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Groundwater circulation and hydrogeochemical evolution in the typical estuary area and coastal zone in Southeast China

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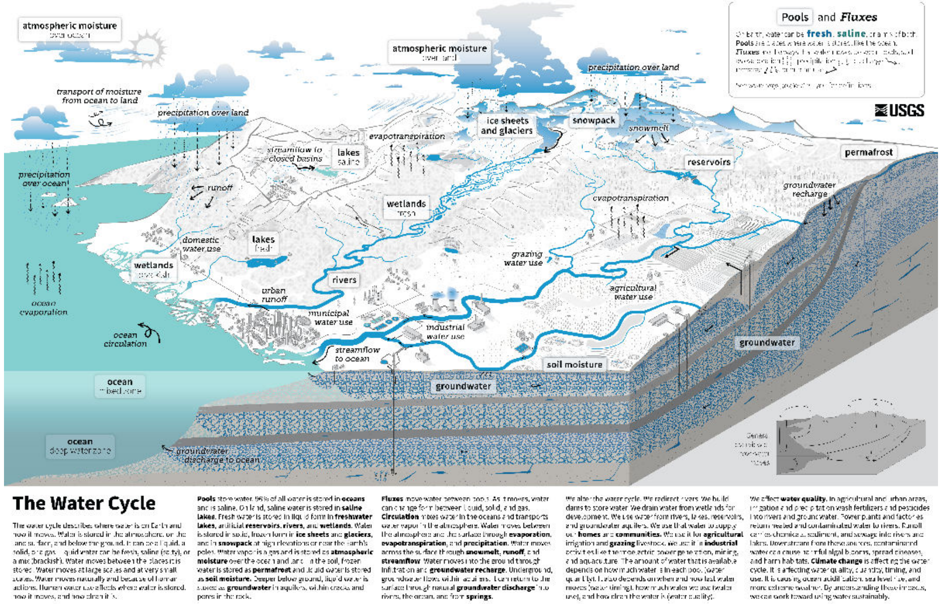
Outline

1. Groundwater Circulation Patterns in the Coastal Zone

2. Hydrogeochemical Evolution and Groundwater Quality

3. Seawater & Sedimentary Quality and Pollution Source



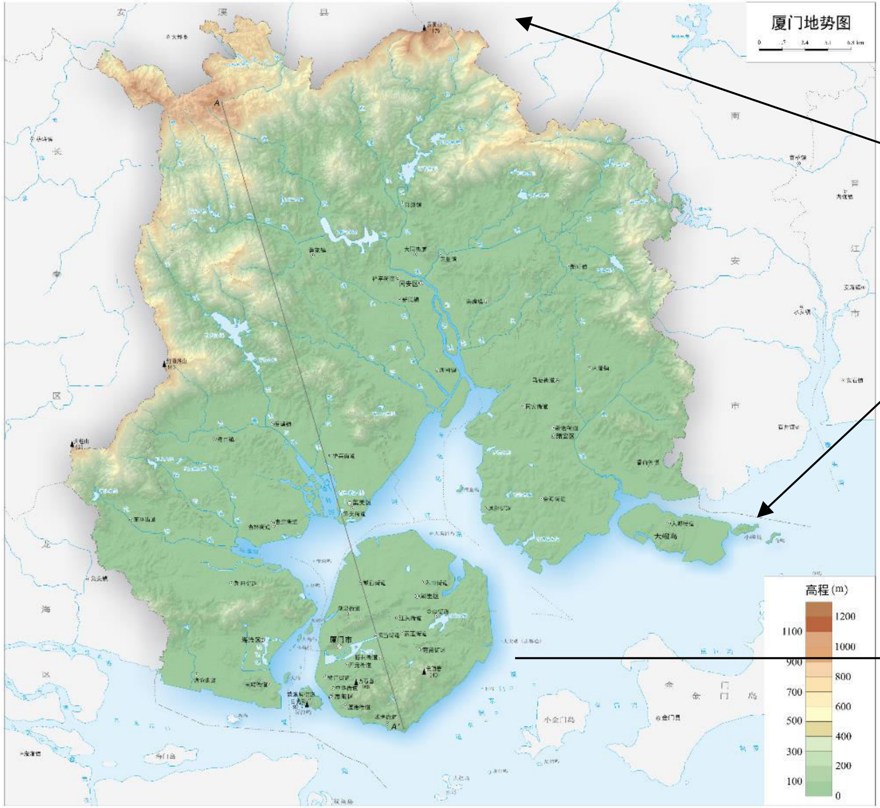
USGS, 2022

PART 01

Groundwater Circulation Patterns in the Coastal Zone

中国地质调查局
CHINA GEOLOGICAL SURVEY

1. Groundwater circulation patterns in the coastal zone



厦门市在福建省位置

厦门市位于福建省东南端，台湾海峡西岸中部，为“闽南金三角”的中心，南北长55km，东西宽58km，东北与泉州市接壤，西南与漳州市接壤。2019年厦门市总面积为1 700.61km^2，其中厦门本岛土地面积约157.76km^2（含鼓浪屿），海域面积约390km^2。

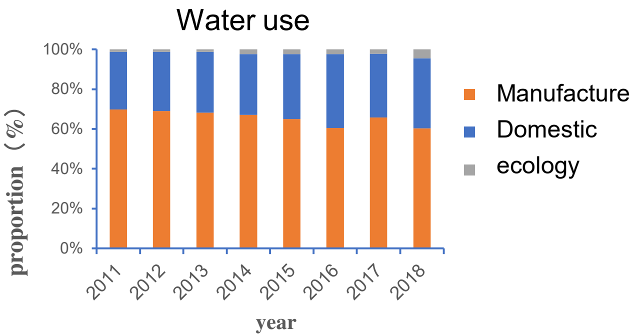
厦门市大陆海岸线长度约128km，海岛岸线长度约118km。厦门共有39个岛屿，除厦门岛外，还有鼓浪屿、大嶝岛、小嶝岛、

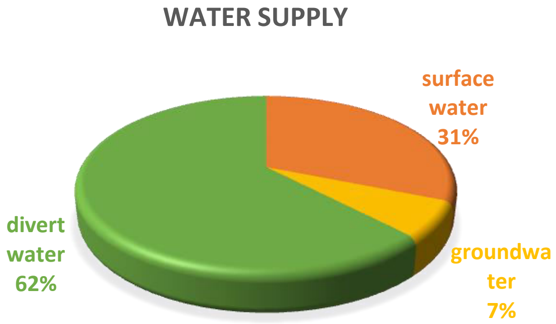
厦门岛地势图

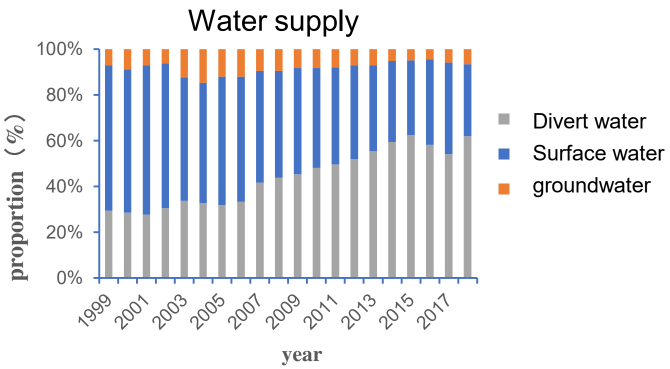
1. Groundwater circulation patterns in the coastal zone

Water Supply and demand in 2020

- Water consumption was mainly for production, but the proportion decreased, while the proportion of domestic water consumption increased.
- The main water source is the transferred water from the Jiulong River, accounting for 62%, and the proportion is increasing year by year, with little underground water supply.







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1. Groundwater circulation patterns in the coastal zone

Water supply and demand in 2030

The first supply and demand balance

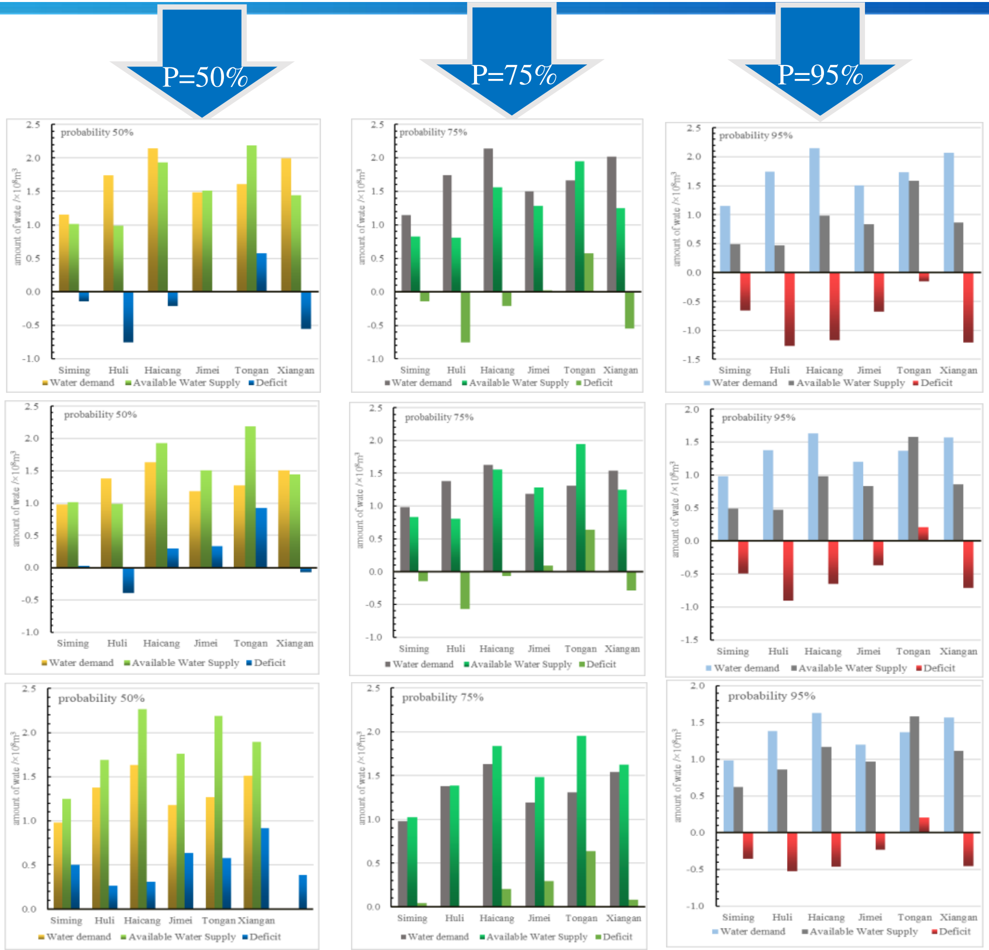
- Taking 2018 as the base year， without supplemental water supply and water conservation；
- quantify the regional water resources supply and demand.

