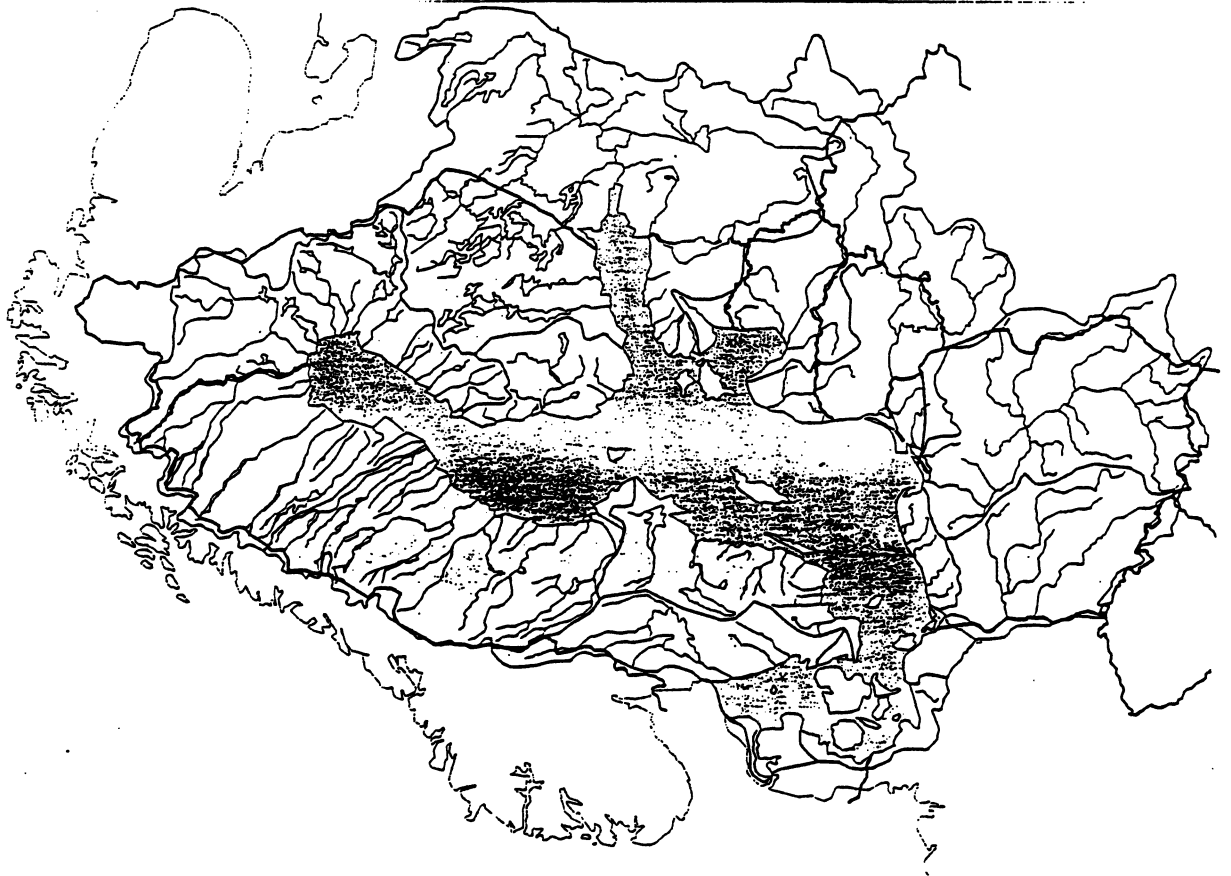
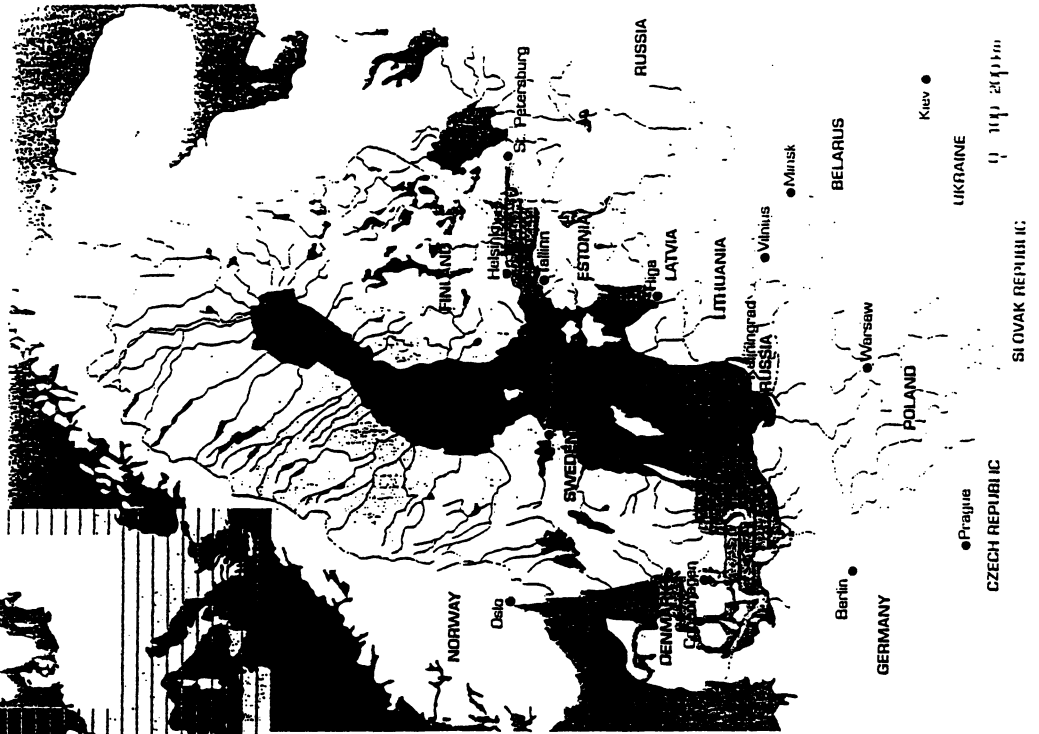
The part of groundwater runoff to the Baltic Sea is not well known. In order to assess the impact of groundwater quality and quantity on the Baltic Sea environment, and the ecological conditions of the Baltic Region it will obviously be of great importance to establish and operate a coordinated groundwater monitoring programme, including comparable methods and standards.

