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Rethinking brine discharge: Should concentrated pollutants be regulated? Insights from China

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01

Background

Desalination brine discharge attracting global concern

"The State of Desalination and Brine Production: A Global Outlook" **(United Nations University, UNU, 2019) (Cited 1,770 times)**

- The global volume of brine discharged from desalination facilities has been severely underestimated.
- It is necessary to strengthen the management of the environmental impacts of brine discharge.


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Review

The state of desalination and brine production: A global outlook

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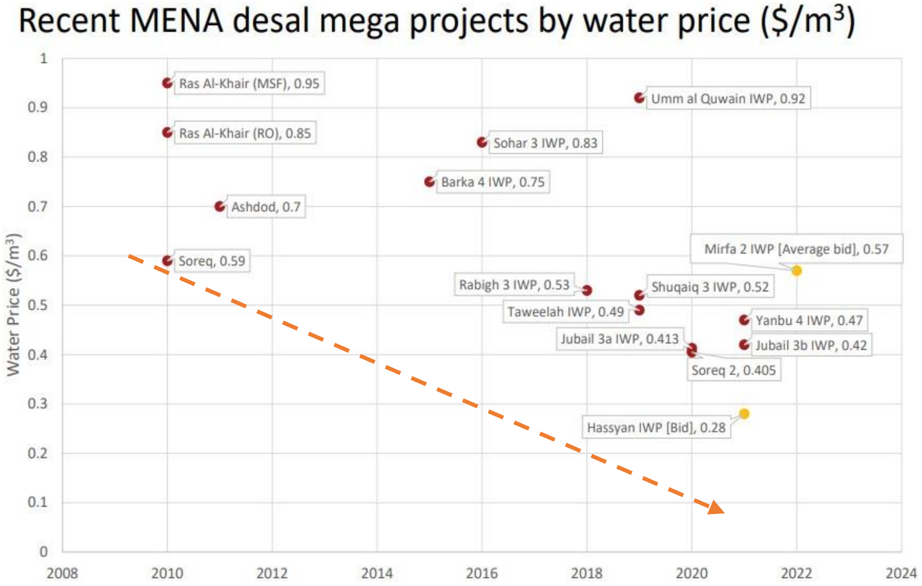
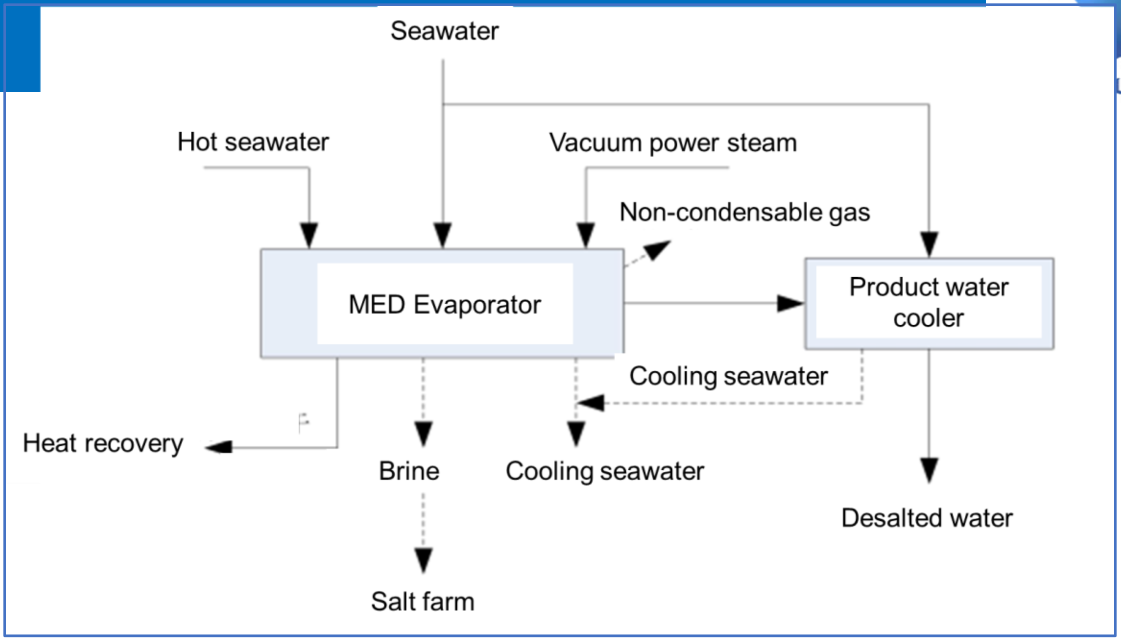
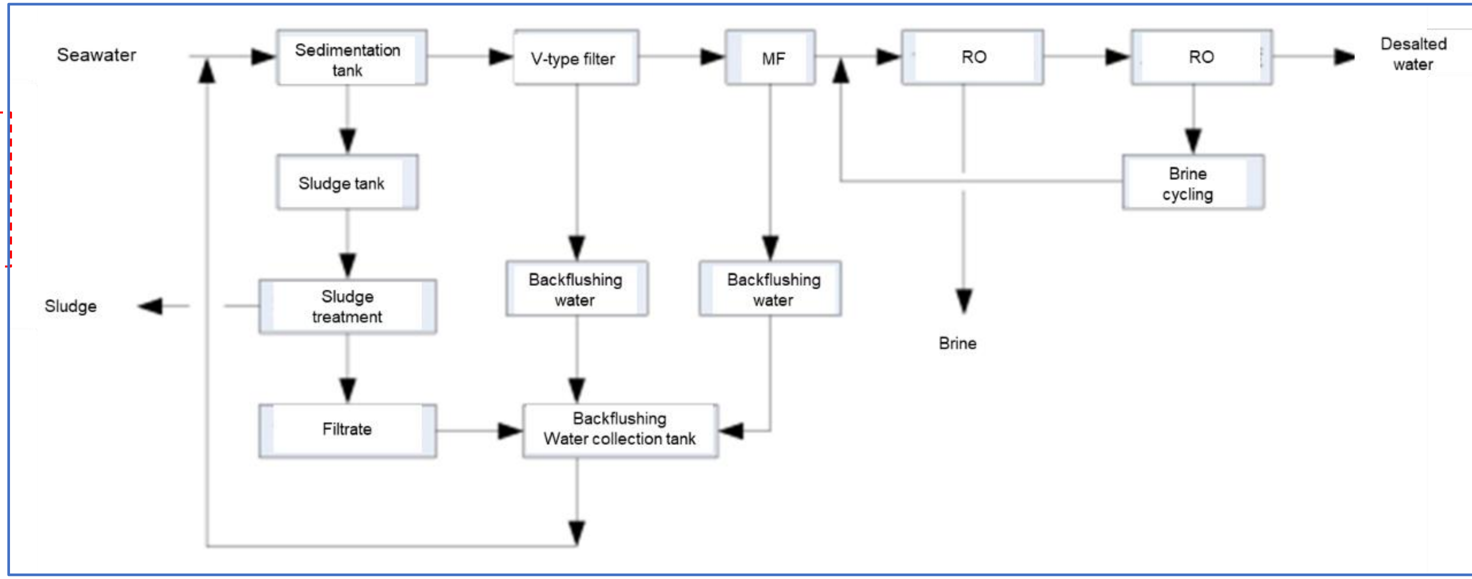


