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SWMM-based Daily Substance Flow Analysis for urban drainage system: a case study in Northern Kunming
Outline

- Introduction
- Materials and methods
- Results and discussion
- Conclusions
Total pollution load control in urban area, especially in China

- Time scale: yearly to daily, (even smaller)
- Spatial scale: whole area to individual unit
- Conventional estimation methods are in the long time scale and statics, thus can not be used for improving environmental quality efficiently.

- In 2015/04/02, “Water Pollution Prevention Act Plan” was promulgated, aiming to eliminate effluvial waterbodies in 2020.

severe situation!
Kunming playing an important role in water pollution control program

- Dianchi Lake, one of the most important inland lakes in China, is suffering from serious pollution.
- Kunming, the main city of the basin, contributes more than 75% pollution load to Dianchi Lake every year.
Background information about Kunming

- Area: nearly 300 km²
- Population: over 3 million
- 7 WWTPs
- A hybrid of combined and separated sewers
- Annual precipitation is more than 900mm.

Study Area

- Urban drainage system in Northern Kunming (NK-UDS)
- Area: about 42 km²
- Population: nearly 0.69 million
- Two WWTPs (WWTP 4 & WWTP 5)
- Precipitation: 539mm in 2011
Materials and methods

Sewage pipes

Combined sewers

Storm pipes

WWTP

Receiving waterbodies

Public service

industry

residence

Underlying surfaces

Public service

industry

residence

Underlying surfaces
Materials and methods

**SWMM-based model of SFA**
- a dynamic and quantitative model with the principle of mass balance in the daily time scale

- Monitoring
- Triangle method
- SWMM model simulation

Framework of NK-UDS and substance flow paths
Materials and methods

MGW: municipal wastewater and groundwater infiltrating into pipes
CW: collected wastewater by WWTPs
UCW: uncollected wastewater
PW: pumped wastewater from WWTP4 to WWTP5
F: flooding
CSO: combined sewer overflows
DDR: direct discharge of rainwater collected by storm sewers
DSR: direct surface runoff
RR: rainwater runoff entering sewer system

$i$ refers to water quantity, COD, SS, TN, TP and NH$_4$-N loads

\[
RR_{1,i} = CW_{4,i} + CW_{5,i} + F_i + CSO_i - MGW_{4,i} - MGW_{5,i}
\]
\[
TW_{4,i} = (CW_{4,i} - PW) \times RC_{4,i}, \quad TW_{5,i} = (CW_{5,i} + PW) \times RC_{5,i}
\]

RC$_{4,i}$ and RC$_{5,i}$ are the pollutant remove coefficients by WWTP4 and WWTP5, separately

\[
UCW_i = \frac{MGW_i}{WCR} - MGW_i
\]

WCR is the wastewater collection rate

RR$_{2,i} = DDR_i$
Results and discussion

- **Discharge patterns of individual unit**
- **Spatial distribution of wastewater**

![Graphs showing discharge patterns and spatial distribution of wastewater](image)
Results and discussion

- Temporal variation of flows from special unit
The horizontal axis is every single day, which is not ranked in chronological order but in ascending order of daily precipitation instead.

- As the precipitation increased, rain-derived pollution increased rapidly.
- During rainy days, DDR and DSR delivered 22.1% contribution of flux into receiving waterbodies, but 69.5% of COD load.
- DDR and DSR contributed 69.9% of flux and 79.4% of COD load on the last day in the figure when the precipitation is 77mm.

- Severe CSO and flooding came out on that day, which contributed 132.5t (12.5%) and 72.7t COD (6.9%) separately.
Results and discussion

The whole year & area result

Municipal Wastewater & Groundwater

- Residential lands
- Public service lands
- Industrial lands
- Ground aquifer

Water (10^4 t)

- COD(t)
- SS(t)
- TN(t)
- TP(t)
- NH_4-N(t)

Water(10^4 t) COD(t) SS(t) TN(t) TP(t) NH_4-N(t)

5155.9 1735.22 14131.1 245.31 13139.0 1245.97

Hybrid Sewer System

- WWTP4 Hybrid Sewer System
- WWTP5 Hybrid Sewer System

Rainwater Runoff

- Urban underlying surfaces
- Roofs
- Roads
- Green Spaces

Rainwater Runoff

- 119.3 13.24 367.1 1.08 137.9 2.68

WWTP4

- 1987.6 228.14 425.8 3.85 82.1 8.03

WWTP5

- 6097.8 625.74 1303.0 14.53 286.3 79.23

Receiving waterbodies
Conclusions

- A SWMM-based model of daily substance flow analysis was conducted to simulate the flows of water, COD, SS, TN, TP and NH$_4$-N in the urban drainage system.
- Substances flow pathways could be identified and the quantity of every single path could be calculated in the daily time scale.
- Different rain-derived pollution sources have their own emission reducing potentials, and thus the results can support water pollution control plans in Kunming.
- Smaller spatial-temporal estimation method should be developed, considering urban drainage system is a dynamic system, especially during the storm period when runoff brings intense impact to UDS.
Thanks for your patience!