The second supply and demand balance

- Based on the local water resources， suppress the demand for water supply;
- reduce the supply-demand gap derived from the first equilibrium analysis.

The third supply and demand analysis

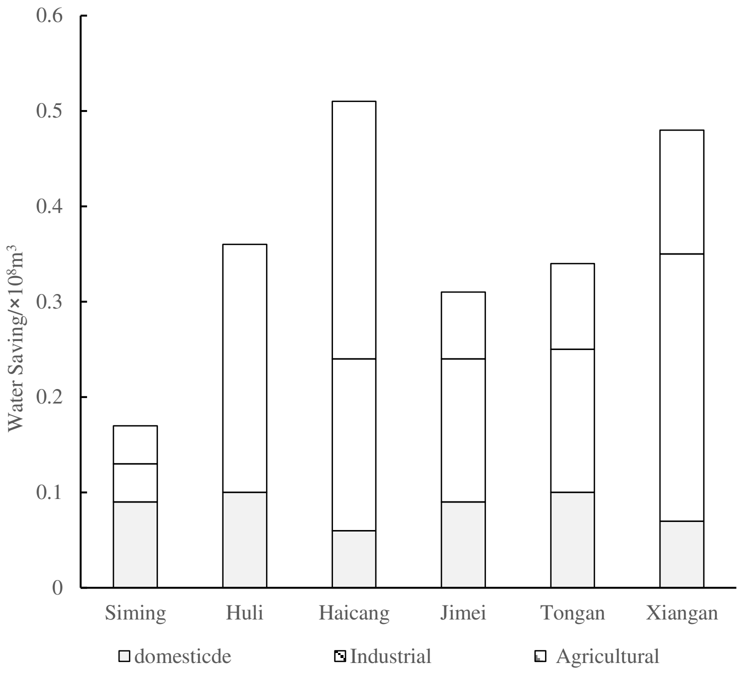
- Based on the second equilibrium， balance the supply and demand at a regional level by transferring water;
- solved shortage of water resources in the target years.



1. Groundwater circulation patterns in the coastal zone

The Problems in Water Supply in Xiamen

- Xiamen is an extremely water-stressed city.
- The maximum water deficiency in an extraordinarily dry year is $5.12 \times 10^8\ m^3$ in 2030, the water deficiency ratio of 49.61%.
- Transferring more water can increase the regional water supply for Xiamen in 2030
- The area still has a water shortage of $1.83 \times 10^8\ m^3$ (p=95%) in extraordinarily dry years, with a water deficiency ratio of 22.51%.
- Domestic water use tends to gradually rise in the Siming and Huli districts, where most water is used for domestic supply, leaving a small potential for water conservation. Their water deficiency ratios will be 36.61% and 37.82% respectively.

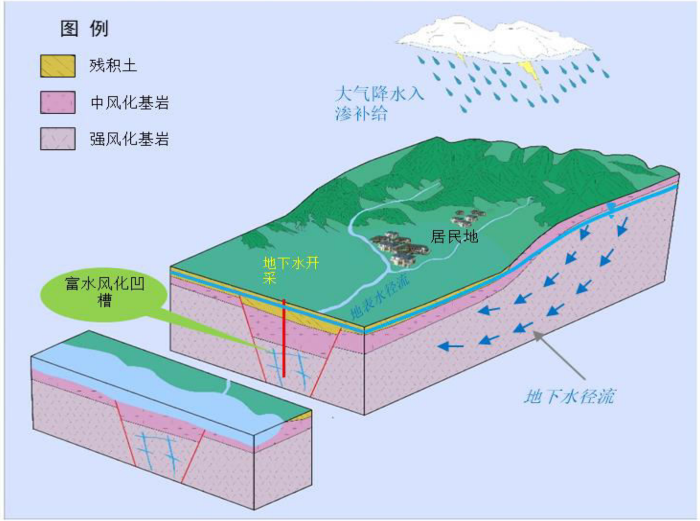


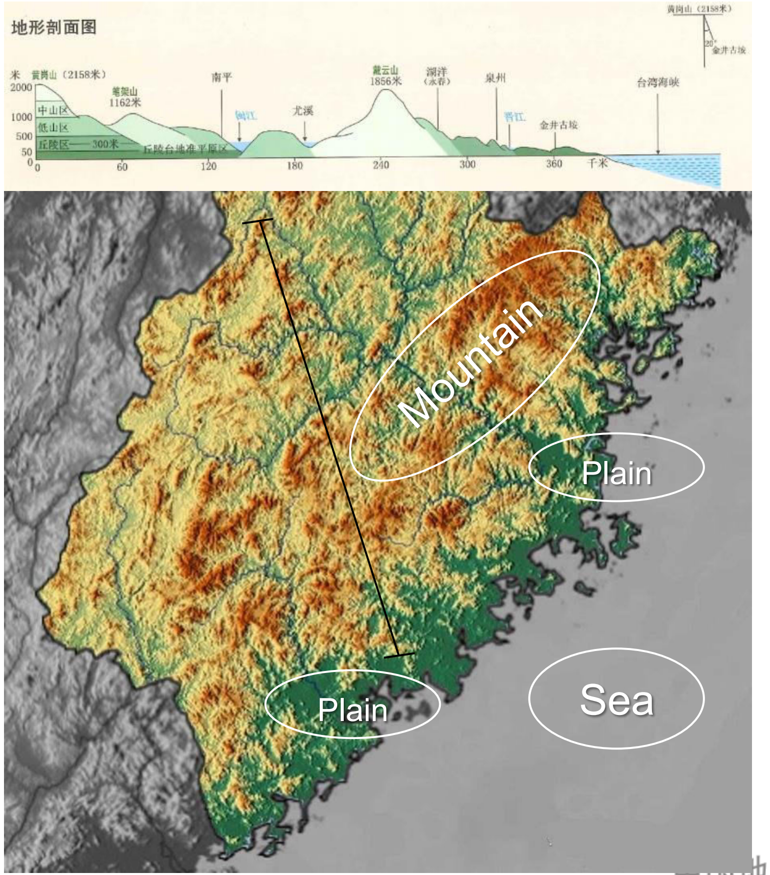
Comparison of water-saving amount of different industry in 2030

1. Groundwater circulation patterns in the coastal zone

Characteristics of the coastal zone in the southeast of China:

- ➢ The average width of the plain area is less than 20 km;
- ➢ Complex medium, including pore and fissure；
- ➢ The heterogeneity is strong and the spatial variability is large.





Topographic map of Fujian Province

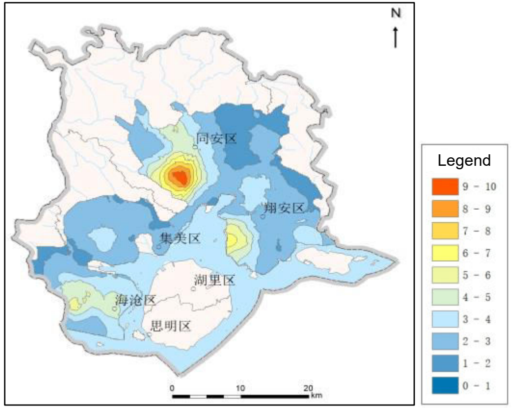
1. Groundwater circulation patterns in the coastal zone

Supposed general characteristics of groundwater circulation:

