NC STATE UNIVERSITY

The challenges and rewards of acquiring high frequency water quality data

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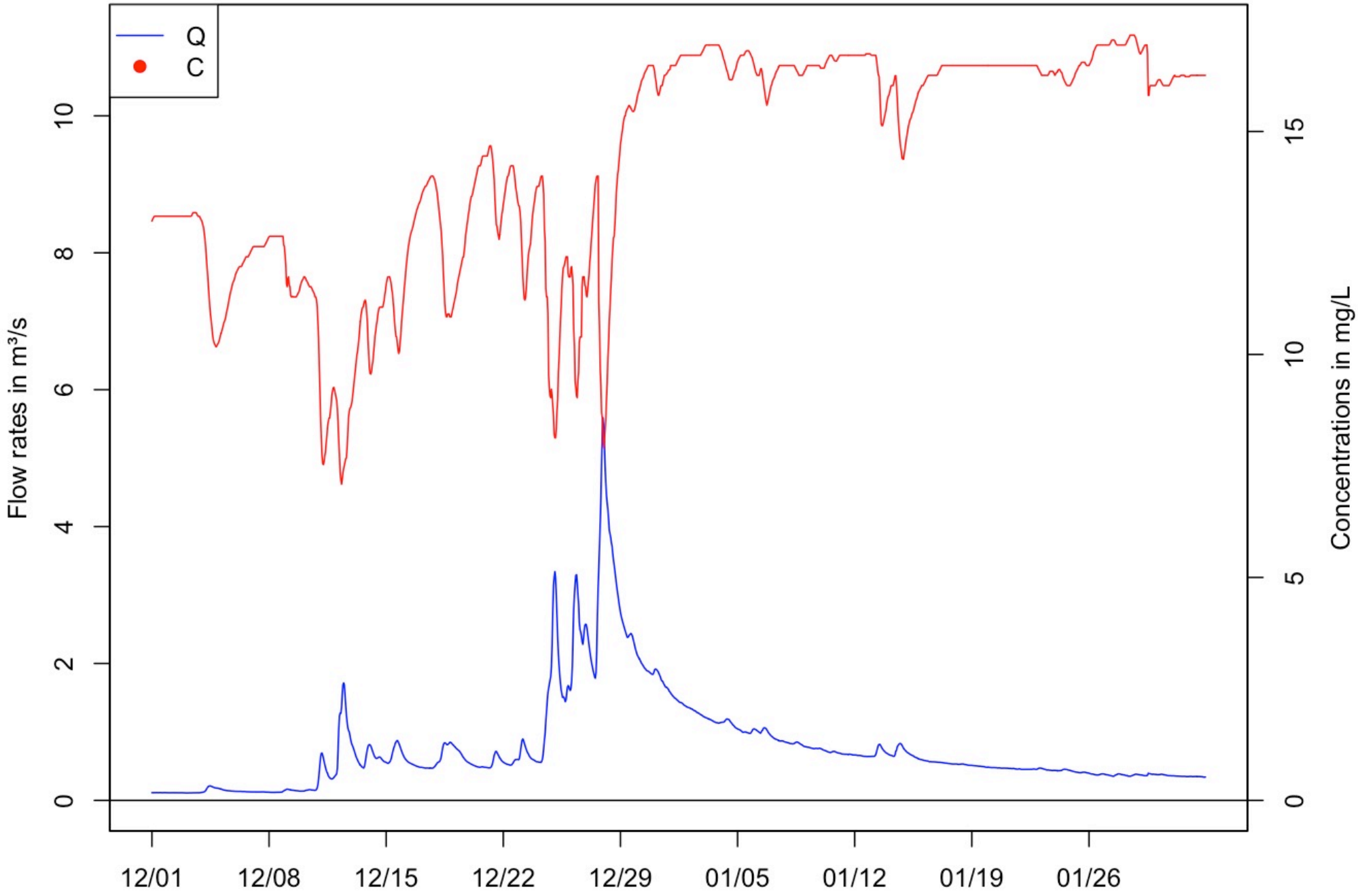
In Environmental Sciences we…

- … want to tell the story of how the world functions
- … make hypotheses
- … we collect data *partial in space and in time*
- … infer processes at play, quantify, extrapolate, model
- … make conclusions on how the world functions and what we should do about it

Why do we need high frequency WQ data?