Seawater desalination

- Seawater desalination
  - Thermal Desalination
    - **Multi-stage flash**
    - **Multi-effect distillation,**
    - Membrane distillation
  - Membrane Desalination
    - **Reverse osmosis**
    - Electrodialysis,
    - Forward osmosis





Brine Discharge Management

Salinity limits of desalination concentrate in selected countries and regions

No	Region/Authority	Salinity Limit	Compliance Point
1	California, US	Increment≤2 psu	100 m
2	US EPA	Increment≤4 psu	——
3	Australia	Increment≤5% psu	——
4	Qakajee port, Australia	Increment≤1 psu	——
5	Perth, Australia	Increment≤1.2 psu (50 m); Increment≤1.2 psu (1000 m)	50m and 100 m
6	Gold Coast, Australia	Increment≤2 psu	120 m
7	Sydney, Australia	Increment≤1 psu	50-75 m
8	Okinawa, Japan	Increment≤1psu	Mixing zone boundary
9	Abu Dhabi	Increment≤5%	
10	Oman	Increment≤2 psu	300 m
11	Spain	Salinity≤38.3 psu	Sensitive Species habitat

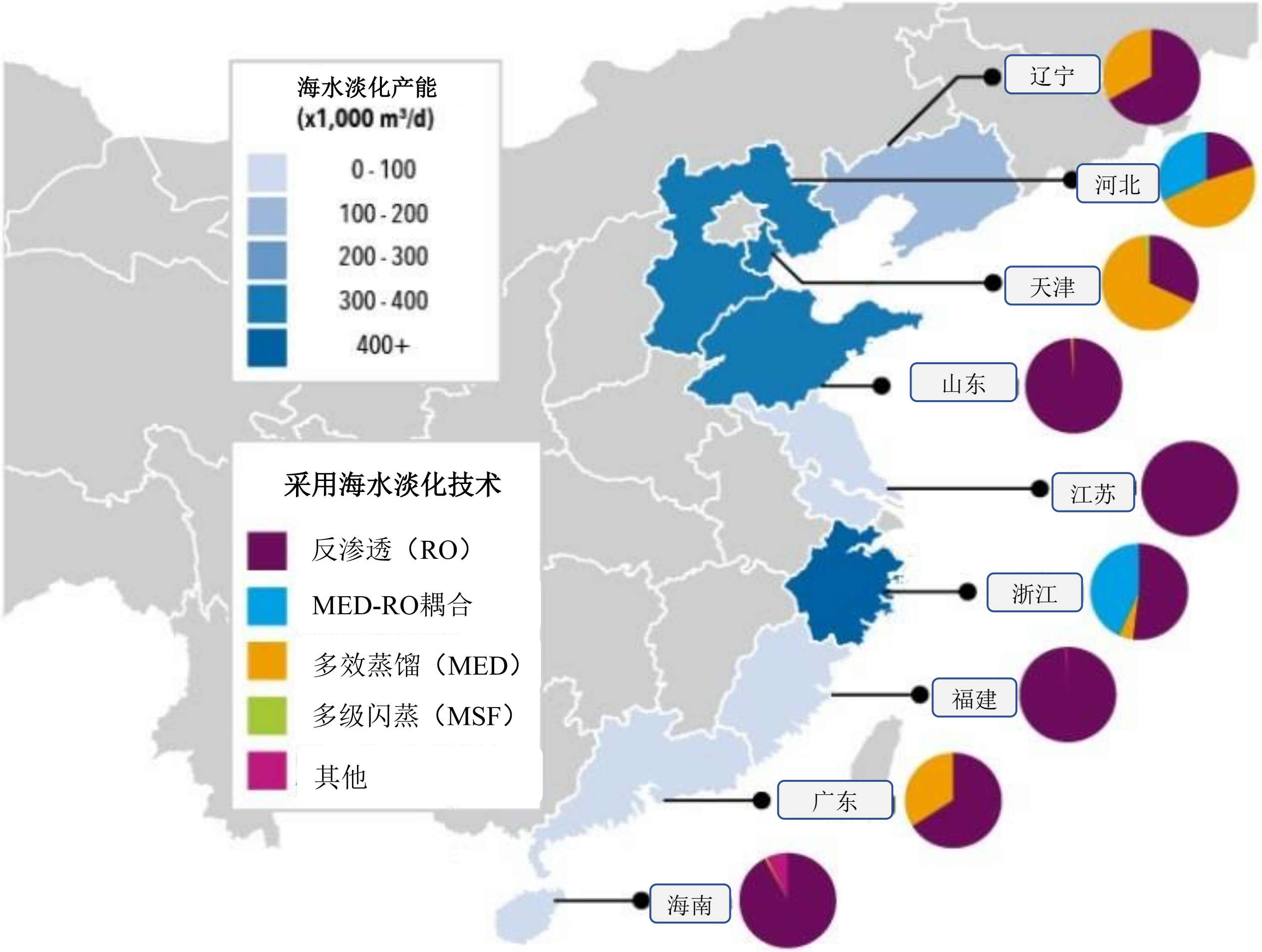
- The ecological impact assessment of brine discharge can fully follow existing environmental impact assessment (EIA) methodologies.
- Unlike other industrial pollution sources, brine discharge typically does not have clearly defined discharge limits. Instead, it is required that the brine be completely mixed within a specified range.