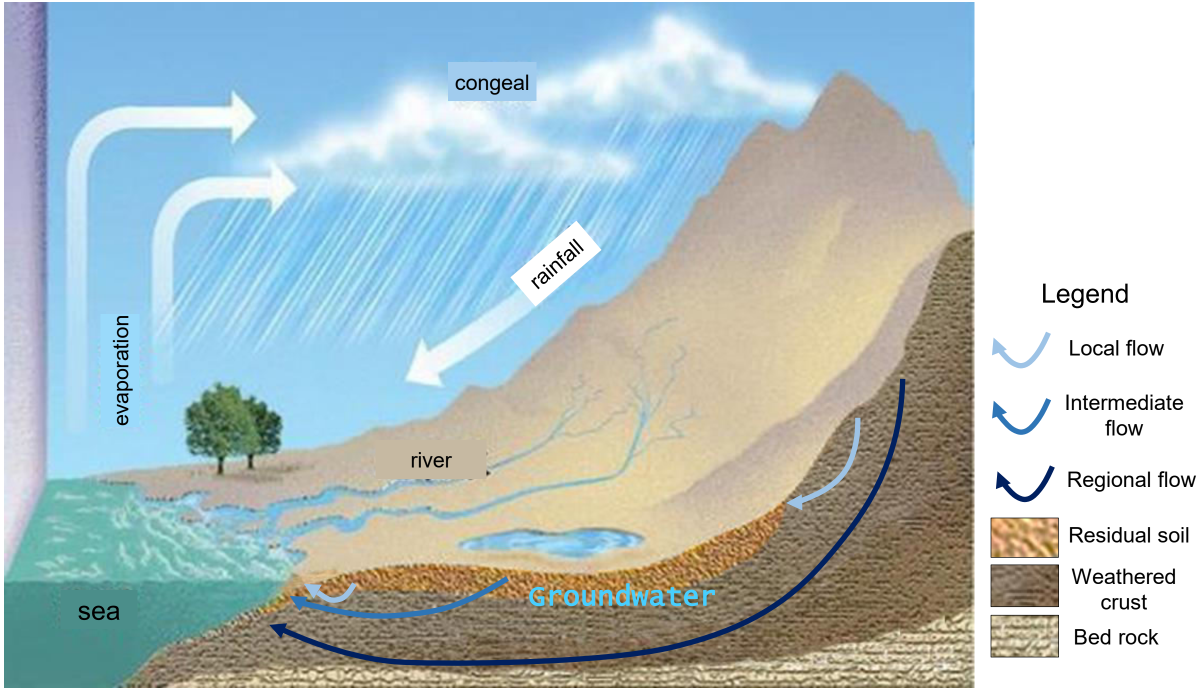
Identified by:

- Multiple environmental isotopes (**^{3}H、D、^{18}O、^{14}C、Ra……**);
- Both 3D and 2D groundwater flow model;
- Geophysical prospecting (Induced polarization sounding)

- Short of flow path
- Shallow circulation
- low depth
- Smooth gradient



Map of groundwater depth in plain area of Xiamen City



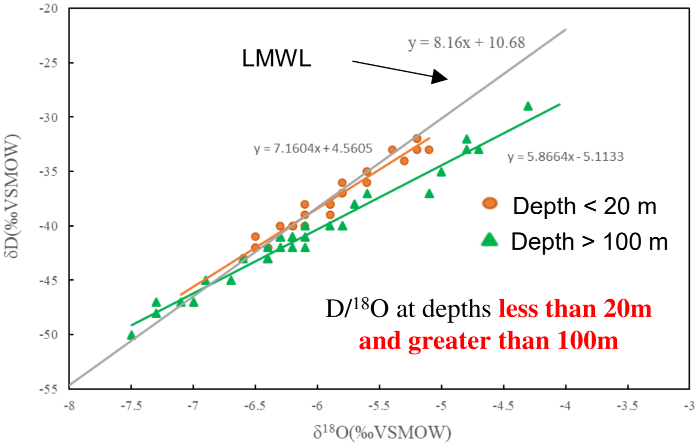
1. Groundwater circulation patterns in the coastal zone

Groundwater samples collected from **different aquifers and depths**

Main tracers: D/^{18}O、 Tritium and ^{14}C

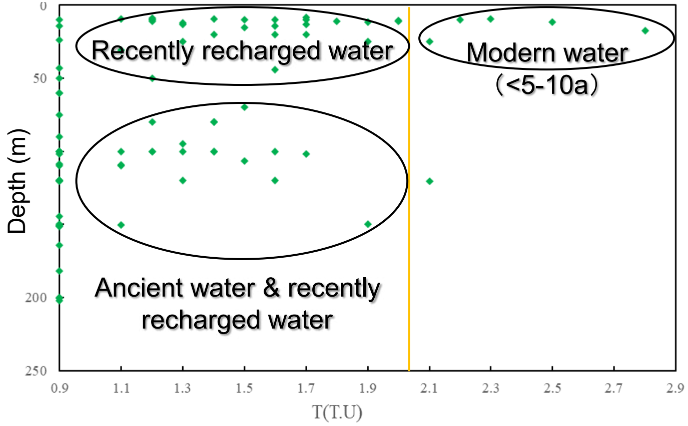
D/^{18}O Characteristics:

- In general, there is a certain deviation from the local atmospheric precipitation line;
- The offset samples are mainly distributed in deep Wells, indicates that the recharge sources of deep water and shallow water are different.

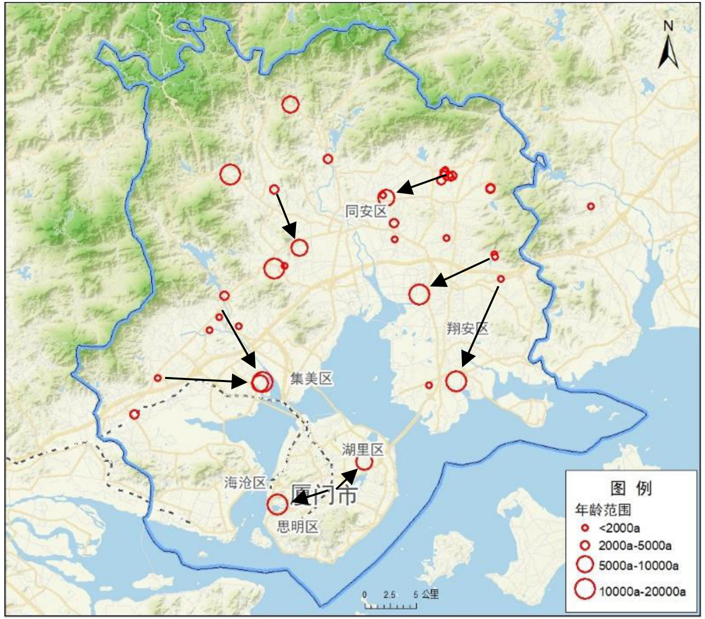


Tritium :

- The shallow aquifer contains both recent water and modern water;
- There is almost no modern water in the deep aquifer, which is mainly a mixture of ancient water and recently recharged water;



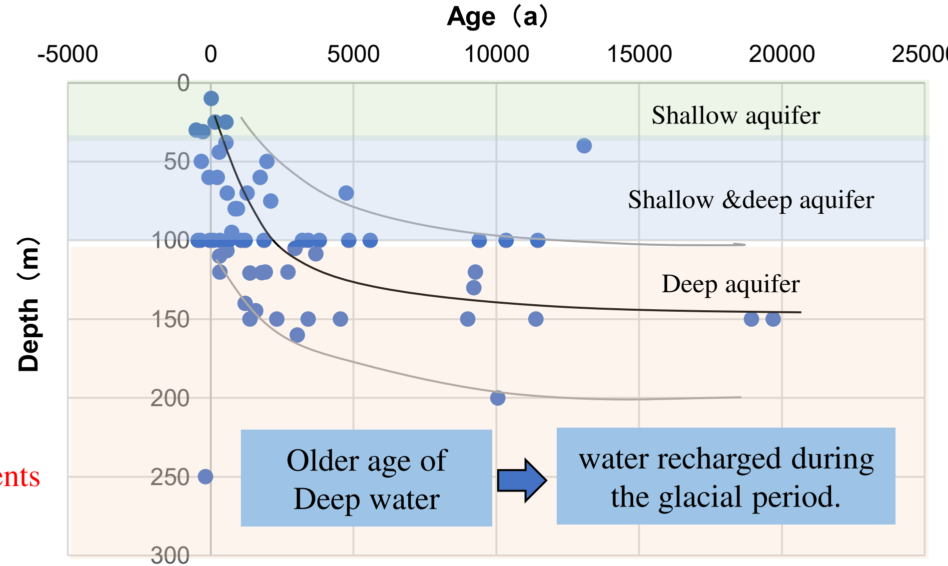
1. Groundwater circulation patterns in the coastal zone



Spatial distribution of deep-water age gained from ^{14}C

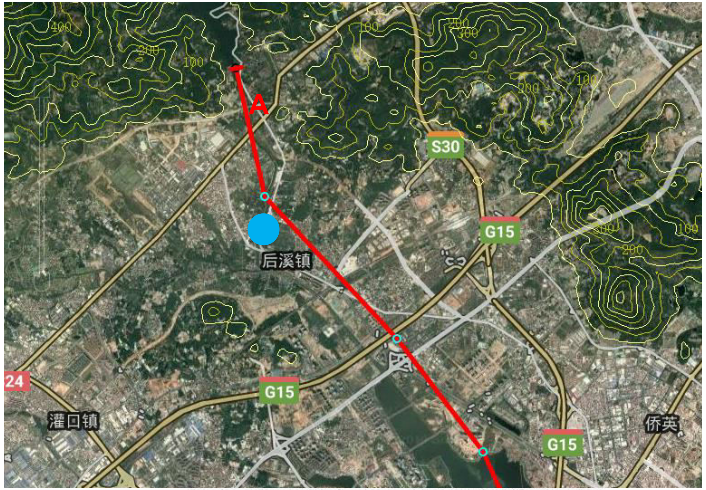
- From the piedmont to the coastal areas, the age generally presents an increasing trend;
- Deep wells at coastal zone generally have older age;
- There are also a few wells with older age in the piedmont.

- The groundwater age increases with the increase of well depth, especially when the well depth exceeds 20-30m;
- When the well depth exceeds about 100m, the rate of age increase significantly;
- The maximum age is about 20,000 years.