Q
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Flow rates in m³/s
Concentrations in mg/L
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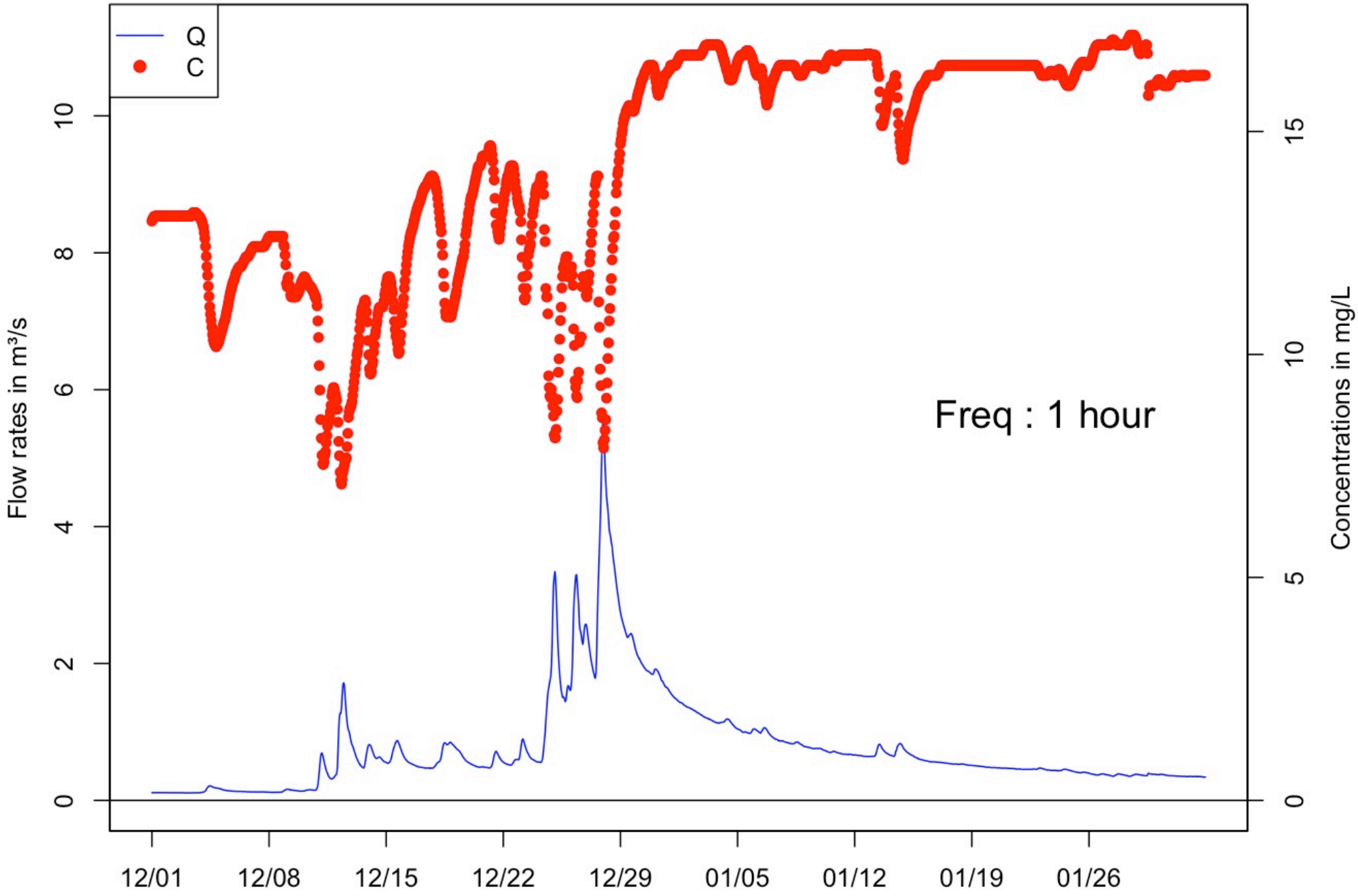
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Flow rates in m³/s
Concentrations in mg/L