Source of risk factors and their discharge pathway in desalination brine

Risk Factor	Purpose of Addition	Type of Substance	Discharge Pathway
Salinity increase	Product of seawater concentration	Inorganic ions	Enters brine after concentration
Temperature increase	Heating of intake seawater	—	Discharged as thermal effluent
Antiscalants	Prevent scaling on RO membrane surface	Polymeric dispersants	Enters brine
Corrosion inhibitors	Prevent corrosion	Phosphates or polyphosphates, chromates, zinc salts, etc.	Enters brine
Defoamers	Prevent foam generation	Fatty acids, fatty alcohols	Enters brine
Coagulants /flocculants	Remove suspended solids during pretreatment	Polyaluminum chloride, ferric chloride, etc.	Enter pretreatment sludge
Biocides	Prevent biofouling and membrane contamination	Chlorine, UV (mainly used in small-scale systems)	Removed before RO process
Reductants	Prevent residual chlorine from damaging membranes	Sodium bisulfite, etc.	Enter brine as reduction products
Disinfection by-products	Secondary pollutants formed during pre-chlorination	Halo-(alkanes, acids, aldehydes, nitriles), etc.	Enter brine
Corrosion products	Secondary pollutants from pipeline corrosion	Heavy metals	Enter brine
Pollutants in raw seawater	—	—	Part enters sludge, part enters brine
Backwash water	Maintain membrane surface cleanliness	Inorganic salts, organics, etc.	Enters brine

Seawater desalination in China

- Total capacity is more than 2.5 million m3/d
- RO seawater desalination majority
- Larger desalination capacity in northern regions
- Primarily used for water supply in industrial parks;
- Brine salinity is relatively low and highly variable;
- High intensity of coastal development with elevated pollutant concentrations



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Research

Desalination plants

Plant I: FengYue MED desalination plant (FY-T)

- Technology: MED
- Capacity: 25,000 m^3/d
- Location: Tangshan

Plant II: FengYue RO desalination plant (FY-M)

- Technology: RO
- Capacity: 125,000 m^3/d
- Location: Tangshan

Plant III: Baifa desalination plant (BF)

- Technology: RO
- Capacity: 200,000 m^3/d
- Location: Qingdao

Plant IV: Dongjiakou desalination plant (DJK)

- Technology: RO
- Capacity: 100,000 m^3/d
- Location: Qingdao

Non-target screening based on GC×GC-qMS

≈7000 features

↓

Filter 1

M＞600 & RM＞700 & RI difference ＞ 2% or M＞700 & RM＞800

↓

404 tentatively identify results

↓

Manually check

Results with poor mass spectrum quality, long alkyl chains and cycloalkane were deleted

↓

List A :280 compounds

Filter 2	Filter 3
Peak volume increase ＞100%	Detection frequency＞75%
List B: 24 compounds	List C: 30 compounds

↓

Confirm by commercial reference standard

↓

Filter 4

i) Half-life ≥60 d, ii) BCF ≥ 2000, iii) LC50 or EC50 < 0.01 mg/L

↓

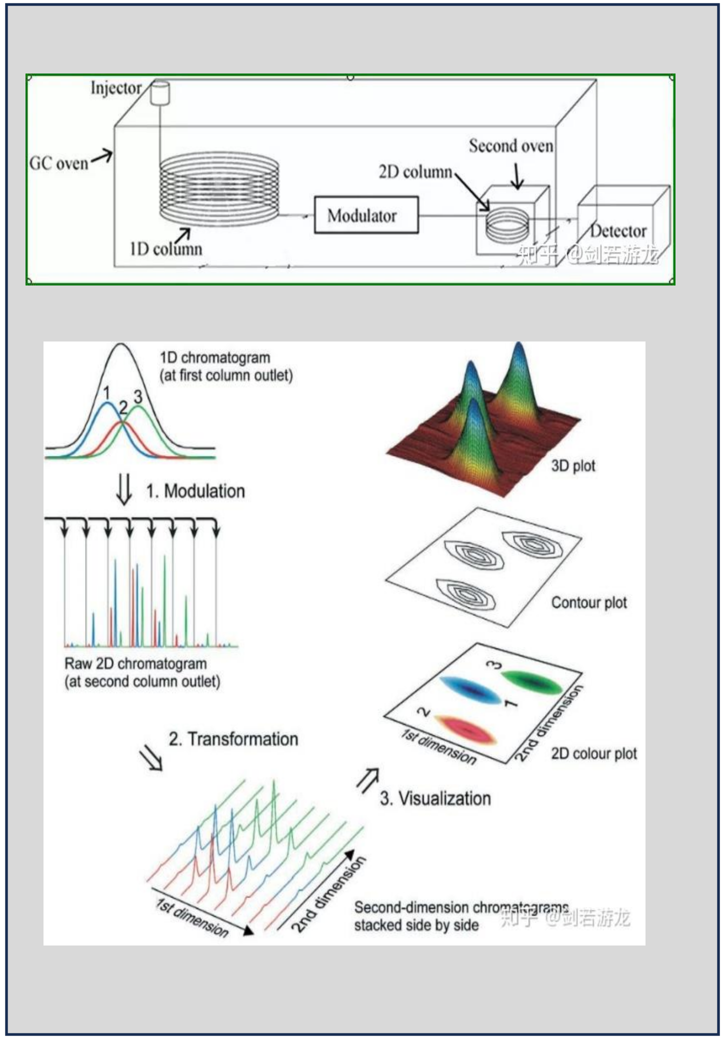
Manually check

Usage, chemical characteristics, expert knowledge

↓

Quantitative analysis list : 21 compounds

1. EPI Suite™ toolbox(https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface)
2. European center for ecotoxicology and toxicology of chemicals (ECETOC), 2001. Risk assessment in marine environments technical report no.82.
3. European Parliament and of the Council, 2006. Registration, evaluation, authorisation and restriction of chemicals (reach), Regulation (EC) No. 1907/2006.