Fig.1. The Baltic Sea drainage area touches upon 14 countries.

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SUOMEN YMPÄRISTÖKESKUS
FINLANDS MILJÖCENTRAL
FINNISH ENVIRONMENT AGENCY

GROUNDWATER DISCHARGE CONTAMINATION TO THE BALTIC SEA AND PLAN OF ITS STUDY VORONOV, A.N., O.V. KUZMITSKAYA and A.A. SHVARTS

The groundwater discharge pollution is very dangerous for inland seas that have limited links with the ocean. The Baltic sea is one of such seas. Twelve industrial developed countries where more than 65 million people live are situated within the Baltic sea basin. A large number of industrial centres – St. Petersburg, Riga, Tallinn, Helsinki, Kaliningrad, Gdansk, Kiel, Copenhagen, Stockholm – are all round the sea. Despite the large sea surface area (above 415000 km²), total water volume is not great.

There is no question that the sea gets a major part of pollution with surface discharge; however, the contamination received by way of groundwater discharge is also considerable. There is a sluggishness of the groundwater changes in bottom sediments that are the most vulnerable part of ecosystem. There are also difficulties in the study of the process. It should be specially noted that although the generalised coast line has 7000 km length, it's length including gulfs and islands is about 22000 km. One should not underestimate the influence of groundwater discharge contamination upon ecosystem; oceanography papers and reports often do not take into consideration underground water flow.

However, not long ago (June 1993) this problem was discussed at the International congress "Ecological Hydrogeology of the Baltic Area" in St. Petersburg. This congress was organised by St. Petersburg and Wroclaw Universities and was sponsored by the International Association of Hydrogeologists, the International Association of Hydrological Sciences, and the Russian Academy of Science. There were more than 200 representatives from 22 countries. The results of study of groundwater discharge to the Baltic sea in different countries were reported. The great pollution of Baltic groundwater due to anthropogenic influence had been pointed out.

The concrete example of influence of underground water flow on the Baltic sea were considered in some reports. Large numbers of contamination types changing the sea water quality were mentioned. This contamination worsens ecological conditions of the waterside zone. However, reports on groundwater pollution influence on biological organisms, geological environments, water-supply quality, and its social and economic results have not yet been submitted.

In the nearest future scientists must focus their attention on following questions:

- estimation of the pollution carried by underground water flow;
- chemical processes of the interaction between bottom deposits and groundwater in the seaside zone;
- new methods of ecological estimates of coastal zone and water state.

For these reasons the Department of Hydrogeology of St. Petersburg University began a systematic investigation of pollution groundwater flow within the Russian part of the coast of the Baltic sea. The coast line of the Finnish Gulf is about 300 km. The depth of the gulf is less than 50-100 m. The hydrological condition of this part of Baltic sea is controlled by the Neva river. The average water flow of the Neva river consists of 3500 km³, and area of its basin is 202000 km². The new dam that separated the most shallow part of gulf from the sea changes the hydrological regime of the gulf.

The underground flow to the Finnish Gulf consists of two parts: immediate discharge of groundwater, and underground flow to rivers and lakes which are connected to the sea. There are two largest fresh water lakes, Ladoga and Onega, within the basin of the Neva river. The Neva river transports Ladoga water to the Finnish Gulf.

The immediate discharge of groundwater in turn can be divided into flow of water from the upper hydrodynamic zone and discharge of deep aquifers that contain unconfined water. The discharge of shallow groundwater occurs all along the coast. On the north part of the gulf it is discharged from fissure zones of crystalline rocks of Archaic basement and from aquifers of glacial layers of the Carelian isthmus. On the south coast of the Finnish Gulf it is discharged from an aquifer of Ordovician limestone which contains large water systems. It is possible that the Gdov aquifer on the Carelian isthmus discharges immediately into the Finnish Gulf. However, because of reduction of water level it is possible that the process has reversed.

The Hydrogeological Department of St. Petersburg University has been carrying out ecological and hydrogeological mapping of subsurface water discharge to eastern part of the Baltic Sea (Finnish Gulf). The methodological principals of such mapping has been worked out. The set of four maps shows pollution of the aquifers.

The first map shows the economic view of the territory, and potential sources and types of water pollution. There are agricultural lands, stock-breeding farms, roads, railways, industrial enterprises, etc.

The second map characterises the degree of aquifer vulnerability. This map is based on the information which makes it possible to estimate the protection of the aquifer from surface pollution and the speed of movement of the front of polluted groundwater.

The third map shows water quality and pollution of the upper aquifer by toxic and bioactive substances.

The fourth map shows the main recipients of pollution, mainly the existing and planned water protection zones, showing area in which the water flows to the water intakes.

The zones of water recharge and discharge, surface water courses, pollution control wells and others are also shown on the map. The maps are not overloaded and can be easily read. The number of maps can be increased according to concrete tasks.

The most contaminated part of the underground flow is the water discharge from urbanised territories. The groundwater of St. Petersburg and its vicinity is very polluted. The degree of contamination increases from residential districts to the central part of city. Heavy metals, organic substances, sulphates, and radioactive elements are founded in the upper horizon of subsurface water. Total mineralisation has increased to 3-4 g/l. The acidity of water also increases in some cases. The water has high agressivity. The groundwater is discharged into the Finnish gulf directly and into a number of flows and rivers.

The Karstic water of the Izhorskoe plateau which is discharged immediately to the Finnish Gulf in the Estonian part of the Baltic coast and by small rivers on the south part of Baltic coast of Russia is very contaminated. The basic type of contamination is agricultural. Nitrate, pesticide, organic substances, and others are found here. The nitrogen contamination is widespread within the region. The main part of this contamination is nitrates. It reaches 50-100 mg/l to the northwest. The main pesticide is Lindan. Industrial and chemical contamination have local characteristics. Oil contamination have also found in some places.