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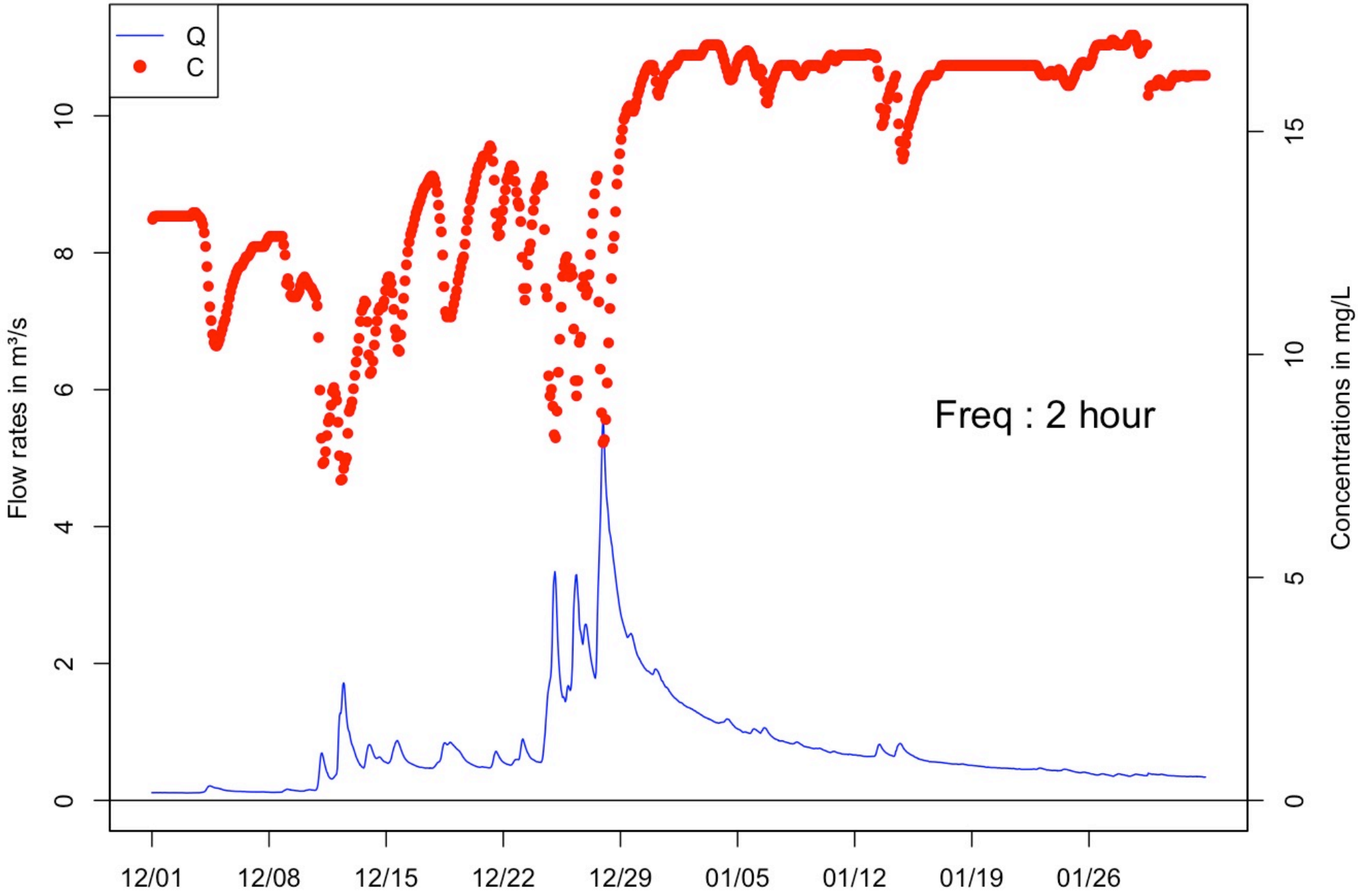
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Flow rates in m³/s
Concentrations in mg/L
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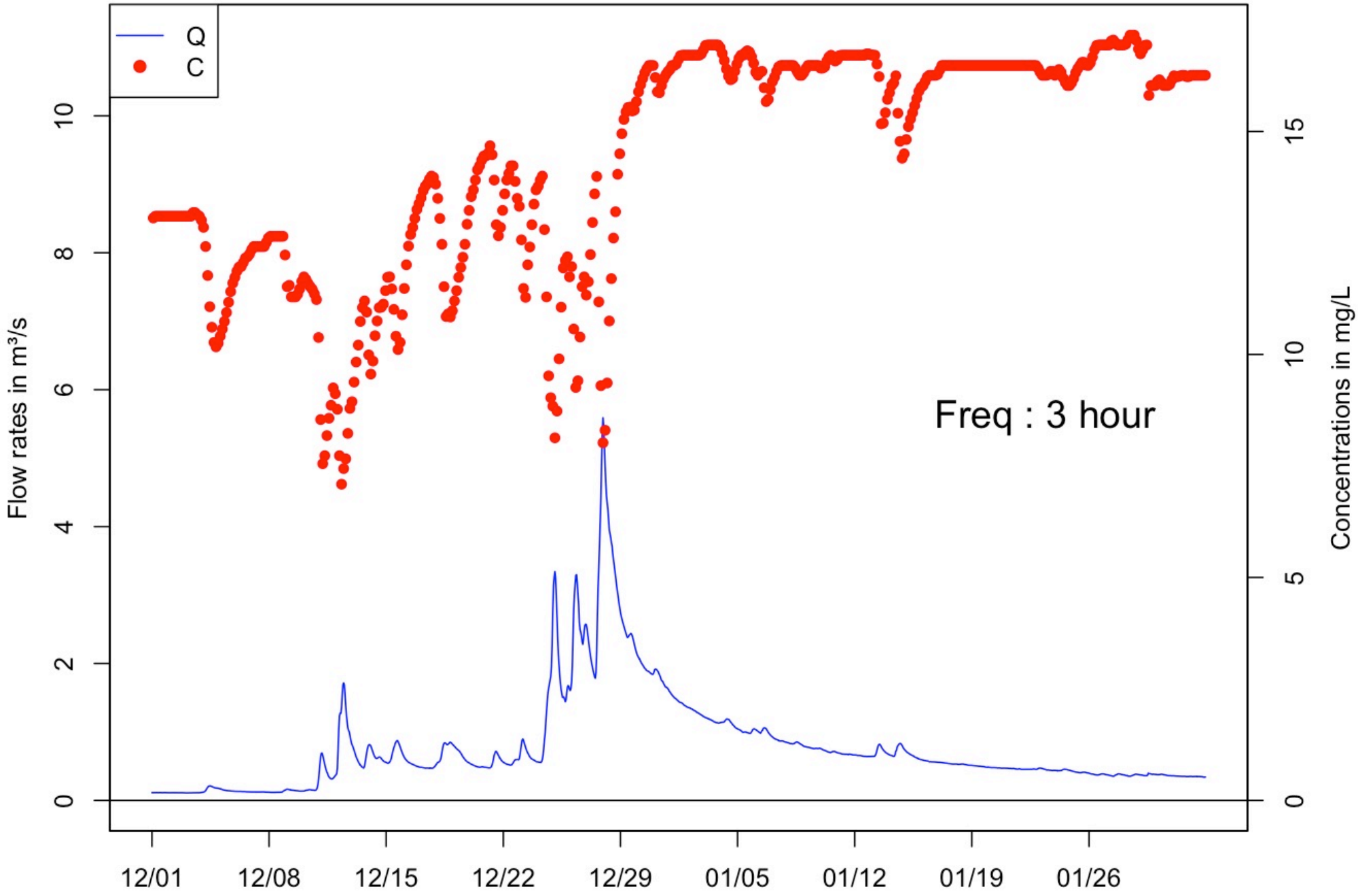
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Concentrations in mg/L