Principle of GC × GC-qMS

Identification of environmentally relevant contaminants in desalination brine

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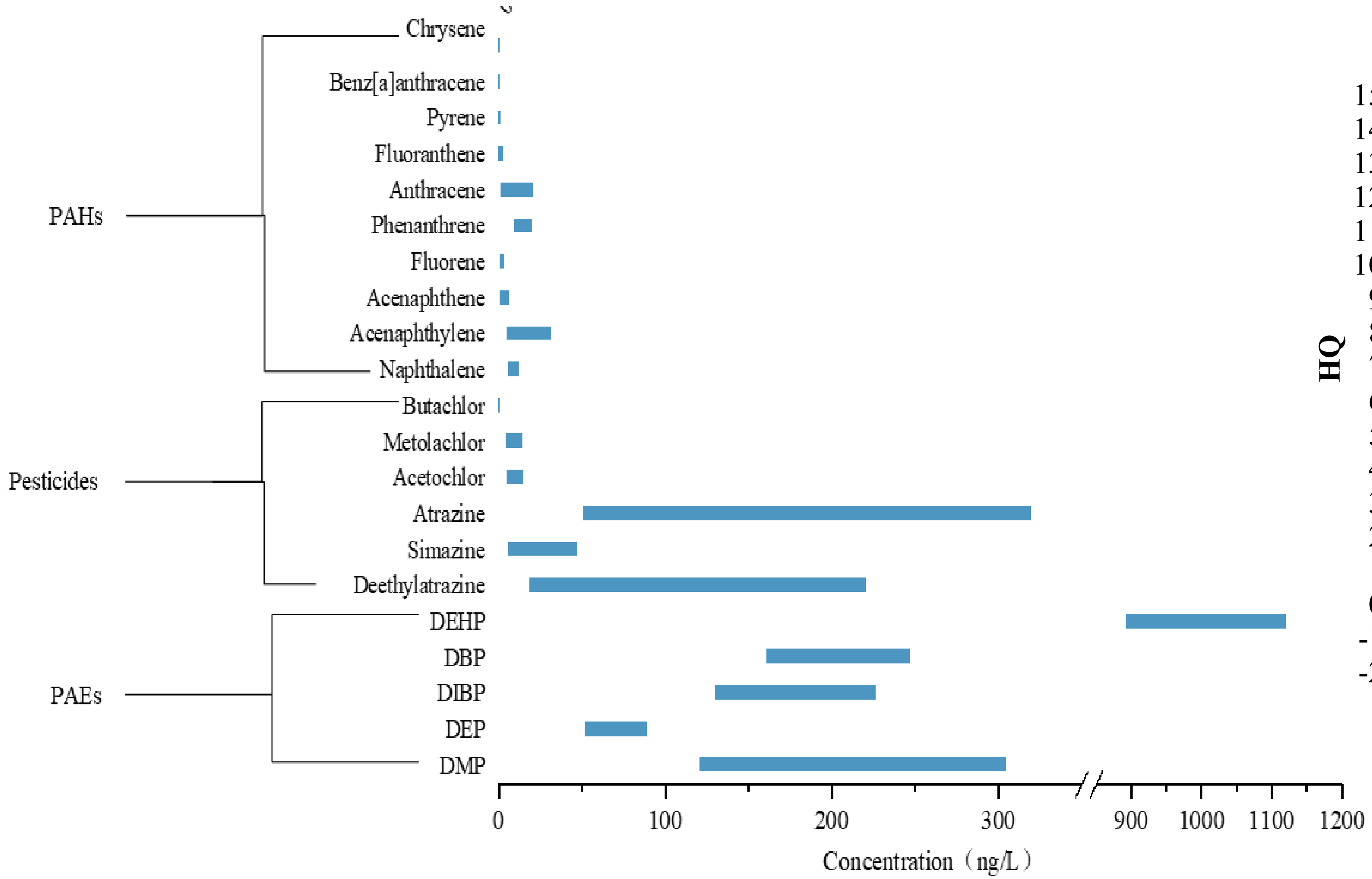
New-introduced compounds

