Delivering quality multi-parameter data from on-line monitoring network in estuaries and bays: a case study in the Bohai Sea

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Outline

- The on-line monitoring network in the Bohai Sea
- A node in the Liaohe river estuary
- Summary and outlook
1.1 Brief of the Bohai Sea

Location and overview

- semi-enclosed marginal sea of the NW Pacific with 77 000 km$^2$
- divided in four parts: Liaodong Bay, Bohai Bay, Laizhou Bay and the central part
- connects to the Yellow Sea with the Bohai Strait
1.2 Its problems

- High eutrophication level in coastal waters
  - high DIN and phosphate concentration
  - regions with high eutrophication level ($E > 3$): all the three bays and Dalian coastal area

![Map of coastal areas with eutrophication levels](image)

$$E = \frac{[COD] \times [DIN] \times [DIP]}{4500} \times 10^6$$

- 2015 National Marine Environment Quality Report
Increasing pollutant discharges

- more than 80% pollutants are from land-based discharge
  - 80% of pollutants discharged into the sea are through rivers;
  - among which, NP agriculture sources contribute to 56% TN, 84% TP

Contribution to TN Flux to Bohai Sea

- Riverine: 6.03%
- Direct Discharge: 3.29%
- Coastal Zone: 1.82%
- Atmosph. Sedim.: 0.05%
- Mariculture: 88.82%

Land-based discharging sources for:

- TN
  - Industry: 10%
  - Municipal: 34%
  - Farming: 32%
  - Livestock: 24%

- TP
  - Municipal: 16%
  - Farming: 15%
  - Livestock: 69%
1.3 Overview of the on-line monitoring network

- Land-based stations, buoys with different sensors
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2.1 Why Liaohe river estuary

**Particularities**

- the biggest river in the Liaodong Bay carrying high N and P fluxes into the sea, resulting in high eutrophication level of the estuary and adjacent
- a typical North China river with **seasonal runoff pattern** and **high turbidity** in its maritime section
2.2 The Liaohe on-line monitoring station

- Synchronized observation of pressure-effect
  - end of the maritime section of Liaohe: land-based station → get the pollutant discharge
  - mouth of Liaohe: buoys → monitor the water quality
Advantages of land-based on-line monitoring station

- stable, flexible and sustainable
- easy to obtain reliable chemical data via the application of wet chemistry method:
  - DIN
  - Phosphate
  - TN
  - TP
  - VPCs,
  - …
Non-immersive segmented-flow detection

- During detection (5~10min): water sample segmentally pumped from the river to the sensors
- Between detections (3~4h): pipelines rinsed and evacuated, sensors non-immersed in water sample
- Non-immersive segmented-flow detection

- (1) monitoring all layers
- (2) anti bio-fouling
2.3 Nutrient sensor adjustment

- (1) Wet chemical method: improve sensor performance with additional filter

- Observations from sensors (25μm filter) comparing to laboratory detection results
  - Filter membrane used in the lab.: 0.45μm (HY/T 147.1-2013)
  - Sensors got lower value (-20%~40% average), poor relativity

**suspended particles** in the water sample significantly affects the performance of the sensors!
Observations from sensors (25µm filter) comparing to laboratory detection results

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suspended particles in the water sample significantly affects the performance of the sensors!
Adjustment: 5μm filter plus 25μm filter before detection

- The performance of the sensors of NO₃-N and PO₄-P improved: recoveries on calibration curve >90%; average discrepancy < 20% compared to Lab. detection

0.45 μm filter was NOT applicable for on-line filtration because of filter clogging.
(2) Optical sensors performance adjustment

- Concentration of nitrate, nitrite and other chemicals are directly detected by **full spectrum analysis**

Advantages: no wet chemical reaction
Defects: suspended particles affected
- Adjustment: optical length of the full spectrum sensor
  - 20mm optical length: high sensitivity, high relative errors
  - 5mm optical length: low sensitivity, low noise, better performance
2.4 The on-line monitoring on the river runoff

**Difficulties**

- The relationship among water level, velocity and runoff is not stable
  
  ① Seasonal variable runoff, controlled by a rubber dam  
  ② Irregular river-bed with bumps, prevents the effective use of the slope ADCP  
  ③ Irregular bathymetry with shallow water
(1) On-line monitoring plan

- Long-term vertical profile: Flowquest 1000 ADCP
- Long-term horizontal profile: Sontek SL 500 ADCP
- Short-term surface, middle layer, bottom point current: Infinity-EM AEM USB
- Short-term cruise survey: TRDI Stream ADCP

![Diagram of monitoring plan](image-url)
(2) Runoff calculation

Runoff is calculated with following equation

\[ Q = \omega V_m \]

\( V_m \) is the mean velocity, \( \omega \) is section area.

To get \( V_m \), the regression \( a, b \) have to be decided with following equations

\[ V = C + aV_f + bV_h \]

\[ V = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}, \quad V_f = \begin{bmatrix} v_{f1} \\ v_{f2} \\ \vdots \\ v_{fn} \end{bmatrix}, \quad V_h = \begin{bmatrix} v_{h1} \\ v_{h2} \\ \vdots \\ v_{hn} \end{bmatrix} \]

\( V_f \) and \( V_h \) are velocities measured by AEMs and FL 1000K, \( V \) are velocities measured by Stream ADCP.
(3) The current distribution during ebb tide and flood tide
(4) Runoff comparison between On-line monitoring and cruise observation

(5) The runoff results

- 250 m$^3$/s during ebb tide
- 100 m$^3$/s during flood tide
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3.1 What we learn from Liaohe river station

- The advantages in deploying land-base station are
  - stable platform for sensors ensuring better data quality
  - easy for maintenance, prevent bio-fouling

- Biological & chemical parameters on-line monitoring in rivers
  - more filters procedure will minimize the effects of contamination and improve the data quality
  - Trios OPUS optical sensors with shorter optical length is more suitable for measuring nitrate concentration in rivers with high turbidity

- On-line monitoring on the river outfall
  - Multiple observation methods are required for on-line monitoring on the river runoff when the river transverse section is irregular
3.2 Suggestions for QA/QC protocol of sensors

- **Performance test of sensors**
  - newly recruited/renewed: calibration curve, detection limit, recovery and span shift
  - Routine maintenance monthly: calibration curve, recovery, accuracy, precision
  - Comparison tests seasonally: On-line monitoring vs. Laboratory method

![Diagram showing the process of QA/QC protocol of sensors]

- Get samples automatically
  - Sensor I
    - Sensor II
      - On-line observation I
        - On-line observation II
          - Statistic test
            - Relativity test
            - Correlation test
            - Significance test...
Weekly routing inspection
- status of the on-line monitoring platform hardware
- abnormal records of the monitoring process

Monthly maintenance
- replenishment of chemical reagents
- rinsing the pipelines and detection cells
- cleaning the sensors and filters and so on…

Before

After
3.3 Outlook

- **Further improvement of the sensors’ performance**
  - Integrate wet chemical method and full spectrum sensors
  - Dissolved nutrients $\rightarrow$ TN and TP

- **Improve the accuracy of the on-line monitoring system on the river outfall**
  - Establish velocity-water level-runoff correlation in different seasons
  - On-line deployed of the seabed based observation platform

- **Improve the synchronization of land-based station and buoys**
  - Comparison between sensors in surface water and sea water
  - On-line monitoring data into numerical model to create public service product
Thanks