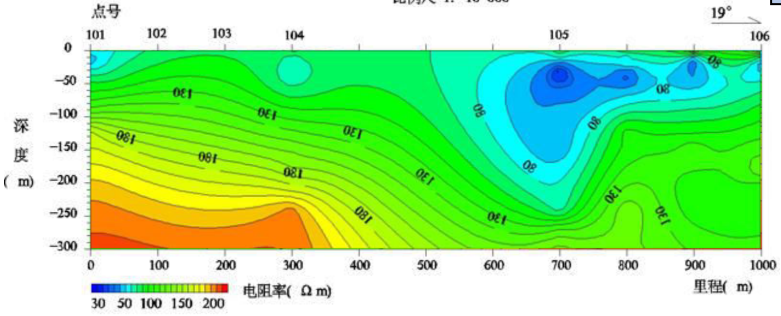
Relationship between groundwater age and well depth

1. Groundwater circulation patterns in the coastal zone

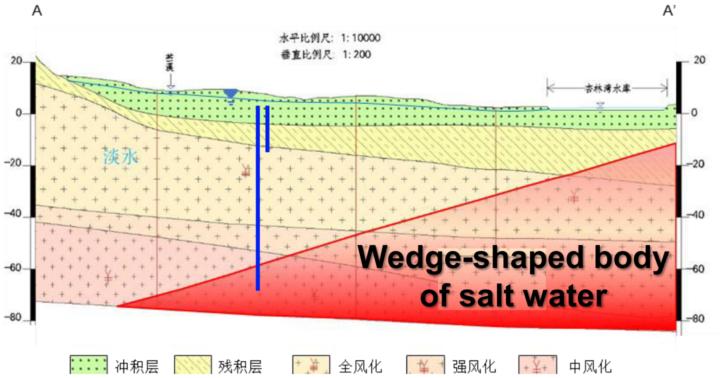


集美区激电测深JMJ1号线电阻率等值断面图

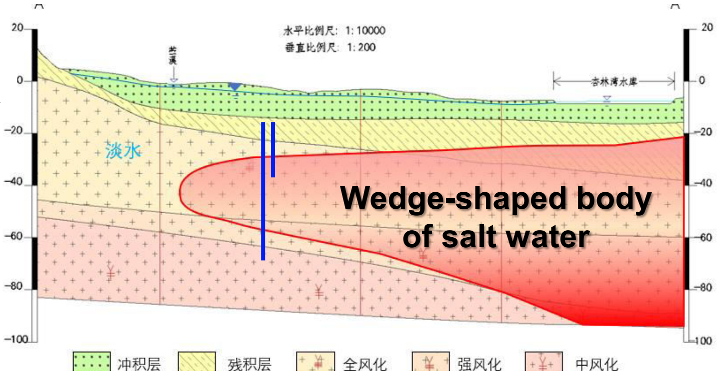
比例尺 1: 10 000



The results of geophysical prospecting shows a different type of salt-water intrusion pattern in coastal area.



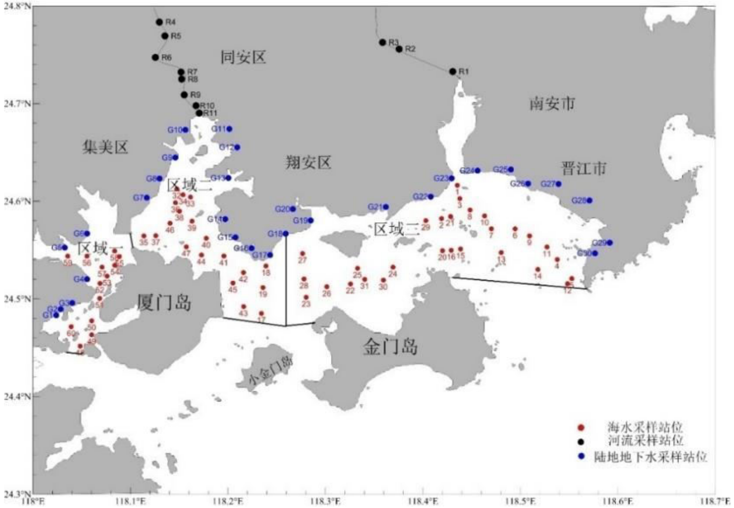
Supposed (typical) distribution of salt-water body



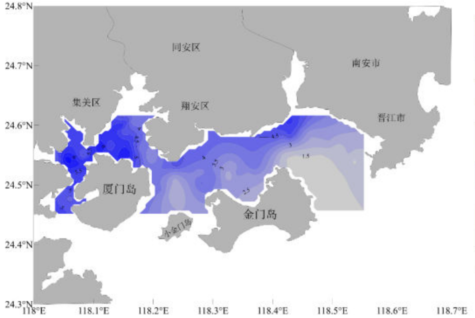
"Real" distribution of salt-water body identified by Induced polarization sounding

1. Groundwater circulation patterns in the coastal zone

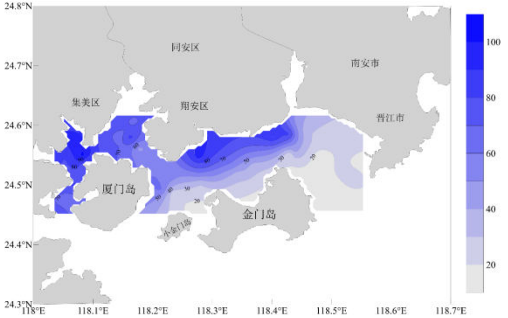
The submarine groundwater discharge flux in Xiamen Bay, calculated using radium isotopes tracing techniques, is approximately 172,500 cubic meters per day. This supports the evaluation of groundwater resources.



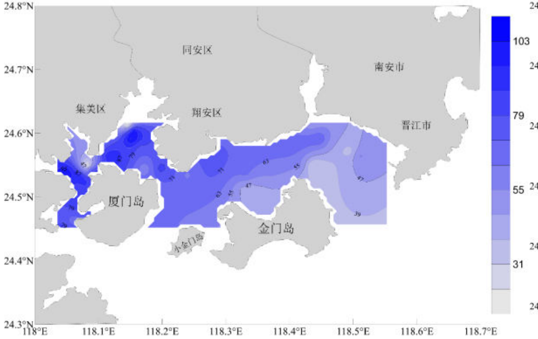
Sampling sites and calculation unit division in Xiamen Bay



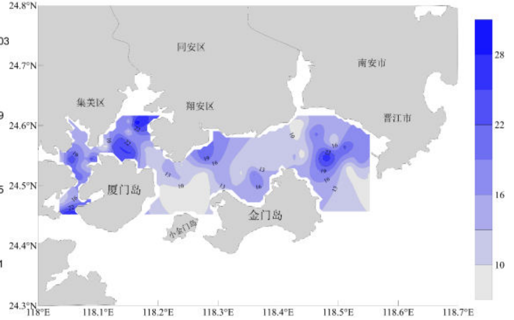
The distribution of ^{223}Ra (dpm/100 L）



The distribution of ^{224}Ra (dpm/100 L)



The distribution of ^{226}Ra (dpm/100L)

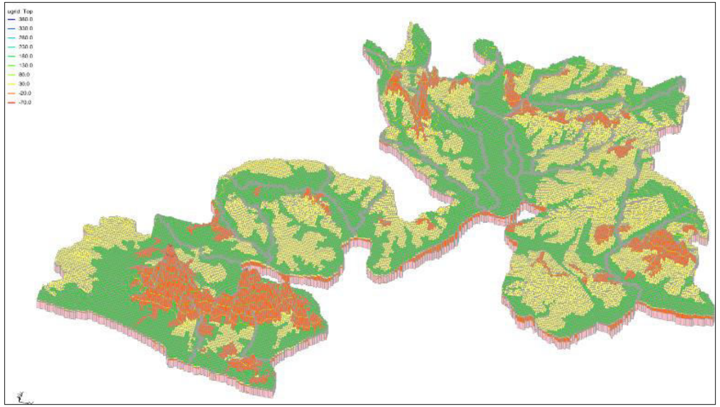


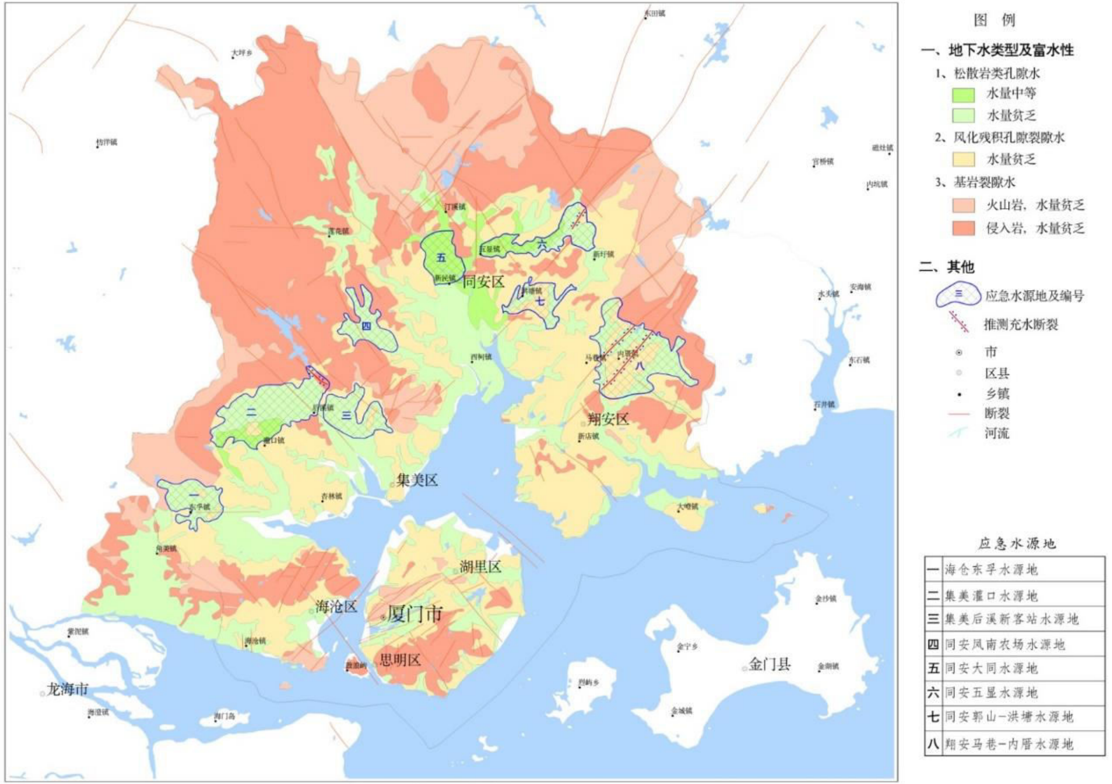
The distribution of ^{228}Ra (dpm/100L)

1. Groundwater circulation patterns in the coastal zone

3D groundwater flow model

- 3D groundwater flow model was established, and the potential groundwater resources was evaluated.
- Eight groundwater source areas were further delineated through comprehensive analysis.
- It is calculated that the emergency groundwater resources of eight potential areas is about 210 million m^3, which can be used as emergency water supply source.