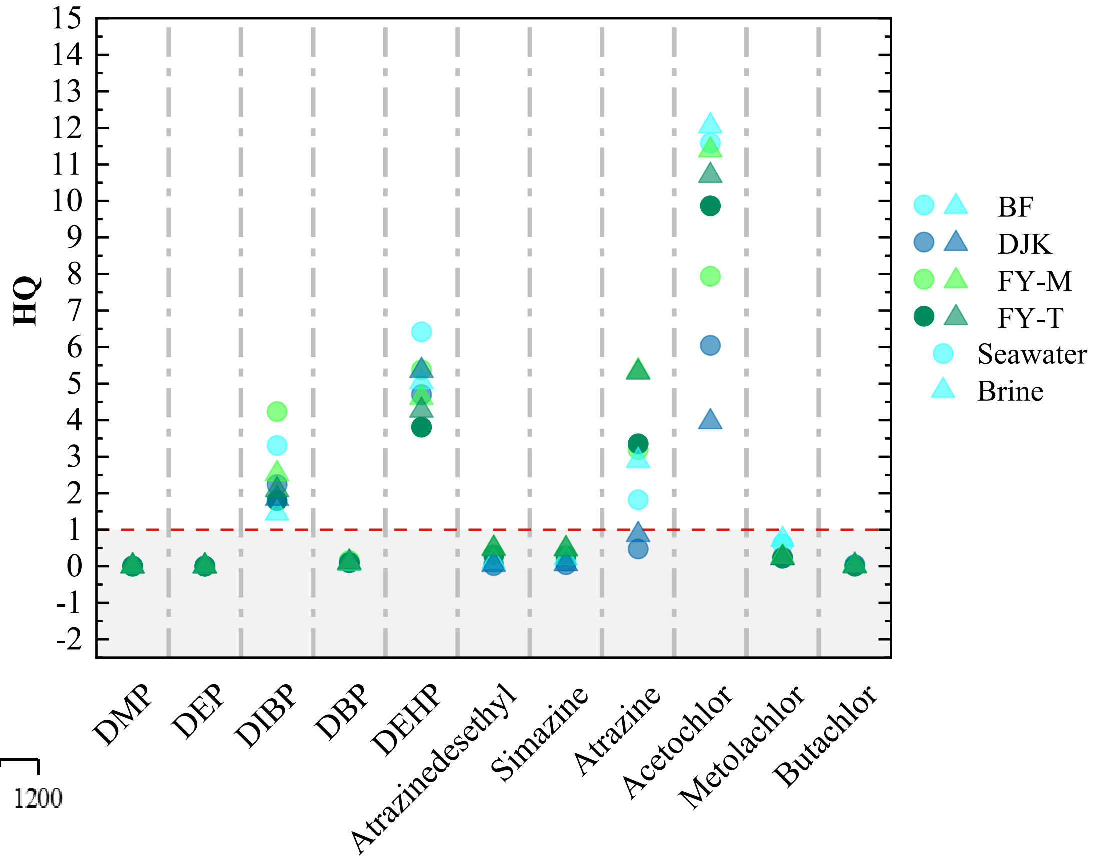
No.	Name
1	Caprolactam
2	Myclobutanil
3	Bromoform
4	Formanilide
5	Anthraquinone
6	Dibenzofuran
7	Diphenylmethane
8	2-Acetylthiophene
9	N-Cyclohexylformamide
10	Methyl Salicylate
11	2,6-Dichlorophenol
12	o-Cresol
13	2-Methylnaphthalene
14	Phenol
15	1,4-Dichlorobenzene
16	Acetophenone
17	Triphenylphosphine oxide
18	Hexaconazole
19	1,1,2,2-Tetrachloroethane
20	4-Methylphenol
21	4-Hydroxymetanilamide
22	4-Ethylbenzaldehyde
23	Isophorone
24	Benzyl Alcohol

Common detected compounds

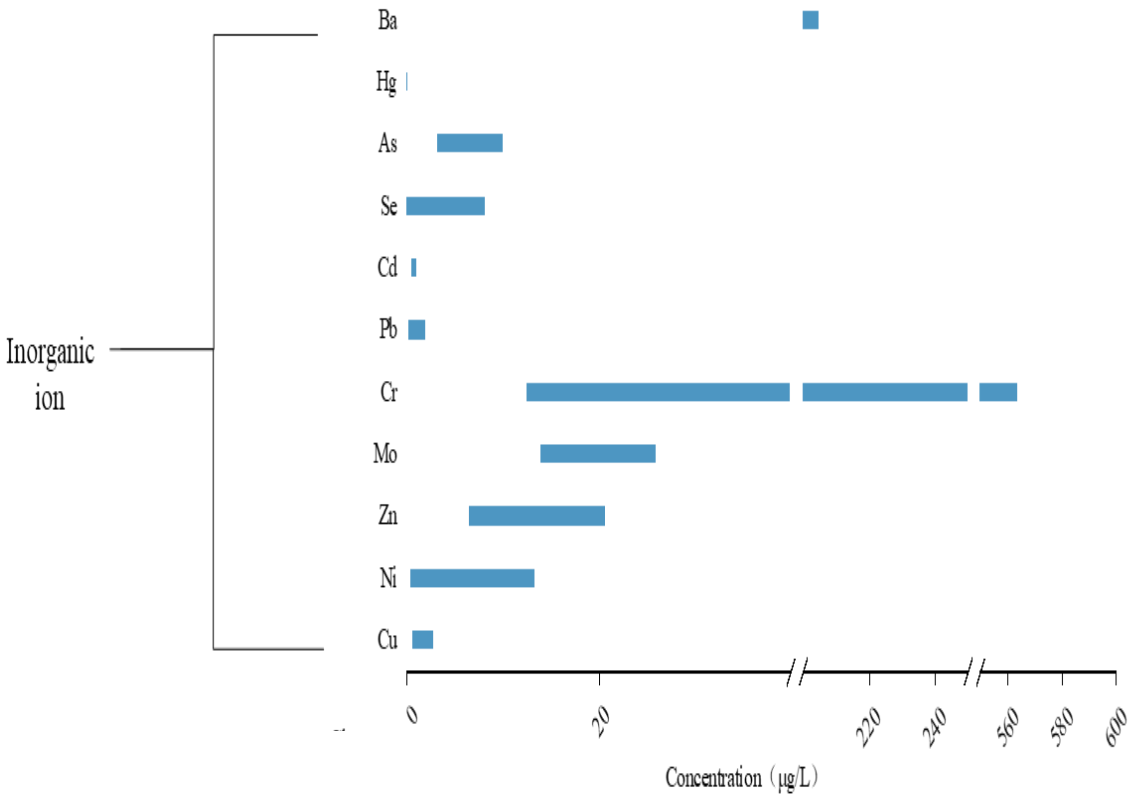
No.	Name
1	Naphthalene
2	Benz(a)anthracene
3	bis(2-Ethylhexyl) phthalate
4	Atrazine
5	1,4-dichloro-benzene
6	2,6-dichloro-phenol
7	Bentazone
8	Diethyltoluamide
9	Fenoxanil
10	Butachlor
11	Chloroxylenol
12	Diphenyl sulfone
13	Epoxiconazole
14	Cycluron
15	Caffeine
16	Di-n-butyl phthalate
17	Dimethyl phthalate
18	Diethyl phthalate
19	Diisobutyl phthalate
20	Triethyl phosphate
21	Paclobutrazol
22	Prometryn
23	Tri(2-chloroethyl) phosphate
24	Tris(3-chloropropyl) phosphate
25	Desethylatrazine
26	Simetryn
27	Uniconazole
28	Acetochlor
29	Metolachlor
30	Camphor