The groundwater of the Carelian isthmus is cleaner. One encounters local contamination only in the places where clays have been removed.

In the course of the Ecobalt congress it was noted that contamination of the Baltic Sea was wide spread and study of the shelf and shore was necessary. It must be a joint project. The international programme of study of contamination water flow was accepted.

Among the main problems to be solved are:

- working out and improvement of methods of ecological and hydrogeological mapping;
- improving of the chemical-analytical base of ecological study;
- working out of complex methods of quality evaluation of water resources and the geological environment;
- elaboration of monitoring principles and creation of effective measures against groundwater flow pollution;
- creation of a data bank on groundwater and creation of a package of ecological hydrological maps for the basin of the Baltic Sea.

3.3 Original Program Abstracts (presentations not represented by a full paper or extended abstract)

METHODS FOR EVALUATING GROUNDWATER DISCHARGE AS APPLIED IN SOUTHERN ITALY AURELI, A.

The study group within the Geology Institute of the Catania University, under the scientific direction of prof. A. Aureli, for more than 20 years has been interested in the problems concerning the exchanges that take place in coastal aquifers between fresh and sea water.

The study has been led by clearly distinguishing diffused exchanges from concentrated ones.

The first ones originate exchanges that are difficult to measure.

The second ones originate submarine or coastal springs.

The most recent techniques such as thermoscopy, salinometers and remote sensing have been used to evaluate their possible utilisation in analysing water exchanges along the coasts.

These methods have been tried along the coasts of Sicily and Calabria, allowing us to identify and study in a particular way the main submarine springs that we have spotted. We have also led sea campaigns to study the behaviour of some of these springs.

In a special case we have identified the paths of ground feeding of some submarine springs through the colorimetric method.

An extreme economical and practical importance have also revealed the studies concerning the sea intrusion phenomena along the coasts.

The editing of detailed Hydrogeological Maps to a scale of 1:50.000 of some of the coastal zones of Sicily has pointed out the entity of the phenomenon of the increasing salinity of coastal aquifers due to primary permeability as well as their path along the tectonic dislocations in aquifers with a secondary permeability.

We have also been able to follow and analyse the link between tectonic structures and the formation and development of karst phenomena in a coastal setting.

In general we have detailedly studied 936 km of coasts in Sicily and 593 km of coasts in Calabria.

We have identified 134 submarine springs in Sicily and 61 in Calabria.

We have reckoned that, altogether, the coastal aquifer losses into the sea, in Sicily, amount to an average 284×10^6 cubic meter a year. For Calabria this figure has come out to correspond to 104×10^6 cubic meters.

The vulnerability maps of the south-east coastal region of Sicily, which are to be seen on posters, give an idea of the researches carried out and of the obtained results.

ESTIMATING SUBSEA GROUNDWATER SEEPAGE FROM A COASTAL PLAIN
BOKUNIEWICZ, H.

ABSTRACT

Coastal plains cover about 5.7 million square kilometers of the earth's surface. The coastal plain of the United States has an area of 940,000 square kilometers. It is one of nine major coastal plains worldwide. The others are along the Caribbean coast of Mexico, in Venezuela and French Guinea, at the Amazon delta, in northern Europe, Mozambique, southeast Asia and Siberia. The hydrology of the U.S. coastal plain has been studied extensively and modeled by the U.S. Geological Survey under its Regional Aquifer Systems Analysis Program between 1979 and 1987. Although specifically focused on the emergent coastal plain, model results showed a diffuse seepage across the shelf corresponding to subsea discharges of up to several thousand liters per day per meter of shoreline. High rates appeared off the coasts of New York and the Carolinas. Seepage of the Long Island coast had been measured; seepage rates have also recently been confirmed at least 37 km off the Carolina coast amounting to 40% of the river flow (Moore, 1996, Nature 380:612). The concentration of subsea seepage near the shore was unresolved by the regional model. Even with this attention, estimates of the magnitude and distribution of the direct seepage of groundwater are difficult to obtain and estimates of less well studied coastal zones are uncertain. A simple, cross-sectional analytical expression may be used to guide professional judgment in making estimates especially where numerical solutions are lacking.

Along the New York coast, the observed rate of seepage decreased rapidly offshore, as expected. For a homogeneous, anisotropic coastal aquifer, the outflow gap is expected to be approximately $4l/k$ where l is the thickness of the aquifer and k is the square root of the ratio of vertical hydraulic conductivity (K) to the horizontal hydraulic conductivity. The total discharge per unit length of shoreline is $\pi K i l / 2k^2$ where i is the hydraulic gradient at the coast. The expression is an upper limit because it does not take into account a substantial recirculation of salt water which can be driven by the same hydraulic potential. Even simple aquifers may not be well-characterized by singled valued parameters and systems of confined aquifers can only be qualitatively described. Observed seepage magnitudes and distributions off the shore of Long Island, NY were fairly well described by the analytical impression, within the range of parameters, very near shore where the surficial aquifers are expected to control the flow. Empirically, the seepage amounted to almost 9000 liters per day per meter of shoreline or 20 to 35% of the total freshwater supply. An outflow gap of at least 8 kilometers was forecast but deep, confined aquifers add an anisotropy which forces low seepage rates far offshore.

STUDY OF THE DISCHARGE OF GROUNDWATER CONTAMINATED BY OIL PRODUCTS IN THE COASTAL ZONE OF SEAS

BOREVSKY, B.V., BOREVSKY, L.V. and SHCHIPANSKY, A.A.

Actually the contamination of sea areas presents a real ecological hazardous problem in the worldwide. One of the most contamination sources is the groundwater discharge to the sea in the coastal zones where are concentrated a number of industrial and civil objects. Ground water contamination by hydrocarbons is the most dangerous and complicated problem for studying. So, were formed two contaminated phases, such as contaminated ground water and free oil products floating on the ground water surface. The last one, moving towards to the sea, creates a visual environmental contamination of the sea on large areas, and the extent of contamination widespreads not only over the sea water but also in bottom sediments, beach deposits, and sea biota. On the other hand, the saturation of clayey rocks by hydrocarbons decrease their structural associations resulting in increasing the rate abrasion seashores.