Distribution of potential groundwater resources areas

PART 02

Hydrogeochemical Evolution and Groundwater Quality

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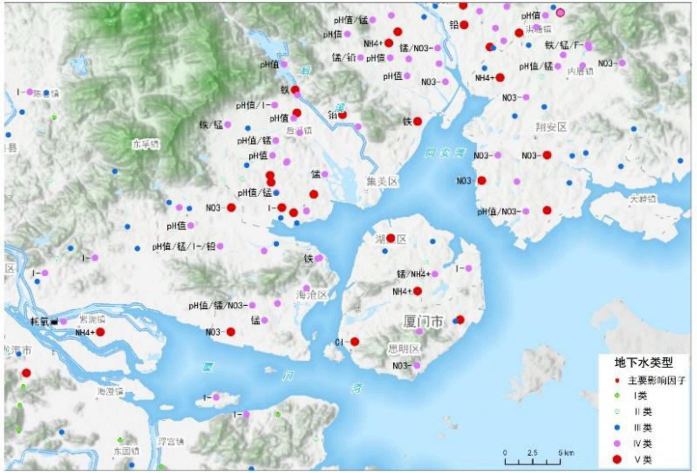
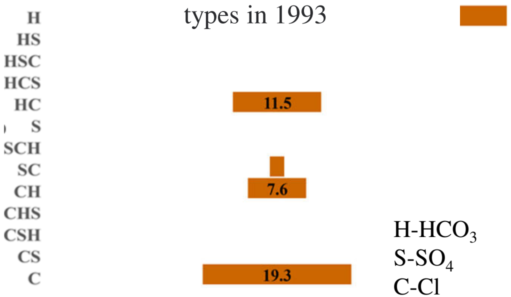
2. Hydrogeochemical evolution and groundwater quality

The characteristics of groundwater quality and evolution of hydrogeochemical facies

- Based on the comprehensive analysis of groundwater quality in recent years, the current terrestrial groundwater quality has been assessed. Comparative analyses have been conducted on between deep and shallow aquifer, and different hydrogeological units.
- Over the past three decades, hydrogeochemical facies has tended to become more complex (increasing from 5 to 13 types). The impact of human activities on groundwater has increased significantly (Evidence from the exceedance rate of nitrate and lead).

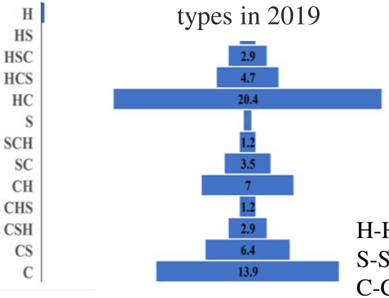


Proportion of water chemical types in 1993



H-HCO_3
S-SO_4
C-Cl

Proportion of water chemical types in 2019



H-HCO_3
S-SO_4
C-Cl

⇨ HCO_3 decrease, SO_4&Cl increase.

Comparison of hydrochemical types of groundwater in different periods （Li et al., 2022）

2. Hydrogeochemical evolution and groundwater quality

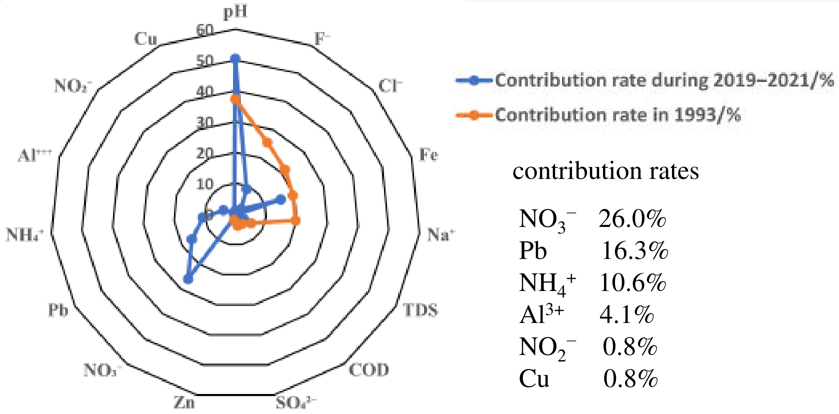
Groundwater quality variation:

Evaluation results of groundwater quality in different years

Year	Number of Samples	Proportion/%					Water Inferior to Class III	
		Class I	Class II	Class III	Class IV	Class V	Number of Samples	Proportion/%
1993	85	12.9	11.8	15.3	28.2	31.8	51	60.0
2019	172	1.2	4.7	22.7	51.2	20.3	123	71.5

- The proportion of Class I-III potable groundwater decreased from 40% in 1993 to 28.5% in 2019;
- The total proportion of poor-quality and undrinkable groundwater (Class IV and V) increased from 60% in 1993 to 71.5% in 2019;
- The proportion of Class IV water that could be used as portable water after proper treatment increased from 28.2% in 1993 to 51.2% in 2019, and the proportion of non-portable Class V water decreased from 31.8% in 1993 to 20.3% in 2019.

Main indices affecting groundwater quality



contribution rates

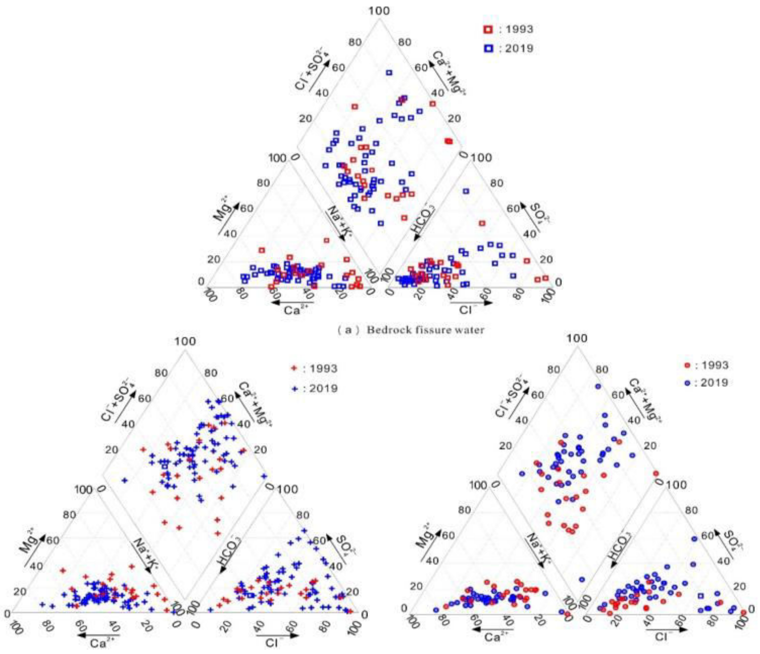
NO_3^-	26.0%
Pb	16.3%
NH_4^+	10.6%
Al^{3+}	4.1%
NO_2^-	0.8%
Cu	0.8%

Main indices affecting groundwater quality and their contribution rates

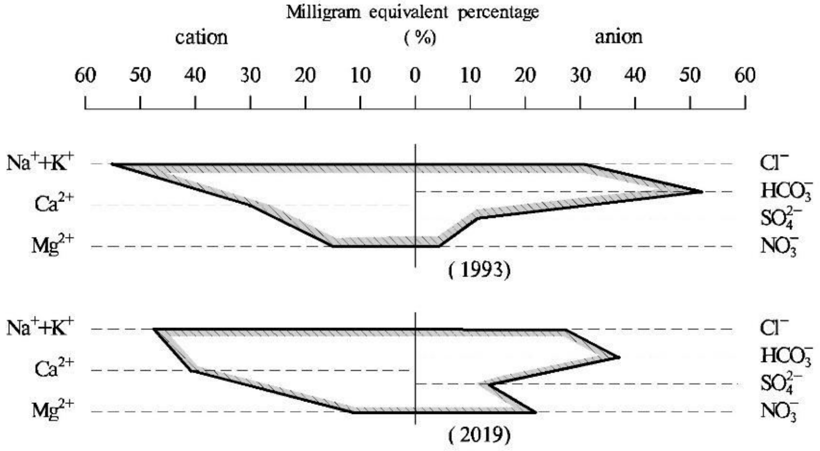
- The number of the indices affecting the groundwater quality increased from 9 in 1993 to 15 in 2019.
- The additional six indices consisted of NO_3^-, Pb, NH_4^+, Al^{3+}, NO_2^-, and Cu
- NO_3^- and Pb had contribution rates second only to pH.