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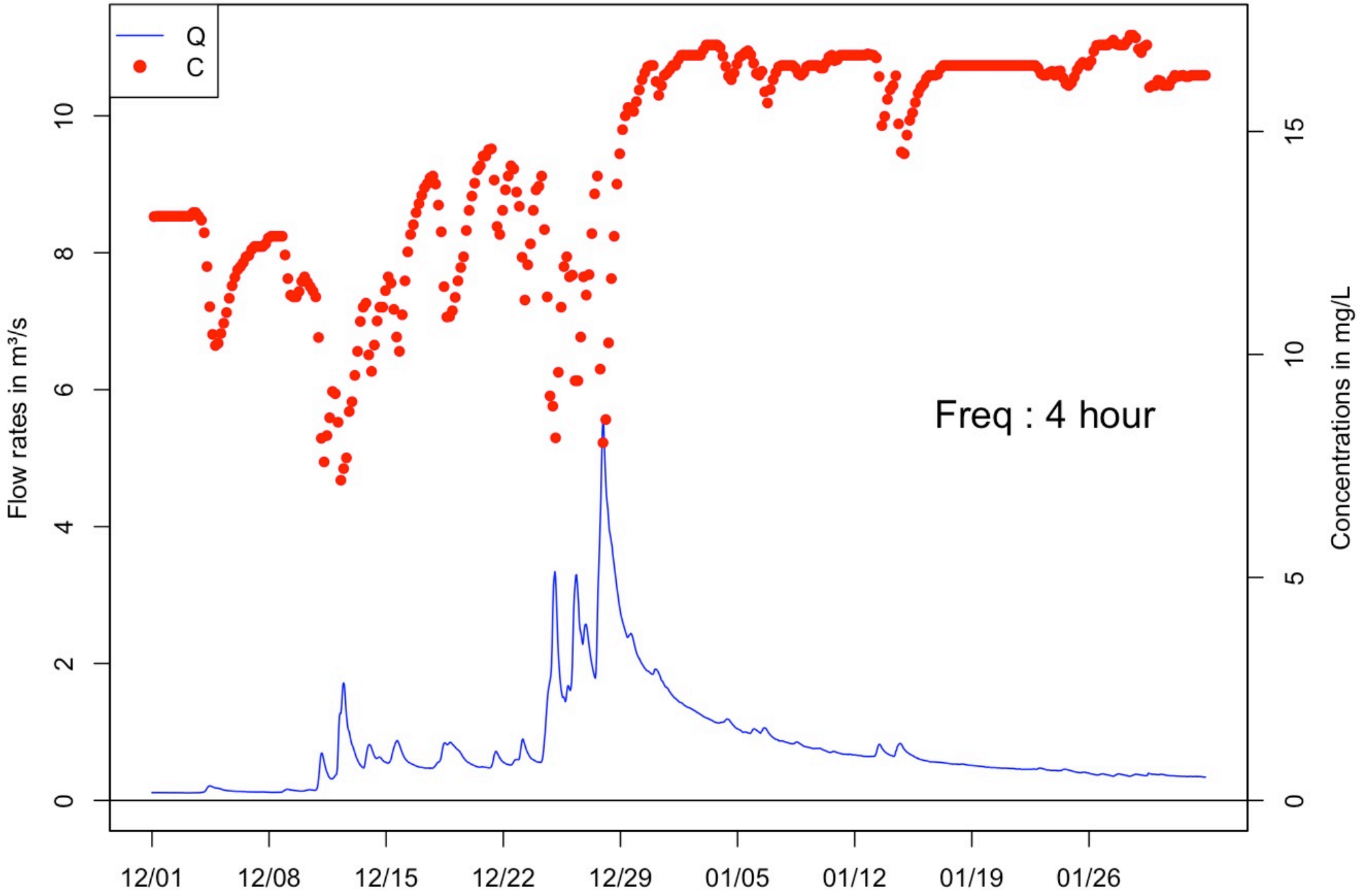
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Flow rates in m³/s
Concentrations in mg/L
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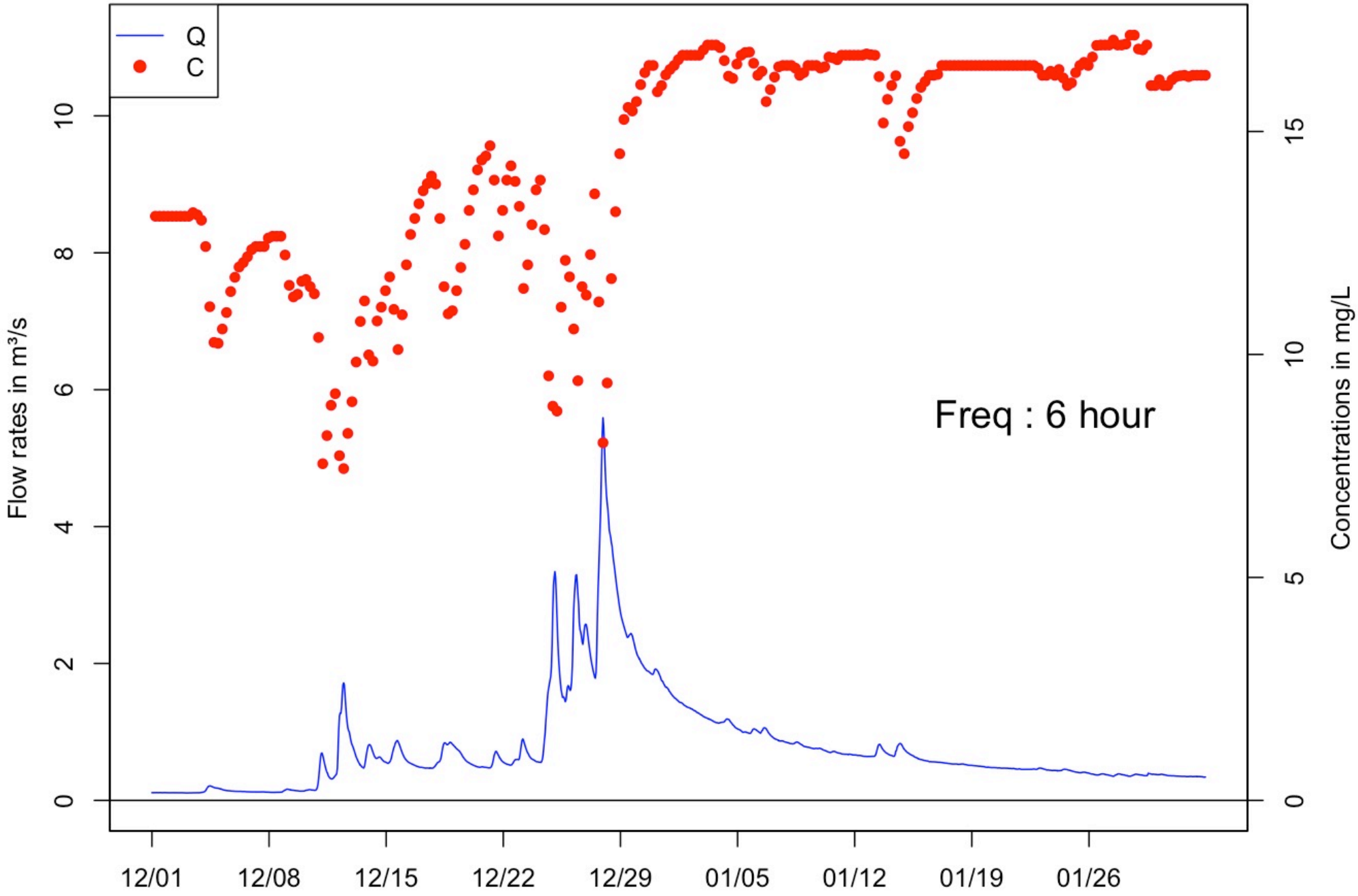