The studying the ground water mass transport in these conditions is a complex and multi-purpose problem. The difficulties of its solving are aggravated by the fact that the theorie of two-phases flow in unconfined aquifers and interaction in the system shore/ sea in conditions of the adverse contamination by hydrocarbons is not aequately developed. Moreover, the evaluation of quantitative characteristics of contaminated ground water and oil products as well as forecasts changes in time and space needs important financial and material expenses.

The investigations results of large technogenic oil products in the coastal zones of the Sea of Azov (town of Eysk) and Black Sea (town of Tuapse) are taken as examples. The above sites are essentially differed one from another by complex hydrogeoecological conditions. If in the first case (Eysk) the ground water flow is confined to semipermeable loess-like loams taking into account the fact that the value of permeability for hydrocarbons is greatly more than that for water, in the second case (Tuapse) the groundwater flow is associated with alluvion deposits having high permeability and variable hydrogeological conditions which are typical for mountain rivers in the Caucasus.

In this paper are considered the concepts and methods of ground water investigations under conditions of geoenvironmental contamination by hydrocarbons in the sea coastal zone as well as forecasts methods of contamination evolution processes.

GEOCHEMICAL APPROACH TO THE EXAMINATION OF SUBMARINE DISCHARGE OF
GROUNDWATER IN THE COAST AREA
BROUSILOVSKI, S. A.

In the wide complex of hydrodynamic, hydrochemical, geophysical, balance, aerospace and other methods of examining submarine discharge of ground water employment of geochemical methods is perspective as well. Display of submarine discharge as geochemical or temperature anomaly in bottom and especially surface sea water can be seen very seldom, only in case of concentrated spring discharge and large expenditure, as bottom currents, turbulent mixing process lead to concentration and temperature equalization, that limits the use of many methods.

The most common features of submarine ground water discharge are interstitial water, anomalous in composition, and chemosedimentation processes of a number components of ground water on oxidation-reduction, hydrogen sulfide and sorption barriers in sea sediments. Almost all iron and manganese as well as a big group of microelements accumulate in discharge areas, making steady complex geochemical anomalies.

Water and ion underground discharge to the sea is estimated by the content of iron in ground water, its ion composition, general quantity of iron excess in bottom sediments of anomalous area and age of iron area.

Identification of water of the discharge area with separate water-bearing formation is being made on the base of comparison of chemical and isotope composition data, taking into consideration possible changes in diagenetic reactions. Geochemical inert chloride ion is a good indicator. This method was tested while studying submarine discharge in the Caspian, Black and Red Sea.

DIFFERENT TYPES OF SUBMARINE DISCHARGE FROM THE GEORGIAN COAST TO THE BLACK SEA

BUACHIDZE, G. and MESKHETELI, A.

General geotectonic structure predetermines, besides other processes, the ground water discharge as well. The coastal part of Georgia involves the Great Caucasus Southern Slope fold system (carbonaceous rocks); Georgian Block with thick Quaternary deposits and Adjara-Trialety fold zone of the Minor Caucasus (volcanogenic rocks). Accordingly are distinguished the types of submarine discharge: the northern one peculiar for prevailing karstic discharge; then southwards comes the type specific for direct seepage from phreatic aquifers and shallow subtidal zone; the southernmost one with deep offshore discharge from volcanic rocks.

The first zone features high pressures of karstic waters (recharge areas are located at the elevation of 2 to 2.5 km), this predetermining intense discharge both of concentrated (with springs yielding over hundred litres per second, Gagra) and areal (Leselidze) pattern.

The second zone presents an area of discharge of shallow ground water flows - Kolkhetty.

The waters of the third zone develop a deep penetrating system of pressure fracture waters, investigation of which happens to be the most difficult one. It coincides with Adjara seacoast.

The researches, that have been conducted herein lately, have revealed that the change in hydrogen sulphide surface in sea water on the shelf is due to the pollution of the coast and the adjoining water area (increased discharge of the organic material). The effect of rising of this surface is very clear - accounting in some places for above 50 m just in 10 years. With this one has a universal criterion of seashore ecological condition.

Problems connecting with outflow of pollutants from the river systems into the sea waters are analysed. Calculations using monitoring data show that yearly thousands tons of pollutants are flew out by the big rivers in Russia. The main part of the total outflow is oil outflow (near 100 thousand tones). Pollution of the river flow is along the whole of hydrographic system. It being known that near half of the whole mass of pollutants flows diffuse way from the watershed area.

The principles of choose of the river protection zones are formulated in the paper from the systematic ecological point of view. The natural (including hydrogeology) and technogenic conditions are also taken into account. The main idea of river protection zones is management of water quality in the river system taken as a whole.

MAJOR ENVIRONMENTAL ISSUES ASSOCIATED WITH COASTAL GROUNDWATER SYSTEMS IN AUSTRALIA

JACOBSON, G., BIEWIRTH, P. and GRAHAM, T.

Major environmental issues are emerging as a result of the intensified urbanisation of the Australian coastal zone, as well as agricultural development in the hinterland catchments. These issues include:

- . Eutrophication of coastal waters in southwest Australia owing to the discharge of nutrients from sewage, fertilisers and industrial effluent. This problem contains a substantial groundwater component, as the Perth coastal plain is underlain by Quaternary sediments containing permeable and productive aquifers. Remedial strategies are being developed, including reduction of fertiliser use.

- . Acidic drainage from acid sulphate soils on Holocene coastal plains along the eastern Australian coastline. Drainage of these soils for urban and other development has resulted in the oxidation of pyrite and consequently the acidification of groundwater and estuarine water. This problem of ecosystem degradation affects the fastest growing region in Australia and is regarded as a major constraint on economic development.