2. Hydrogeochemical evolution and groundwater quality

Forming a new groundwater type of NO_3



Piper trilinear diagrams



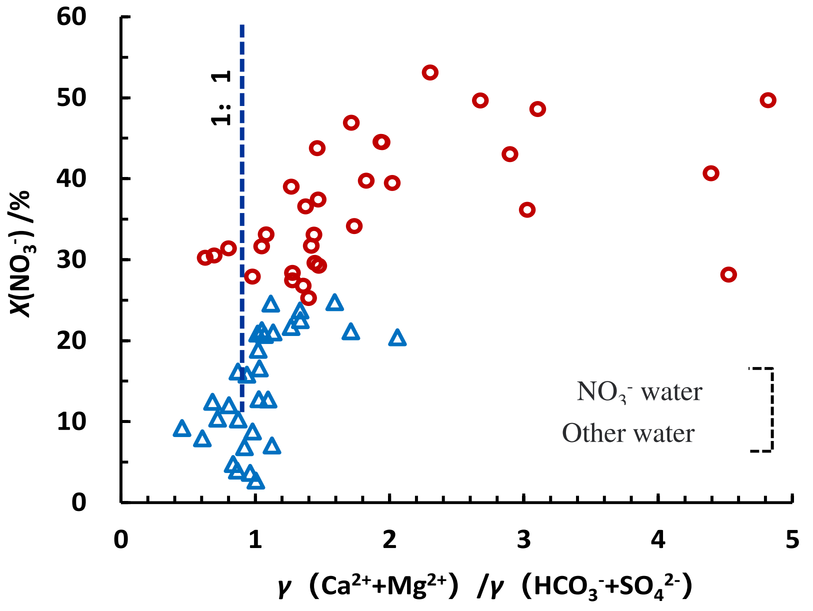
Polygon diagram

- Both the maximum and average relative content of NO_3^- exceed those of SO_4^{2-}.
- The increase in the relative contents of nitrates in the groundwater has changed the hydrochemical characteristics of the groundwater.
- NO_3^- has become a major anion affecting the hydrochemical nomenclature, forming the water of NO_3 type.

2. Hydrogeochemical evolution and groundwater quality

The origin of NO3 water

- In the natural state, soluble rocks (or minerals) dissolve at a fixed rate during groundwater flow, the ratio of $\gamma(Ca^{2+}+Mg^{2+})/\gamma(HCO_3^- + SO_4^{2-})$ in water should fall along the 1:1 line.
- With the increase of NO_3 content, The ratio of $\gamma(Ca^{2+}+Mg^{2+})/\gamma(HCO_3^- + SO_4^{2-})$ in NO_3 water obviously deviated from the 1:1 line, It indicates that polluted water is mixed into the groundwater.



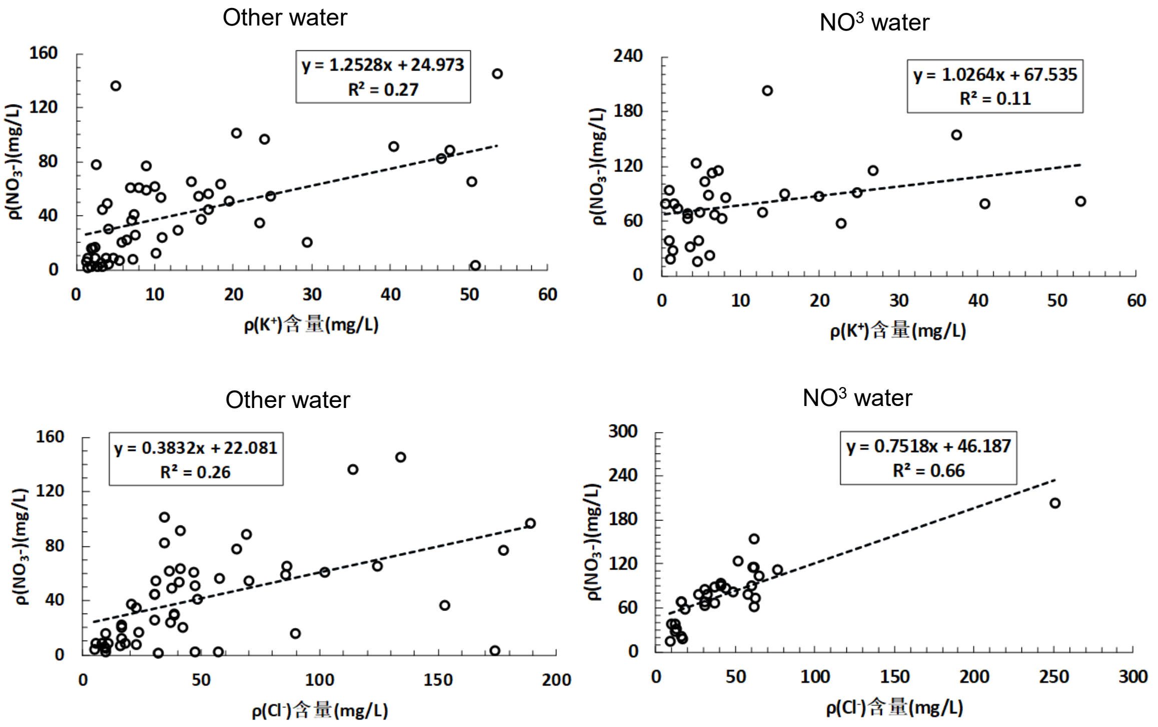
Ratio of ion in different water

2. Hydrogeochemical evolution and groundwater quality

The origin of NO_3 water

- $\rho(NO_3^-)$ is weakly correlated with $\rho(K^+)$. Suggesting that agricultural fertilization influenced the formation of NO_3 water, but the effect was small.
- The strong correlation between $\rho(NO_3^-)$ and $\rho(Cl^-)$ suggests that NO_3^- is predominantly derived from domestic sewage or landfill leachate infiltration.

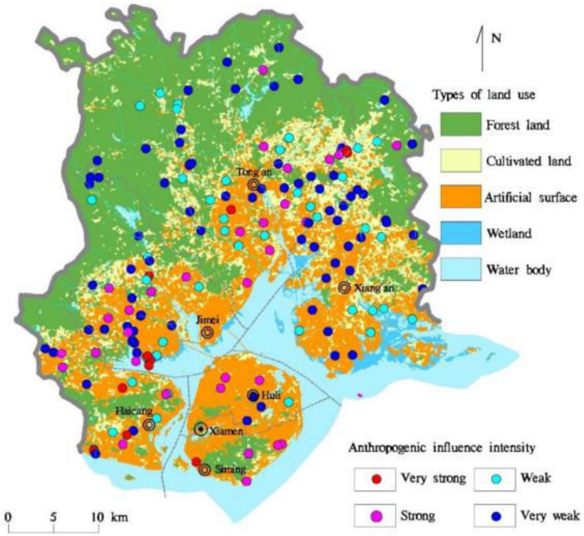
Domestic sewage or landfill leachate is the main source of NO_3^- in groundwater.



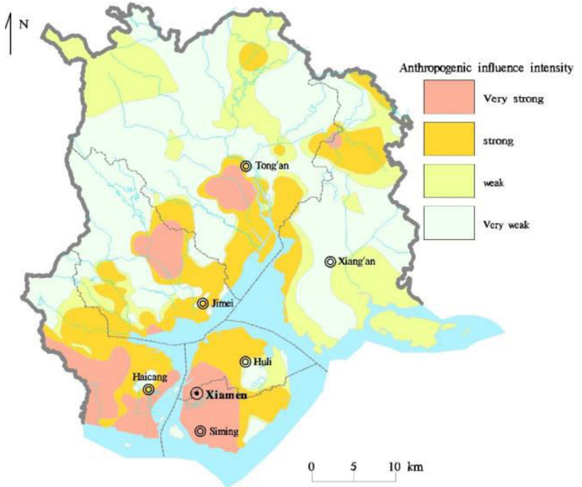
Ratio of ion concentration in different water

2. Hydrogeochemical evolution and groundwater quality

The distribution of the intensity of anthropogenic influences



The zones of the intensity of anthropogenic influences



The groundwater subject to strong or relatively strong anthropogenic influences is mostly distributed on artificial surfaces and cultivated land, while the anthropogenic influences on the groundwater sites in forest land areas were mostly rated as weak.

Zones with very strong anthropogenic influences on groundwater include Houxi Town in Jimei District and Haicang Street in Haicang District, while zones with very weak an-thropogenic influences on groundwater include the northern bedrock mountainous area.

PART 03

Seawater & Sedimentary Quality and emerging contaminants

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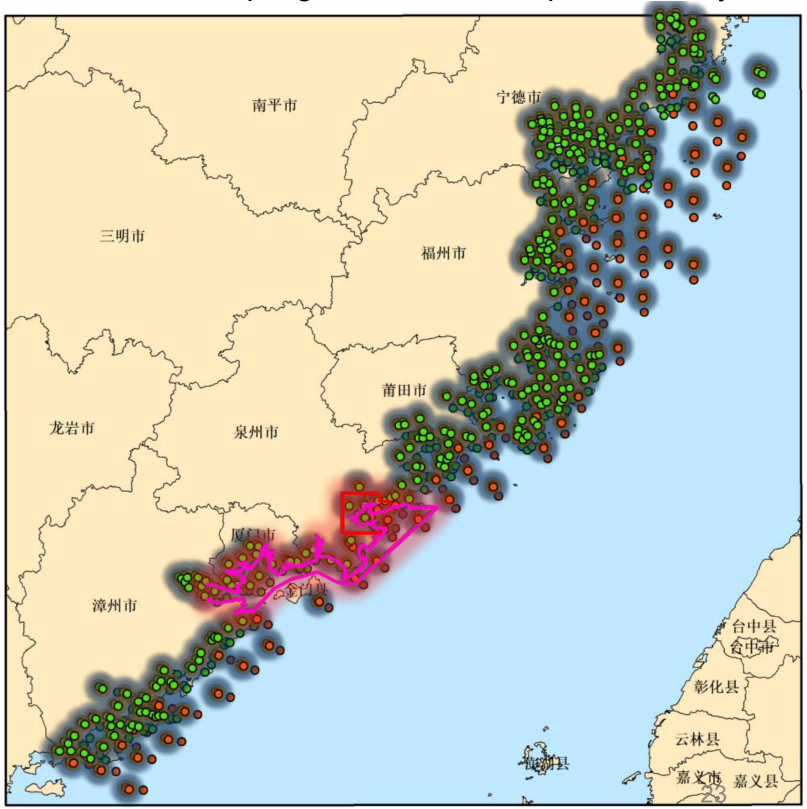
3. Seawater & sedimentary quality and pollution source

Investigation and sampling

- 63 surface seawater samples;
- 132 intertidal and coastal sediment samples;
- Compared with the 908 special survey data collected from the Ministry of Natural Resources.