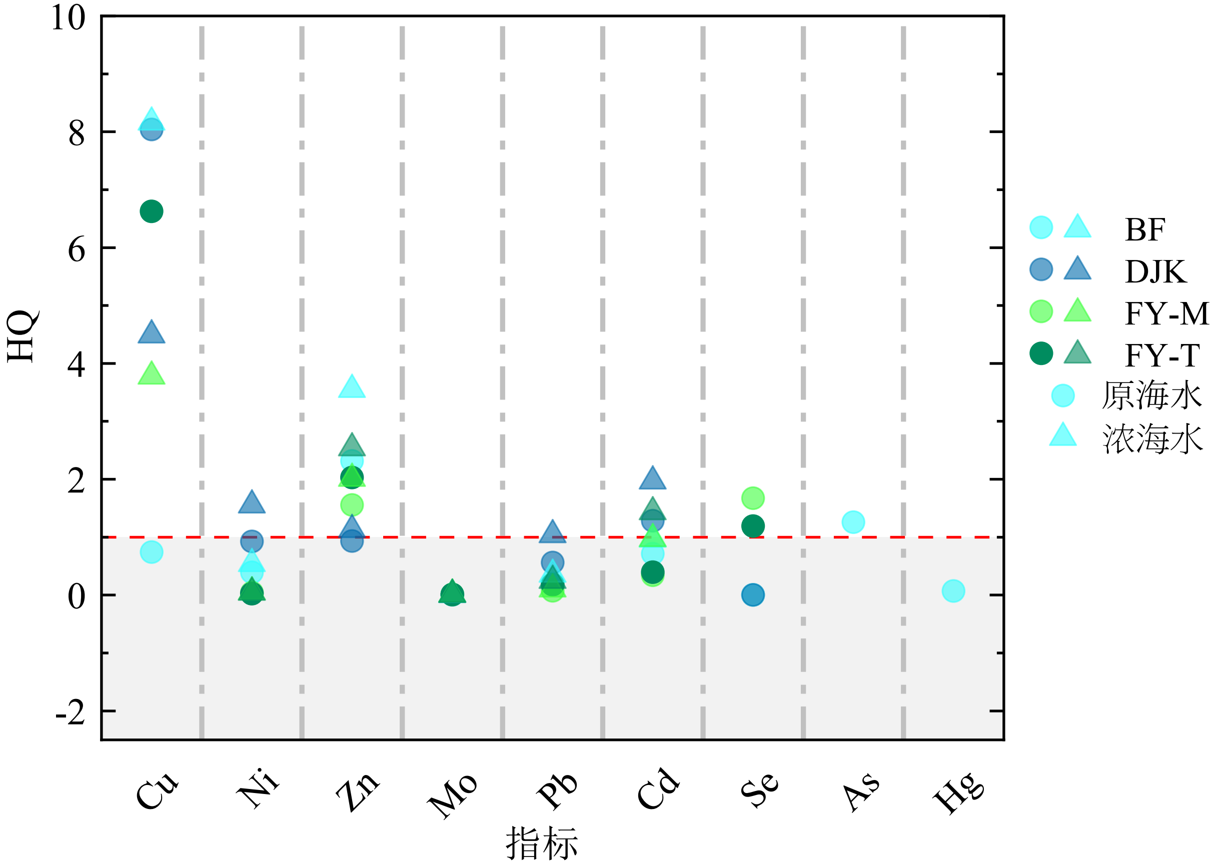
Concentration and ecological risk of organic pollutants