- . Significant degradation of the Great Barrier Reef has occurred through the export of nutrients from North Queensland catchments to the coastal zone. The nutrients are mainly derived from fertilisers used in sugar cane and other farming. This problem is under intensive study.

- . Seawater intrusion is a problem in several important regional aquifers along the east and south coasts of Australia. Management strategies include the conjunctive use of surface water for irrigation, and artificial recharge.

An annotated bibliography of recent Australian research on these problems will be made available to participants.

NORTH CHINA PLAIN: THE NEED AND PLAN TO JOIN THE LAND-OCEAN INTERACTIONS IN THE
COASTAL ZONE PROJECT
JIN, F.

In China, such work like studying on Land-ocean interaction with the view point of groundwater discharge into ocean and its impact on global climate change, has not yet carried out. However, in order to explore and utilize groundwater, quite a lot of hydrogeological studies have been done throughout the country for more than 40 years, and abundant data as well as work experience have been accumulated. For recent years, along with China's rapid economy development, arises problem of groundwater resource sustainable utilization. In order to solve the problem, Chinese hydrogeologists realize that it is essential to solve the problem of mid and long term regional climate changes and their impact on groundwater resources. On the other hand, Chinese hydrogeologists are more and more concerned about the impact of groundwater change itself on climate changes. Among other problems, the role of groundwater discharge that could reflect the functioning of the Earth System and its consequence is a very interesting and important problem to study. Now a 4 year key project has already been set up for this purpose. The selected area for this project is the North China Plain -- the coastal area of Bohai sea, with the following considerations:

- Total area -- 320,000 km², population -- more than 100,000,000.
- This is the most important economic area in China.
- The area is highly dependent on groundwater water supply, more than 80% of the total water supply.

- Due to the long time and large scale overexploitation, as well as pollution problems, groundwater and river water in this plain have greatly changed both in quantity and quality, for example, in some places of Tangshan area, close to Bohai Bay, the NO_3 and NO_2 contents in groundwater are observed as high as 275 mg/l, while it was less than 0.05 mg/l 30 years ago.
- There is a big gap between water demand and water resources. It is urgently needed to solve the problem of groundwater resource mid or long term prediction and the problem of interaction between groundwater overexploitation and climate change (at least, regional change).
- Abundant hydrogeological data. There are hundreds of monitoring wells of more than 20 years observation history on groundwater level (head) change and change in chemical components of Ca, Mg, K, Na, HCO_3 , SO_4 , Cl. Other necessary data are available too.

The project was approved in May, 1996 by the Ministry of Geology and Mineral Resources of China P.R.. The title of the project is "The evolution process of regional groundwater and its interaction with neighboring spheres". Under this project, there is a topic of "The Evolution of Regional Groundwater and its Interaction with Ocean". The preliminary idea to carry out the topic is as follows:

- Collect all necessary data.
- Establish a data base and hope to set up data exchange with relevant institutions or persons of common interest.
- Select a typical profile to study changes of groundwater discharge and chemical component carried by groundwater into ocean.
- Study the changes of nitrogen content in groundwater and its circulation in bio-rock-water spheres.

About furthermore study on land-ocean interaction problems, Chinese hydrogeologists are still looking for cooperation from oceanologists.

Existing problems:

- Need to establish an international network to strengthen data exchange.
- It is hopeful that the LOICZ Core Project office would promote the progress of relevant studies throughout the world by activities such as publicizing progresses of certain case studies, holding workshops to exchange experiences, strengthening discussions via emails etc..

Current deterioration of quality and productivity of natural environment in the system "Coast-Shore" is connected mainly with economic activity of Man. First of all this is contamination of air, soil and water. It caused by industrial wastes disposal, outwash of nutrients and chemicals from arable lands, dumping of raw materials and industrial wastes in the sea, underwater disposal of municipal wastes, ports activity etc. This leads to contamination of the environment by biogenic elements and organic matter, by toxic compounds and heavy metals, oil and aromatic hydrocarbons etc. Taking into consideration all components quality deterioration (air, soil, river and sea water as well as bottom sediments) to controle the state and improve environment it is necessary systematic measurement of environment components to see their changes, i.e. to carry out complex monitoring.

Main tasks of complex monitoring are the following:

- finding sources of pollution on land and in the sea;
- finding factors of influence (or contamination) which may be subdivided by chemical, physical and biological;
- definition of character and intencity of the environment responce on these impacts.

Complex monitoring includes:

- meteorological monitoring;
- monitoring of geological environment;
- hydromonitoring;

- geochemical monitoring;
- biomonitoring.

Monitoring of geological environment solves the following problems: ways of transportation, places of erosion and accumulation of sediments; concentration and movement of suspended materials and connected with them toxic contaminants; composition of bottom sediments, suspended matter and investigation of geochemical associations of elements and compounds; geological-geochemical transformation of current sedimentation conditions, the role endogenous, exogenous and biogenic material in the flux of the matter; estimation of submarine ground water discharge and bottom sediments contamination as well as appearing of geochemical anomalies; distribution and dynamics of contaminants brought by surface run-off and disposal of untreated municipal and industrial wastes.

The basis of monitoring is the model-oriented network of observation sites in the system “coast-sea” located using the same methodological and organisational principle and containing observation points and regime polygons. Programmes of observations are different for various types of monitoring and depend on intensity and changeability of components being observed.

Results of monitoring in different media which is carried out by different organisations are stored in data bases permitting interchange of data and usage of the same GIS. Usage of GIS in management decisions will permit sufficiently improve their quality and efficiency.