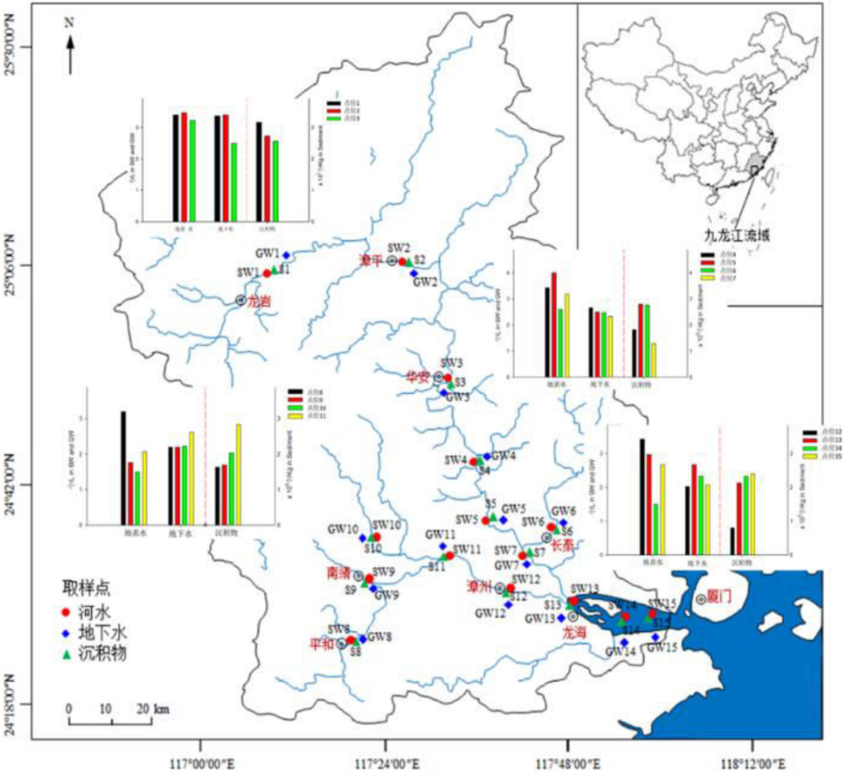
Coastal sampling site of the 908 special survey



潮间带采样点 海水及海洋底质采样点 1:10万海岸带调查区 1:5万海岸带调查区

3. Seawater & sedimentary quality and pollution source

Distribution and environmental risks of emerging contaminants (Microplastics, antibiotics and PFAS)



The threat of new pollutants of different kinds

The risk factor of Sulfamethoxazole(SMX)、perfluoro caprylic acid(PFOA)、atrazine(AZ) et al. in surface water and groundwater is greater than 1, with high environmental risk.

The detectable rate of microplastic samples was 100%

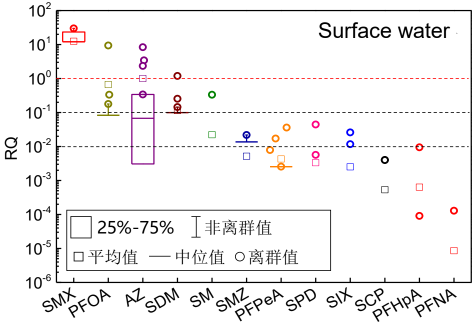
- Surface water：1.5 – 4.0 /L
- groundwater：2.2 – 3.4 /L
- sediment：800 – 3167/kg

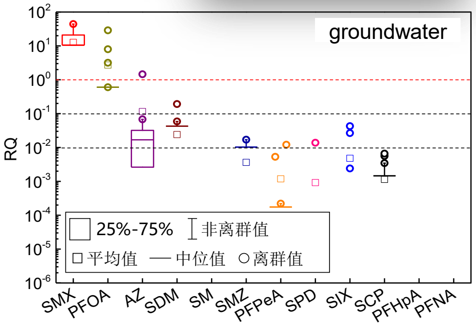
➢ The proportion of fragments is the highest;

➢ White microplastics has the largest proportion;

➢ PE&PVC have the highest proportion.


Occurrence and Risk Assessment of Perfluorooctanoate (PFOA) and Perfluorooctane Sulfonate (PFOS) in Surface Water, Groundwater and Sediments of the Jin River Basin, Southeastern China

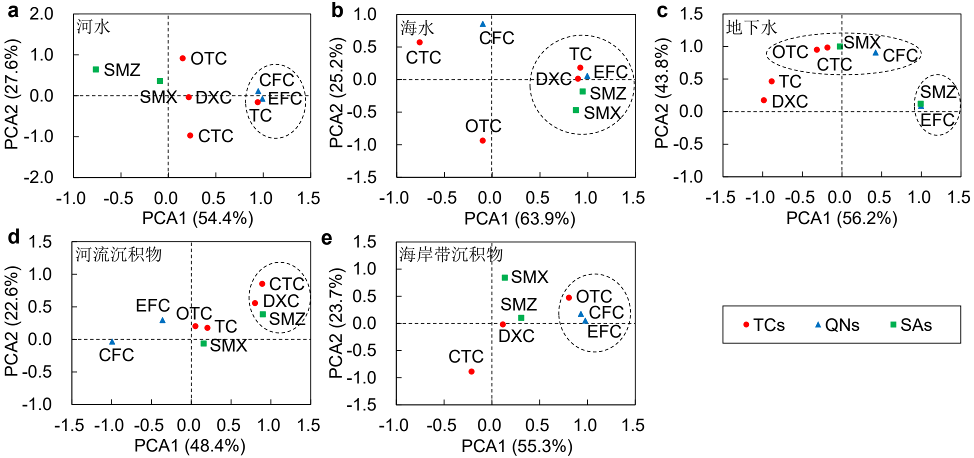


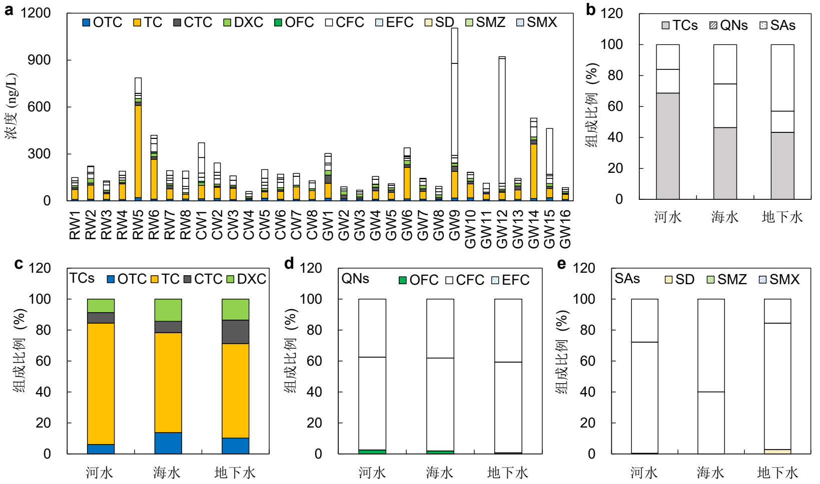


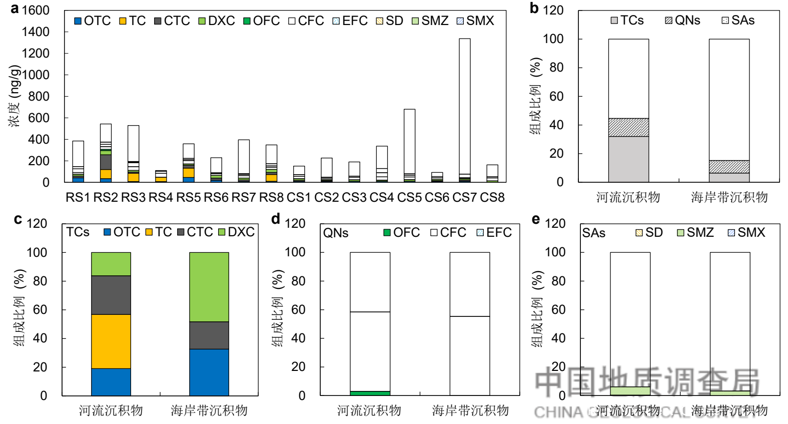
3. Seawater & sedimentary quality and pollution source

The distribution and sources of antibiotics

- Tetracyclines (TCs) were the most frequently detected antibiotics in all water (62.5%-100% detection rate) and the main antibiotics in different water sources (43.3%-68.7%).
- Antibiotics can be transferred to groundwater and gradually accumulate. Wastewater from human as well as from aquaculture were the main sources of antibiotics. The composition of antibiotics in groundwater was similar to that in river water and seawater, suggesting that infiltration of surface water may be the source of antibiotics in groundwater.