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Concentrations in mg/L
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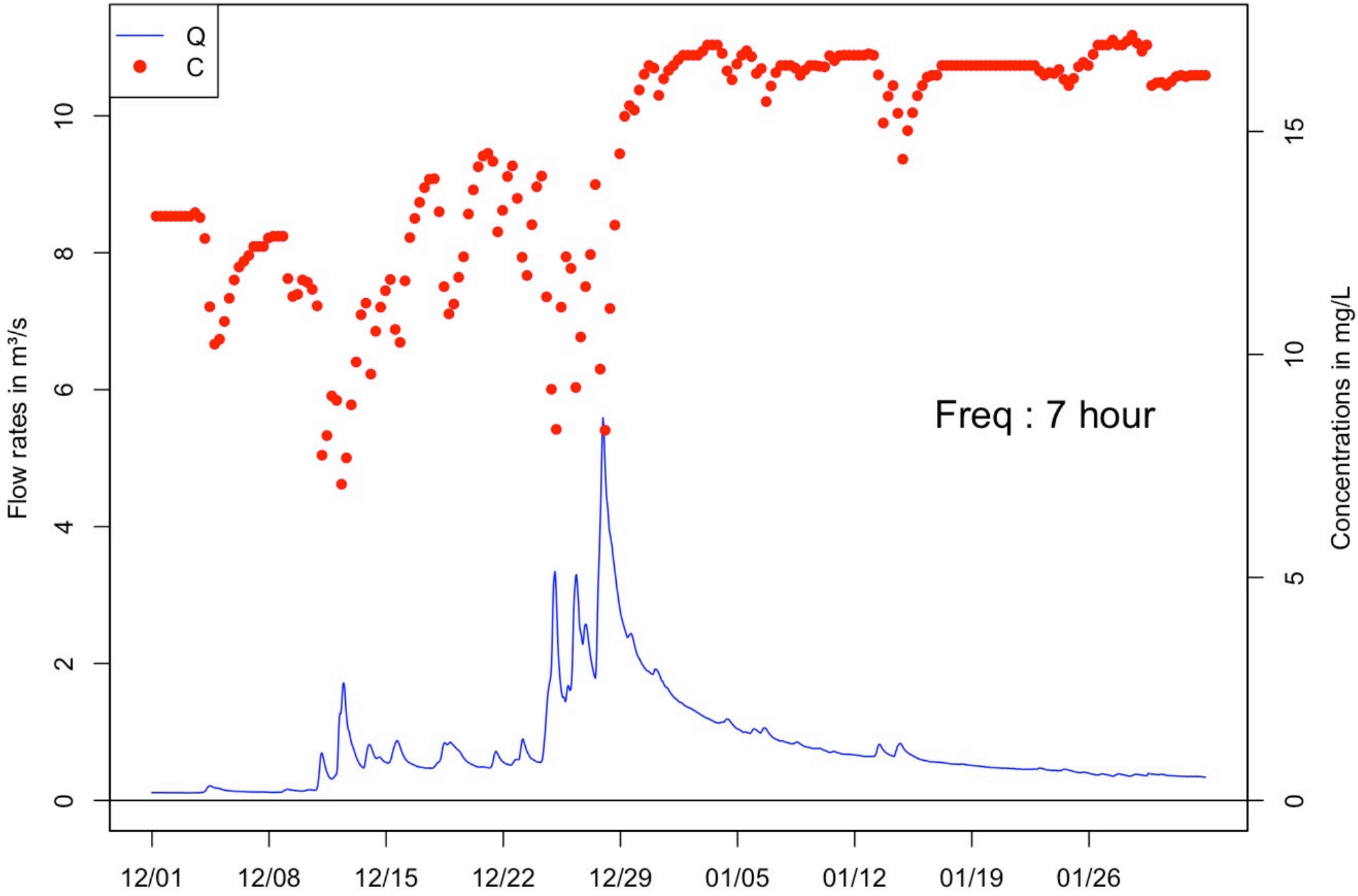
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C
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Flow rates in m³/s