The horizontal components of the flow velocity and the temperature of the bottom boundary layer (BBL) in the coastal zones of the Black and Mediterranean Seas and the Atlantic Ocean (in the vicinity of Coastal Canary Upwelling Zone) were measured 2.5 m above the bottom. The measurements were made continuously over the 6-day period. The Potok meters were incorporated into the self-recovering (pop-up) self-contained bottom stations. In the Black and Mediterranean Seas our study includes the discovery of bottom (benthic) storms in the coastal zone. These storms contain clear evidence of deposits, termed 'turbidites', which result from episodic down slope gravity transport of a dense suspension of water and sediment in a 'turbidity current'. Our data thus suggests a strong unsteadily mass transport in the coastal zone. The coastal zone BBL dynamics are complicated by variety of physical phenomena that show up as bottom storms, sometimes correlating with temperature variations in the bottom water. This latter fact has not been previously observed. In the Atlantic Ocean our measurements indicated that the BBL in the area of the Coastal Canary Upwelling Zone has highly variable dynamics. The complex interaction of the counter-flowing strong geostrophic currents, with flow velocities of 22 and 26 cm/sec, that was identified in the BBL by our measurements inevitably give rise to energy-consuming processes, which may influence the development of the upwelling in the coastal zone. For example the recorded speeds of the bottom currents undoubtedly produce erosion of bottom sediments, increasing the turbidity of the water in the BBL. The boundary region between the counter-flowing currents exhibits high levels of turbulence and a high degree of vortex generation, and these factors cause efficient transport of momentum and of substance in the coastal zone. The pronounced tidal phenomena in the measurement area increase the size of the zone in which the currents interact vigorously, and thus intensify eddy generation, which may follow the sea-floor relief to subsurface level or even emerge at the sea surface, forming the tongues and patches of relatively cold water typical of the upwelling.

Abstract

During 1970 -1996 a lot of research were done for groundwater inflow estimation from aquifers to Great Lakes in the USA and to Baltic sea and some lakes in Poland . From 1994-1998 this a joint US- Poland research supported by a scientific Russian expert. In the first phase, of analysis an evaluation of applied methods and next selection of the best approach to solve the problem in the case study were done. An extended data base on hydrogeological conditions and parameters for four experimental catchments in shore zones in both countries have been prepared. At the present moment, numerical models and fields studies are begining in order to verify in the best way the interaction and water exchange between aquifer and surface water reservoirs. Up to this moment published results stated only calculation of groundwater contribution by rivers flowing to the lakes and sea. The present research attempt to evaluate direct groundwater inflow to the lakes by bottom sediments.

The weak point of this research is a lack or insufficient data about the hydrodynamic field around or/and underlying formation of the resevoir. This situation creates problem not only for boundary condition of inflowing groundwater but also, in some cases for precise calculations. The only inland sea and gigantic lakes are the cases where stable hydrodynamic fields exist and udergoing small seasonal fluctuation considering shallow groundwater. Stability of these fields are confirmed by regional observation and monitoring of chemical and isotopic composition which allows analitical calculation. As a results preliminary average value of discharge is available. The local and partly regional flow system of Great Lakes are not stable and sesonal as well as long term variation can be observed. This makes it sometimes impossible to apply analitical methods for the budget calculation. Results obtained from different studies show groundwater budgets, for the same region, differ by more than one-hundred percent. In my opinion the most problematic issue for detail calculation of inflow is a lack of-suffioient recognition of hydrodynamic field in the lake vicinity . On the coastal zone of the Baltic Sea and Lake Michigan there exist rivers which act as parallel barriers to the regional flow to these bodies. In some cases the barrier continue along tens of kilometers in distance few hundred meters. None of authors publishing on problem under consideration attempted to design boundary $q=0$ under the lake bottom. For the Great Lakes its extention is important issue for modelling. In most cases, this determines quantitative budget evaluation around reservoir and under the bottom of lakes. The other critical issue is regional evaluation of parameters. Collected data should be the base for regional modell construction. Parameters distribution can be based on numerous geological cross-section across costal zone using the 2D flow net model. It has been confirmed during model construction of Lake Michigan and selected lakes in Poland. Models are prepeared for Modflow and Flownet computer programs and could be basis for 3D model applied in Visualmodflow used in the Polish study. Model validation should be supported with field research, infiltration measurements, geophysical sounding, thermal and chemical monitoring, and isotopic and microbiological study of seeping water. Comprehensive research and method verification of direct inflow with predominant of modelling method can provide detail recognition of groundwater inflow to the lakes.

Fluctuation in sea-level leads to variation in water-level of rivers. Variation of water-level being also a possible result.

Under industrial, agricultural influence, etc. quality of ground water and surface water often degrades. It's expressed as variation in redox and other conditions, concentration of pollutants and others.

Deterioration is supposed to be a result of either upward or downward fluctuation in sea-level. It depends, on the one hand, on the contribution of polluted groundwater flow discharge to the total river runoff. On the other hand, it's conditioned by variation in concentrations of pollutants in the discharge from the fact that the contribution of polluted groundwater to the total one is variable.

As the sea-level elevates, the elevation of rivers water-levels is expected. It causes decrease of a groundwater flow discharge. In the same time, share of polluted discharge increases. In the case of sea-level lowering the opposite tendency is expected.

So, resulting changes in the surface water quality are not similar. That's why they must be estimated quantitatively in the each case. In so doing, the changes of components concentrations caused by complexed physical and chemical processes (including mechanisms of increase and decrease of components concentration) must also be estimated.

In the context of the elevation of Caspian sea-level the increase of the surface water level is predicted to the area affected by Astrachan Gas-Condensate (AGS) industrial complex. A special identified groundwater flow and mass transport model is used to estimate pollutants and other species concentrations (boron, total dissolved concentration, etc.) In the rivers, under the most dangerous conditions of the lowest rivers discharge. The identified model structure makes it possible to estimate the concentrations exactly at given conditions of sewage infiltration rates and concentrations of pollutants in: infiltrated sewage, and given levels of the rivers.

The decrease of the groundwater flow discharge from $7,81 \cdot 10^{-3}$ to $6,08 \cdot 10^{-3}$ m³/d, the decrease of the total dissolved concentration from 13,9 to 10,9 g/L, but the increase of boron concentration from 1,877 to 2,053 mg/L have been calculated with respect to the polluted groundwater flow discharge. The decrease of the resulting total dissolved concentration and boron concentration in the rivers from 1,16 to 0,85 g/L and from 0,164 to 0,152 mg/L respectively has been obtained. All the changes have been predicted as the given levels of modelled rivers elevate by 0,5 - 1,0 m as a whole. So, the influence of the polluted groundwater flow on the quality of the rivers is reduced as the level of Caspian sea elevates.