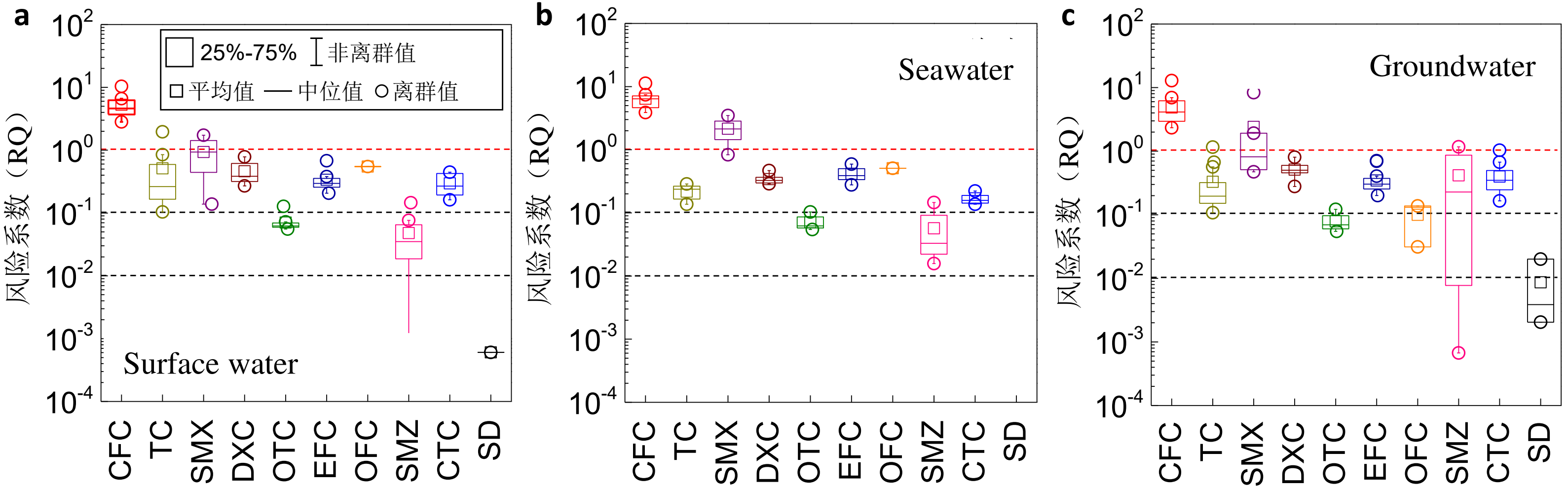




3. Seawater & sedimentary quality and pollution source

The environmental risk assessment of antibiotics and PFAS

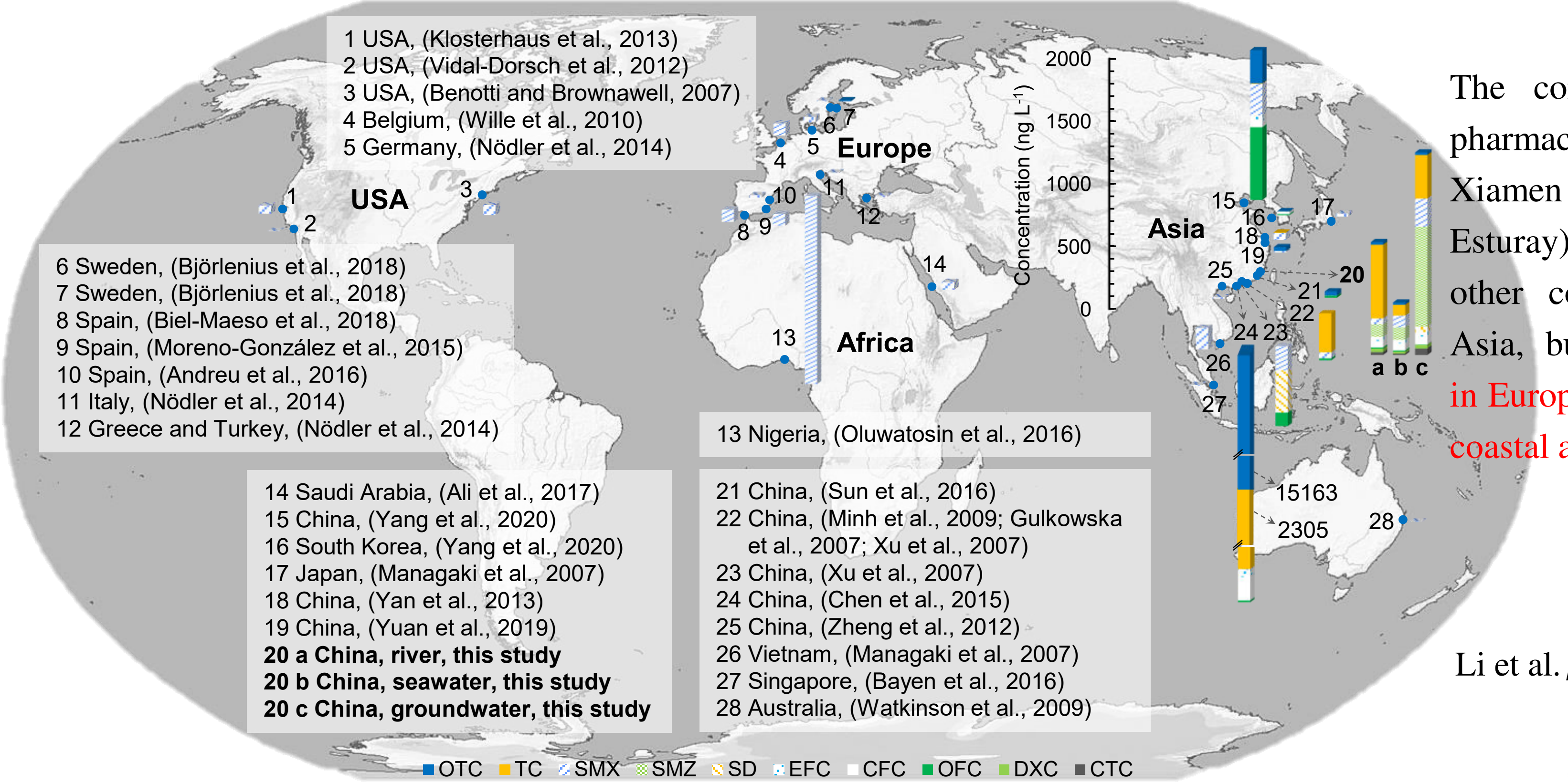
The risk quotient (RQ) values for nine antibiotics (CFC, TC, SMX, DXC, OTC, EFC, OFC, SMZ, and CTC) exceed 0.01, posing at least a low risk to the aquatic environment. Among them, CFC and SMX present a high risk (RQ≥1) in all water bodies. For PFOA, high environmental risks are present in 12.5% of surface water samples and 37.5% of groundwater samples. For PFOS, both surface water and groundwater samples show a low to moderate environmental risk.



Risk quotient (RQ) of antibiotics in different water bodies at basin scale

3. Seawater & sedimentary quality and pollution source

The global comparison of **pharmaceuticals' detection rates** in the aquatic environment in coastal areas.



The concentration of pharmaceuticals in Xiamen bay (Jiulong Esturay) is equal to other coastal area in Asia, but higher than in Europe and America coastal areas.

Li et al., 2022

Published papers

- Li, Y., Oliver, D. P., & Kookana, R. S. (2018). A critical analysis of published data to discern the role of soil and sediment properties in determining sorption of per and polyfluoroalkyl substances (PFAS). *Science of The Total Environment*, 628-629, 110-120. （他引201次）
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- Liu, Y., Wu, L., Shi, G., Cao, S., Li, Y*. 2022. Characteristics and sources of microplastic pollution in the water and sediments of the Jinjiang River Basin, Fujian Province, China, China Geology, 5, 429-438.
- Wu, L., Shi, G., Liu, Y., Li, Y*., Liu, C., Hao, Q., Cao, W., Li, Q. (2022). Pharmaceuticals in multi-media environment from the Jin River to adjacent marine embayment in Southeast China. *Environmental Science and Pollution Research*, https://doi.org/10.1007/s11356-022-24173-4.
- Li, Y., Liu, Y., Shi, G., Liu, C., Hao, Q., & Wu, L. (2022). Occurrence and Risk Assessment of Perfuorooctanoate (PFOA) and Perfuorooctane Sulfonate (PFOS) in Surface Water, Groundwater and Sediments of the Jin River Basin, Southeastern China. *Bulletin of Environmental Contamination and Toxicology*. 108:1026–1032
- Wu, L., Li, Y., Kong, X., Zhu, X. (2022). Mechanism evolution and prediction of carbamazepine sorption by mangrove plant residue–derived biochars. *Journal of Environmental Qqulity*, 1-10.
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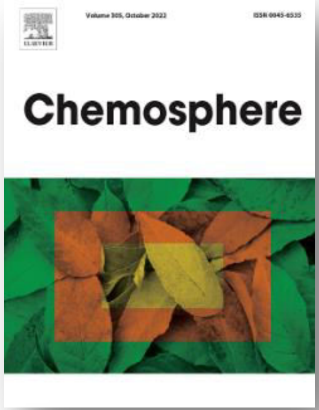

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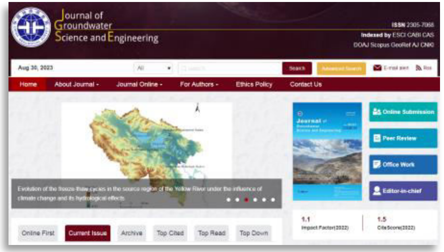

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