Concentrations in mg/L
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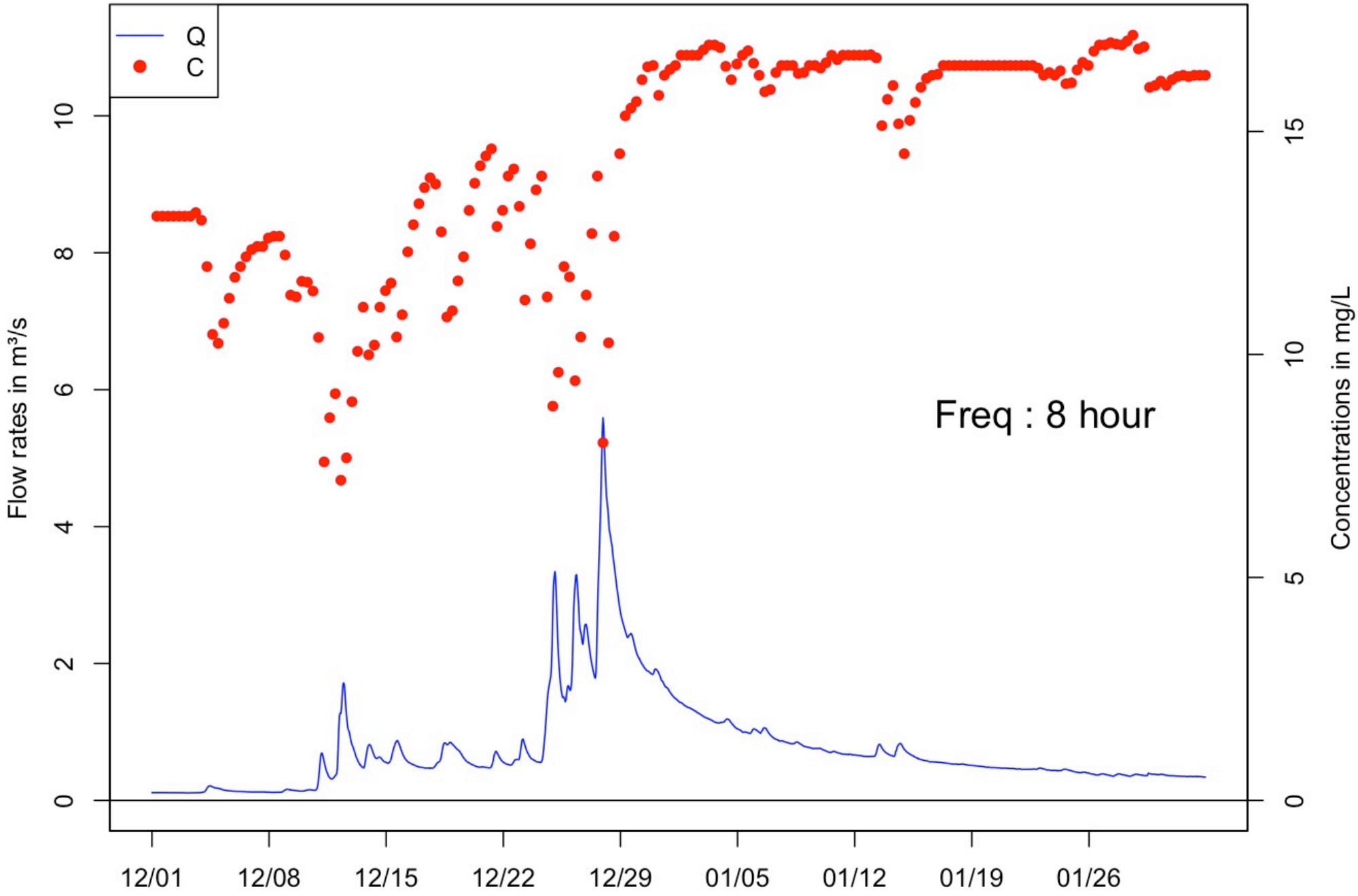
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C
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Flow rates in m³/s
Concentrations in mg/L
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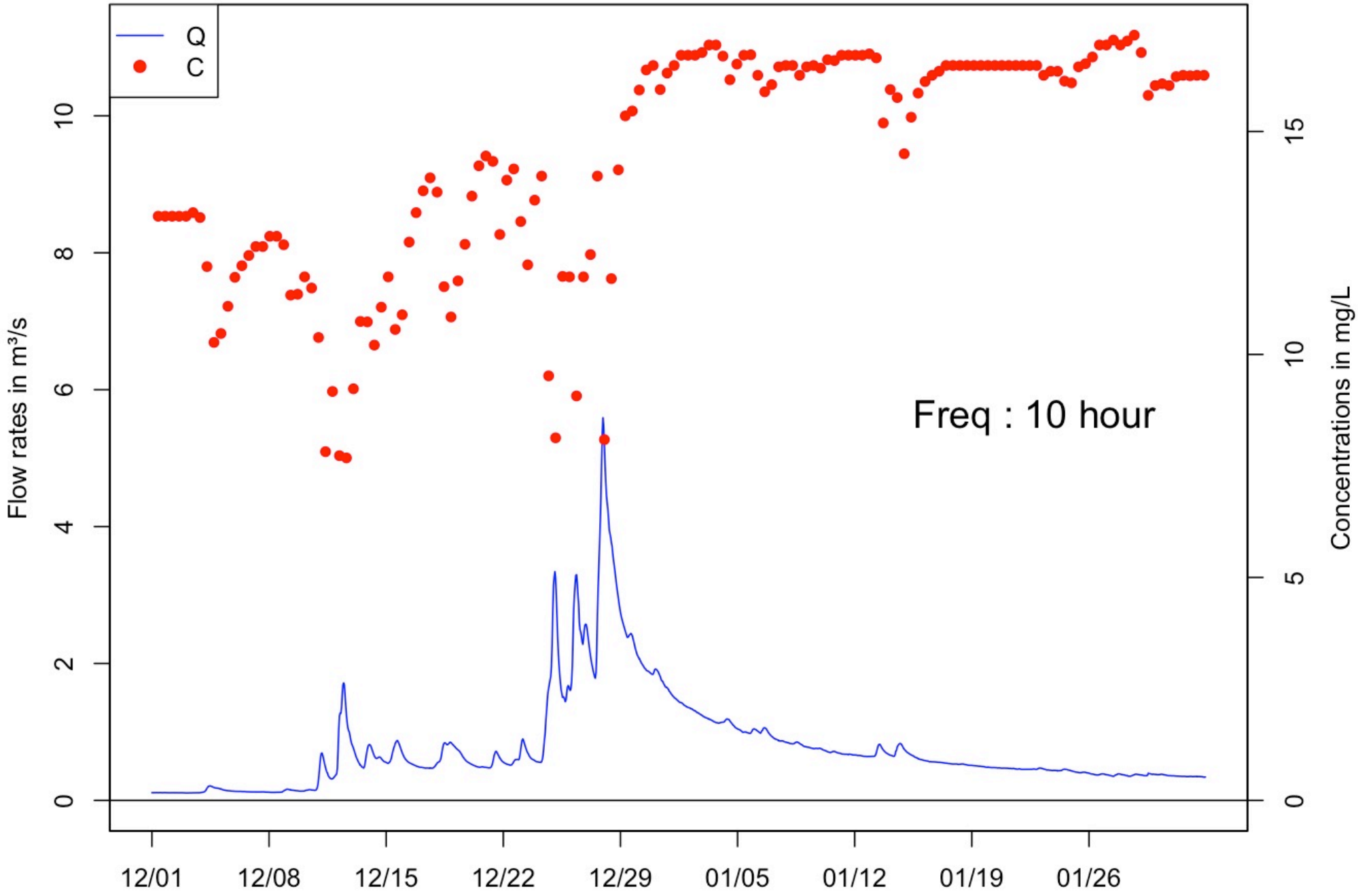