Abstract

A method to couple agricultural data with a soil map in a Geographic Information System (GIS) to predict the spatial distribution of nitrate leaching in a Danish County is proposed. The agricultural farm structure in Vejle County, Denmark, is described using a set of seven farm types distributed on three soil types to give 21 different combinations of farm types and soil types. The spatial distribution of the farms is derived from General Agricultural Register (GAR), Danish Institute of Agricultural and Fisheries Economics (DIAFE) statistics, an address-coordinate register and CORINE Landcover map (Larsen and Soerensen, 1996) using a heuristic spatial allocation procedure in GIS. The allocation procedure consist of the following seven steps, 1) classification of the farms in GAR according to the seven farm classes 2) generation of a point coverage with the location of the addresses of the farms in GAR, 3) rasterisation of the point coverage, 4) overlaying rasterised point coverage with CORINE Landcover map and soil map and reclassifying pixels with agricultural land use (according to GAR) located on non agricultural areas (according to CORINE Landcover) and/or on special soil types to non agricultural land use, 5) creating weighted Thiessen polygons around the pixels located on farm addresses, 6) overlaying weighted Thiessen polygons with a landcover-map to determine areas available for agricultural production, and 7) overlaying with a soil map to derive the soil distributed farm structure.

Nitrate leaching from Vejle County is calculated for each combination of farm classes and soil types by means of a statistical regression model (Simmelsgaard 1991; Skop, 1995), and GIS is used to generate the spatial distribution of the nitrate leaching. Directional trends caused by soil and farm type distributions are easily identified. Large differences between the farm classes can be seen. N-leaching per ha is largest on sandy soils and least on loamy soils. Small differences in N-leaching can be identified as a result of farm sizes, whereas large differences can be seen between pig, cattle, plant and part time farms. Part time and plant cultivation farms have less N-leaching than the cattle and pig production farms, primarily as a result of fewer livestock units per ha and application of small amounts of organic fertilizers. The leaching model does not encompass effects of variations, e.g. in climate. Therefore, the results only show what the nitrate leaching would be, *ceteris paribus*, i.e. the results are static-comparative.

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GEOHYDROCHEMICAL AND HYDROGEOLOGICAL STUDIES TO DELINEATE GROUNDWATER DISCHARGE ZONES IN EASTERN GHATS REGION OF INDIA
SWAMY, A.N.

The Eastern Ghats of India are disconnected hill ranges running almost parallel to the east coast of India adjoining the sea known as Bay of Bengal. The northern part of eastern Ghats run NE-SW closely with a narrow strip of coastal plain area. The hills are steep sloping in nature and are studded with a number of peaks. Average elevation is 750 meters, though individual peaks rise to heights of 1500 meters above sea level. Hydroclimatological investigations indicated the region to be semi-arid. Geologically the northern eastern Ghats are mostly uniform in nature with dominant rock types known as Khondalites which are highly metamorphosed sediments of Archaean age. Several smaller rivers having their origin in the eastern Ghats have well developed basins in their watersheds and groundwater from these basins and adjoining coastal plains discharges into the sea. In the present study the nature of hydrogeochemical and hydrogeological variations associated with groundwater as it travels from recharge to discharge zone has been investigated in a representative topographic basin located in the middle of northern part of eastern Ghats. The study area known as Visakhapatnam basin is surrounded by hill ranges and extends to an area of 148 square kilometres with mean monthly temperatures ranging from 23.3°C in January to 30.4°C in May. The sea enters to the mud and marsh located at the central part of the basin from the south-eastern flank where a natural harbour is formed and thus may exert influence on groundwater discharge zones of the basin. Water table data was collected from a network of observation wells and groundwater samples were collected. Chemical analyses has been carried out for conductivity, total hardness, chloride, bicarbonate, sulphate, calcium, magnesium and sodium plus potassium ion concentrations. In addition vertical geoelectrical soundings were made to study the hydrogeological nature of the aquifer. Stiff, Piper, Schoeller and Chebotarev methods of classification has been adopted for geochemical analyses and used in conjunction with the hydrogeological data to study the groundwater chemistry as it travels from the recharge areas to the discharge zones where groundwater enters the sea. The results are presented in the paper.

SIGNIFICANCE OF GROUNDWATER DISCHARGE OF NITRATE FROM RESORT ISLANDS OF THE GREAT BARRIER REEF, AUSTRALIA

VOLKER, R.E. and GALLAGHER, M.R.

The influence of water-borne chemicals, especially nutrients such as phosphorus and nitrogen, on the water quality of the Great Barrier Reef Lagoon is assuming greater importance as pressures for development, both on the adjacent mainland and on islands in the lagoon, increase. Maintenance of acceptable water quality is vital to the main reef structure itself but there are also numerous fringing reefs associated with islands scattered throughout the region and the local marine environment around these fringing reefs is likely to be susceptible to discharges from the islands. Evidence suggests that coral reef ecology is sensitive to relatively small elevations of nitrate above natural background levels. The management of water and waste-water in resorts on the islands around which the reefs occur must, therefore, take proper account of the associated nutrient loadings and will rely on accurate predictions of the eventual fate of those nutrients.

Data collection and analysis has concentrated to date on two islands which have been instrumented with soil moisture samplers. One island disposes of its waste-water by irrigation of secondary treated effluent on lawns, golf courses and gardens. The other island pipes its discharge to the sea but is in the process of implementing an effluent irrigation program with most of it to go on the golf course.

On the first island, water supply is from surface sources although some groundwater sources have been identified. The consequences of land based effluent irrigation on the subsurface water quality has been assessed by sampling of soil moisture at monthly intervals over a 6 month period. From these samples the time averaged nitrate-N concentrations vary spatially from 0.1 to 3.0 mg/L.