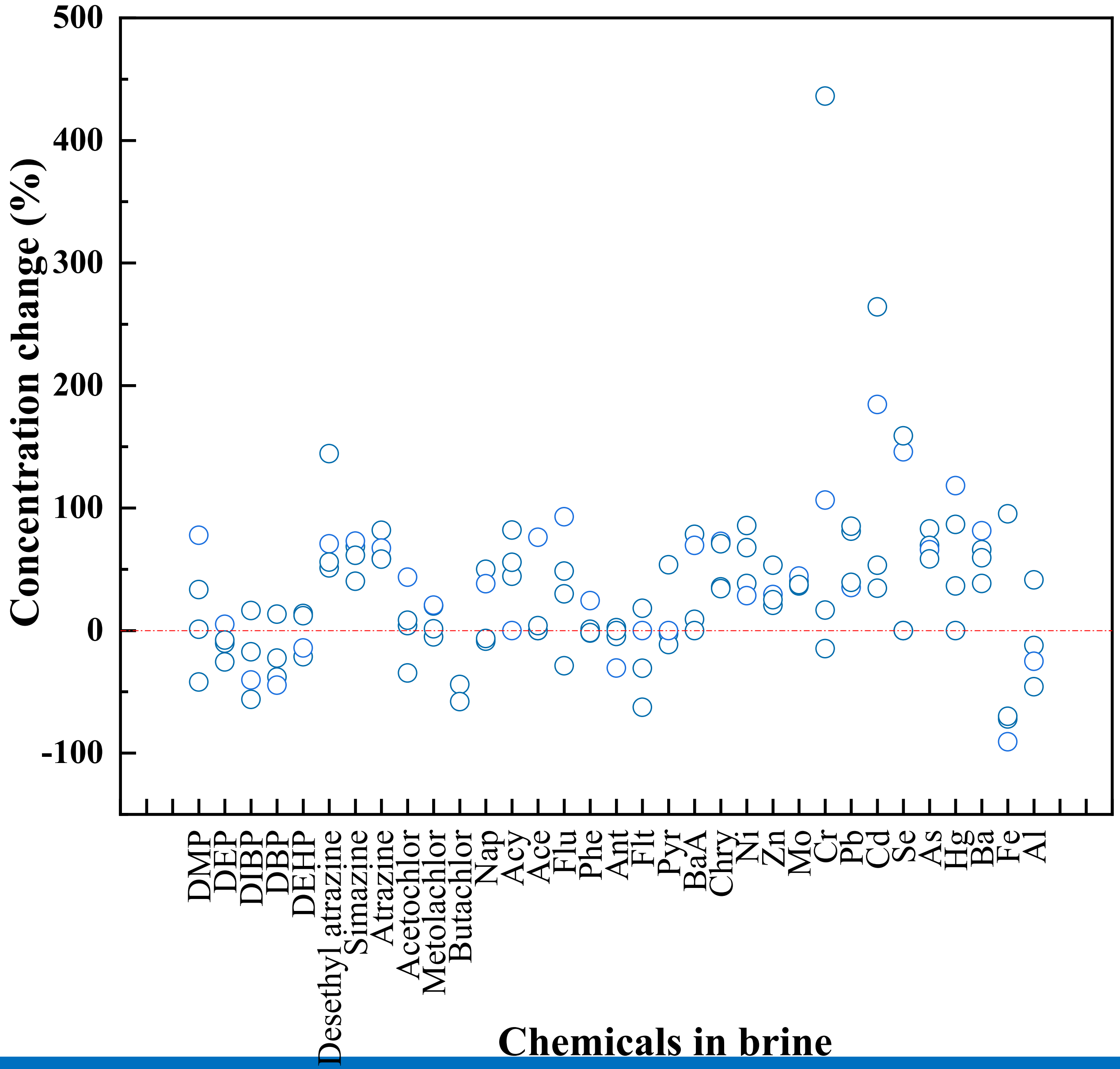


Concentration and ecological risk of inorganic pollutants



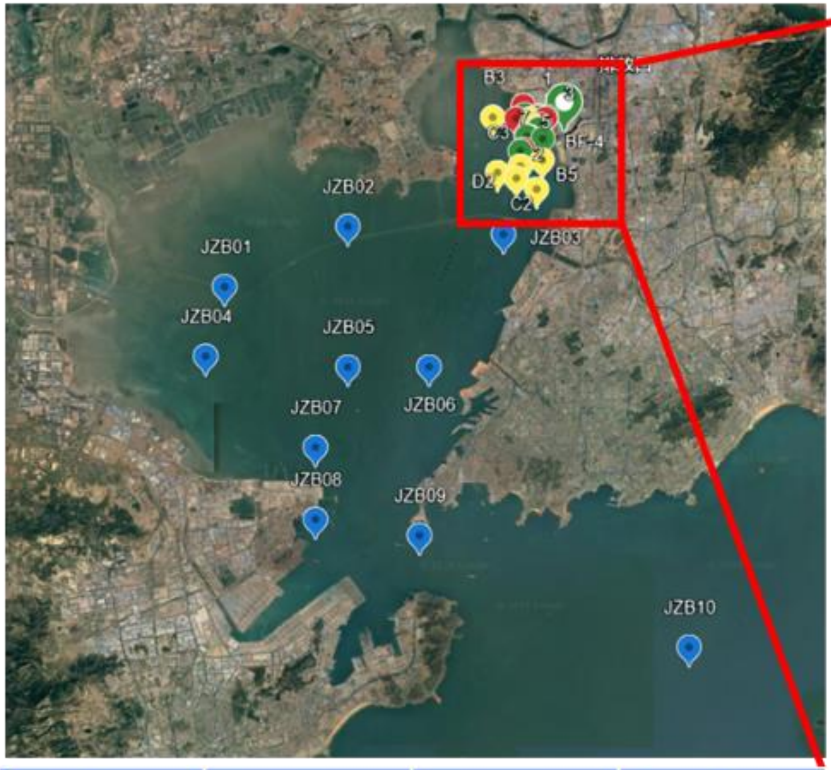


Concentration comparison between seawater and brine



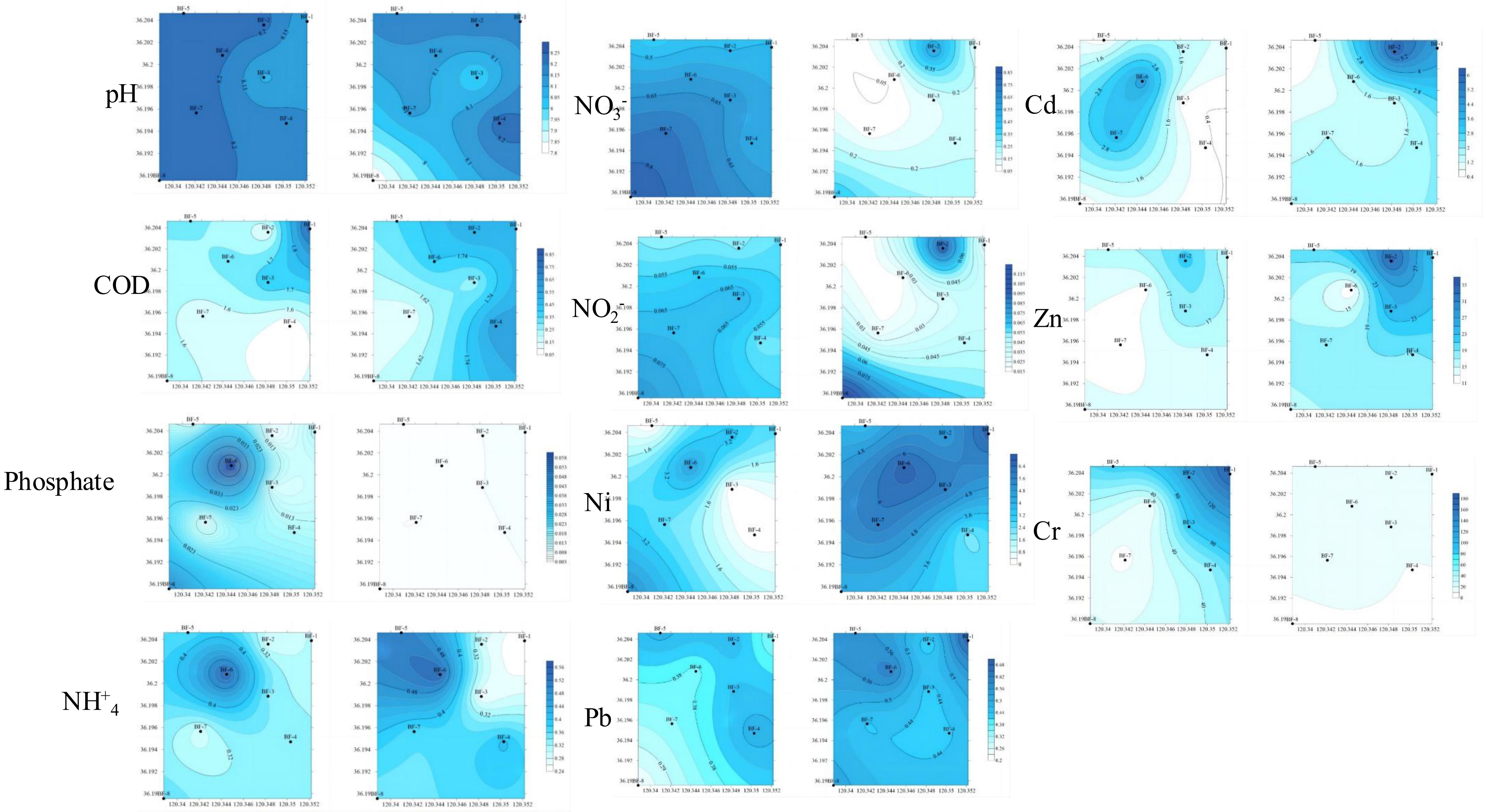
- Some organic pollutants are removed during the seawater desalination process;
- Inorganic pollutants do not show any significant removal effect;
- This phenomenon is mainly attributed to the pretreatment process of seawater desalination.

Story after brine discharge

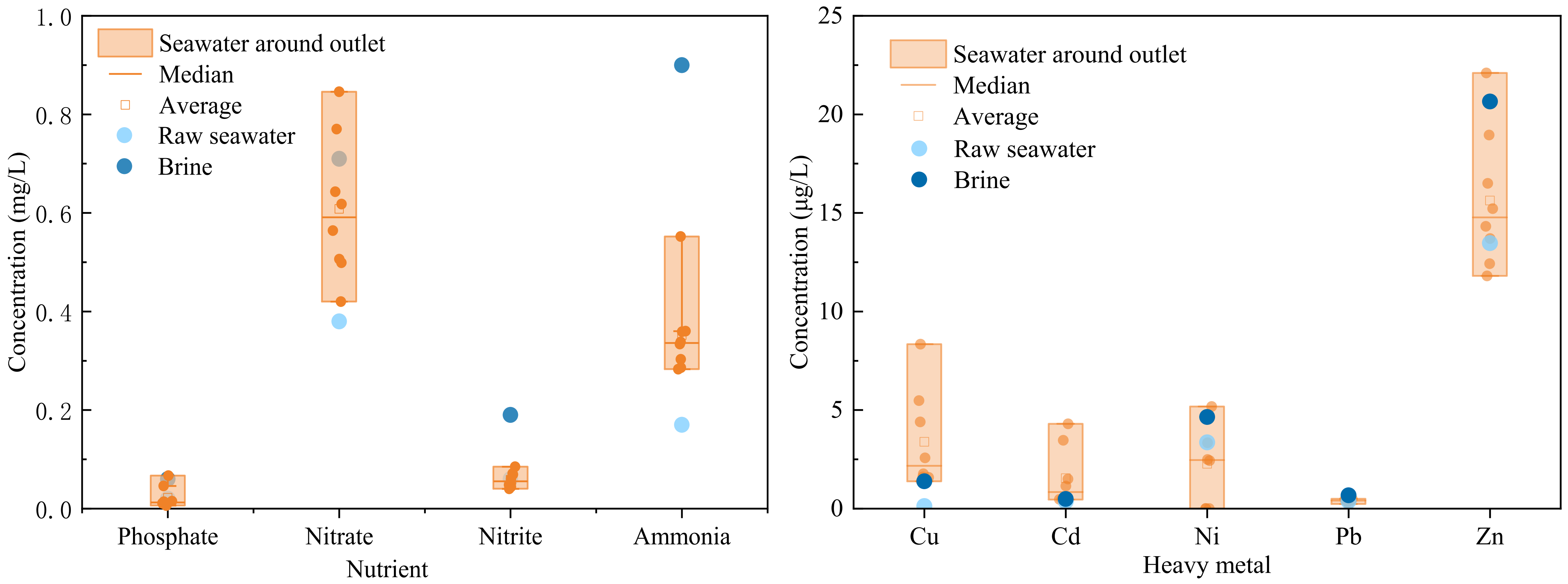


Site No.	Depth(m)	Site No.	Depth(m)
BF-1	2	BF-5	2
BF-2	2	BF-6	2
BF-3	2	BF-7	2.5
BF-4	4.5	BF-8	3.5

Effects of Desalination Brine Discharge on the Temporal and Spatial Distribution of Pollutants in the Receiving Area



Story after brine discharge



- As the intake water quality is generally better than that of the discharge area, the contribution of brine discharge to other pollutants is relatively low;
- The overall decline in marine environmental quality caused by pollutant concentration may not be significant.

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Conclusion

- The presence of pollutants in concentrated brine increases the ecological risk associated with brine discharge;
- The ecological risk of pollutants can be effectively controlled by selecting appropriate pretreatment processes and optimizing the locations of intake and outfall;
- Green seawater desalination technology is not simply about reducing or eliminating chemical additives, but rather about targeted optimization based on the sources of ecological risk.

Thank You!

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