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C
Freq : 10 hour
Flow rates in m³/s
Concentrations in mg/L
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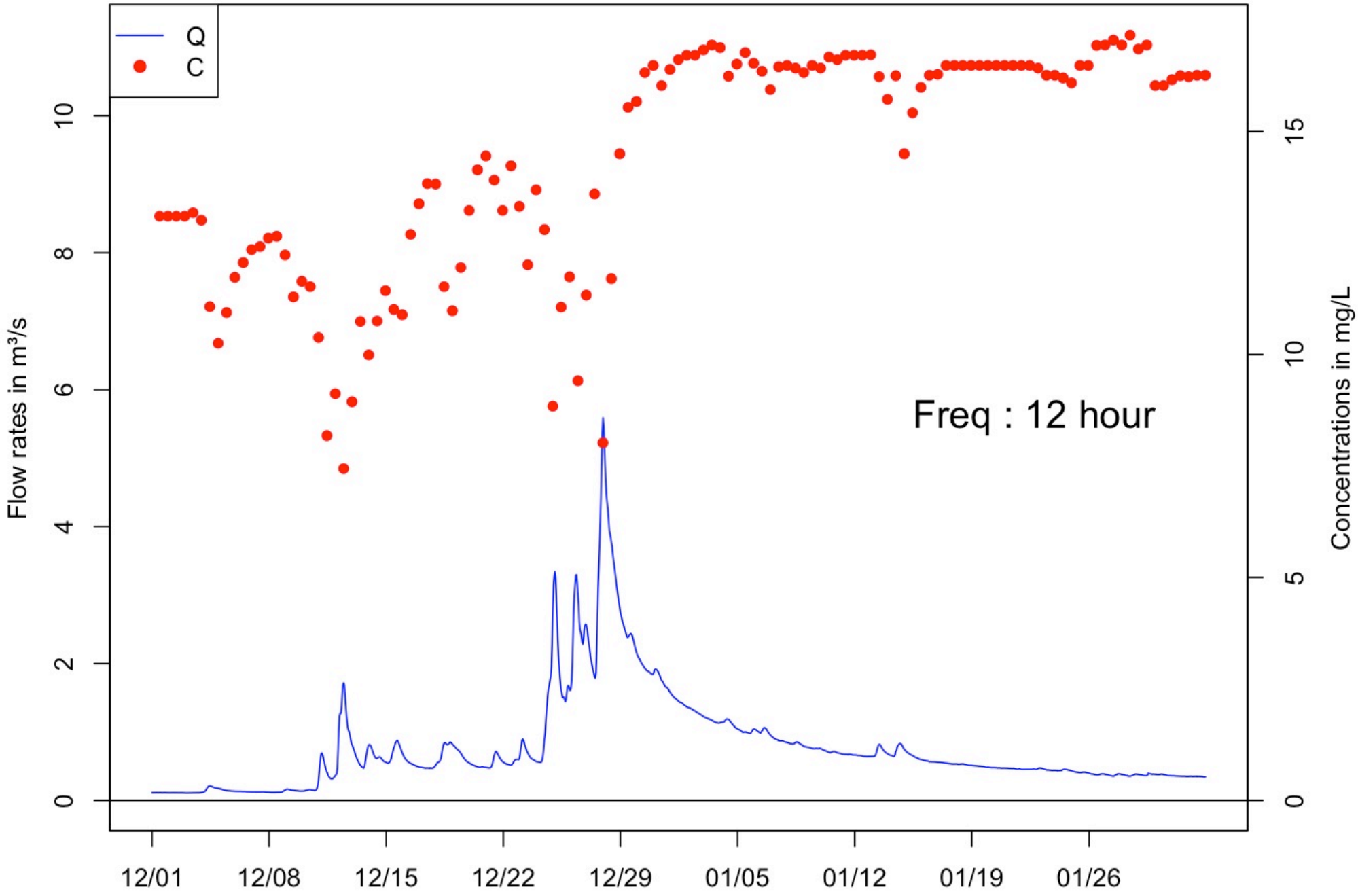
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C