The resort on the second island draws its water supply from groundwater in the Holocene/Pleistocene dune sands. Average total daily water use by the resort is approximately 294 kilolitres (kL). Of this, approximately 50 kL per day was used for golf course irrigation. Wastewater is generated at the rate of about 183 kL per day with a nitrate-NO₃ average concentration of 8.5 mg/L. The range of nitrate concentrations was from about 1.0 to 19 mg/L. On this second island, monitoring of soil and groundwater has commenced and will continue over the time during which effluent irrigation is introduced and thereafter. The groundwater was sampled from several supply wells and found to have nitrate-N concentrations in the range 0.7 to 1.2 mg/L. The aquifer has a relatively high hydraulic conductivity and is well connected hydraulically to the sea since sea-water intrusion has been detected in bores close to the beach areas in the dry season. Soil moisture samplers at 1.0 metre depth in the vadose zone have returned samples with nitrate-N concentrations in the range 0.7 to 1.5 mg/L over a 3 month period. Even though effluent irrigation is not yet practiced on this island, fertilising of the golf course does occur and the higher nitrate concentrations were measured under the golf course.

While the nitrate levels so far detected in soil or groundwater on both islands are relatively low by drinking water limits, it should be noted that fertilising of lawns and irrigation of treated effluent has been practiced for only a relatively short period, and continued monitoring and associated numerical modelling is warranted to predict longer term consequences.

The best estimates of nutrient output of major rivers from the mainland shows that the potential contributions from resort islands are minimal by comparison in terms of the overall nutrient budget of the Great Barrier Reef Lagoon. Based on loadings from effluent produced on the islands and assuming output to the marine environment in the immediate vicinity, calculations have shown that rises in nitrate concentrations sufficient to be detrimental to the marine ecology are possible. These calculations involve assumptions about residence times around the coast of the islands before transport away by currents and tides. Work on this aspect is being undertaken in conjunction with physical oceanographers modelling currents in the Lagoon under different meteorological conditions.

ANNEX 1 CONCLUSIONS AND RECOMMENDATIONS OF THE INTERNATIONAL SYMPOSIUM

[The following material is an edited excerpt from LOICZ Meeting Report No. 16, which also contains reports of the Symposium Working Groups and discussion rapporteurs.]

At the final session of the Symposium, the chairs presented a list of draft conclusions and recommendations derived from the discussion sessions and working group reports. These were discussed in plenary, following which a recess was taken to allow for revisions and additions based on the plenary discussions. The final plenary session then reconvened and adopted the following statements and recommendations:

A1.1 Conclusions

1. Groundwater flux to the coastal marine environment is an important biogeochemical and environmental factor in many coastal regions.
2. The physical and chemical processes involved in groundwater flux to the coastal marine environment are complex, and highly variable in space and time.
3. In view of the general scientific significance of the subject and to ensure that groundwater fluxes are properly accounted for in the LOICZ Programme, it is necessary to expand our understanding of coastal groundwater flux, and to improve the methods available for its assessment.

A1.2 Recommendations

To address item #3 (Conclusions, above), the following general objectives are identified:

- Elaborate and improve methods, approaches, and field/analytical equipment;
- Study and assess the significance and mechanisms of submarine groundwater flux;
- Investigate contributions of groundwater to biogeochemical regimes in the coastal zone; and,
- Assess potential changes in groundwater flow to the coastal zone connected with global change and human activities.

As initial steps toward achieving these objectives, the Symposium participants recommend the specific actions listed in the following categories:

A1.2.1 Information exchange, distribution, and general co-ordination:

- Prepare, distribute and maintain
 - A directory of researchers and agencies.
 - A bibliography of relevant publications.
 - A catalogue of data sources and access information.
- Publish and distribute
 - Symposium meeting report.
 - Symposium proceedings volume.
 - An overview report summarising and reviewing relevant concepts and methods.
- Establish an international working group to co-ordinate and advise on the further development of the field.

A1.2.2 Research and research co-ordination: The Symposium participants recommend the establishment and co-operative use of test sites and case study areas that will provide integrated investigations and opportunities for methods development and comparison. The characteristics of such sites and studies should include some or all of the following:

- Application to areas of potentially significant groundwater flux and/or changes in flux;
- Application of multiple methods; and,
- Links to LOICZ research activities such as biogeochemical modelling.

Although other sites will be identified in the future, participants constructed a preliminary list of possible test or case study sites that included:

- The Baltic Sea (see proposal in Appendix 5, LOICZ Meeting Report No. 16)
- Karst locations (Mediterranean: see Appendix 5, LOICZ Meeting Report No. 16)
- The North China coast (see Fei Jin abstract, Appendix 6, LOICZ Meeting Report No. 16)
- LOICZ Core Research sites (Indonesia, Malaysia, Philippines, Vietnam, and study sites identified by the biogeochemical modelling node)
- The Black Sea (see proposal in Appendix 5, LOICZ Meeting Report No. 16).

A1.2.3 The Symposium participants also recommend attention to and action on the comments and recommendations of the Symposium Working Groups, contained in Appendix 4 of LOICZ Meeting Report No. 16.

ANNEX 2 CONTACT INFORMATION: Symposium Participants and Others

The following names and addresses represent the first draft of a directory of scientists and program administrators interested in some aspect of interactions between groundwater and the coastal marine environment. It includes not only participants in the Moscow Symposium, but also other contacts and individuals who have responded to requests for information, or have published in the field.

This information is printed from a Microsoft Access contact database maintained by the LOICZ Core Project Office. The Project is also in the process of developing a linked database describing the available databases, scientific interests, geographic or environmental areas of study, and the principal techniques used by researchers who have responded to LOICZ questionnaires. In addition to these databases, there has been initial assembly of some relevant literature citations into an EndNote reference library.

Requests or suggestions for inclusion, corrections, or deletion from the databases should be directed to LOICZ at the address on the title page of this volume. LOICZ is interested in promoting better communication and availability of data in the general field of coastal groundwater and solute flux, and solicits information or collaboration to support that objective.

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