Freq : 12 hour
Flow rates in m³/s
Concentrations in mg/L
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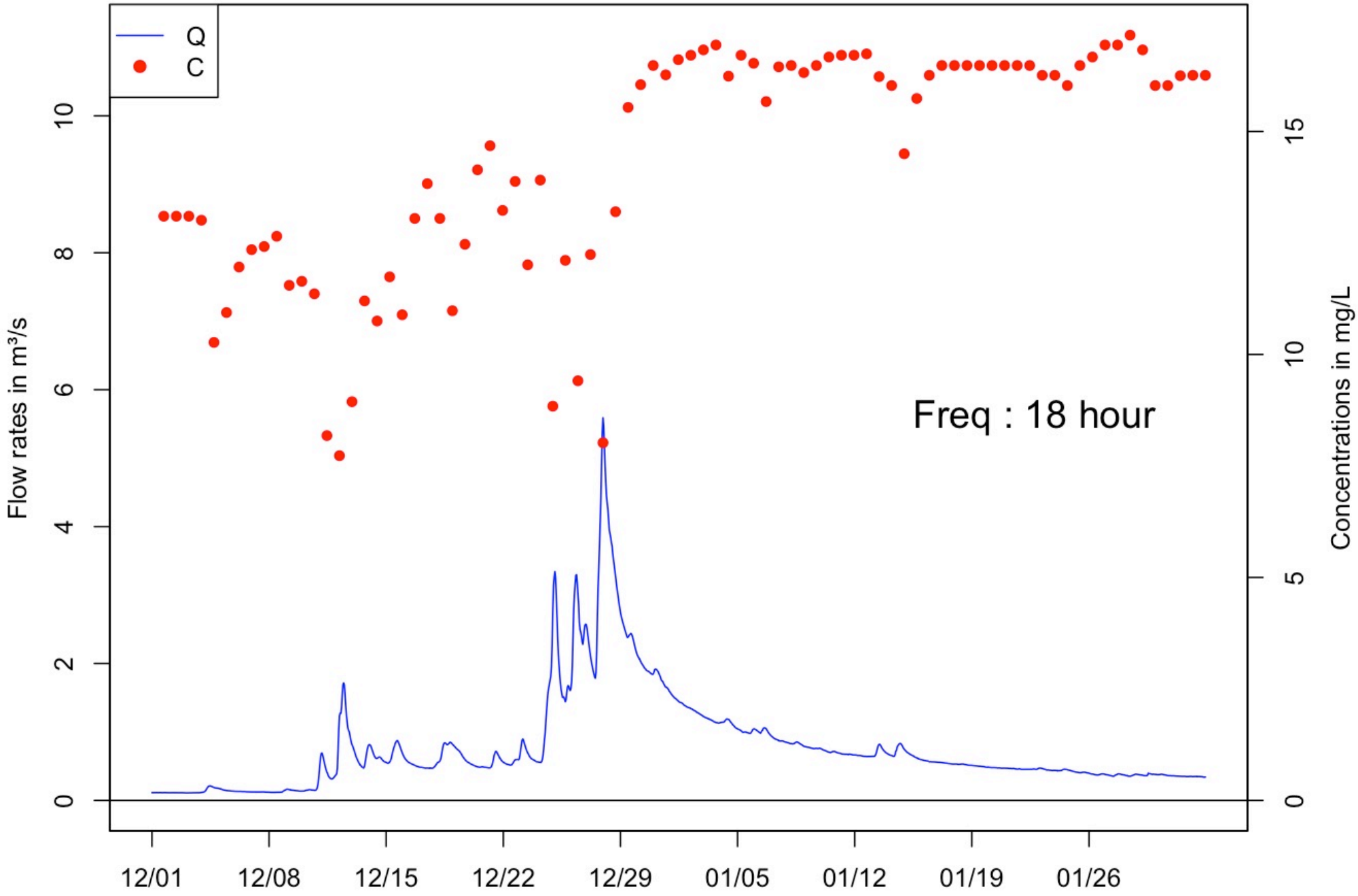
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C
Freq : 18 hour
Flow rates in m³/s
Concentrations in mg/L
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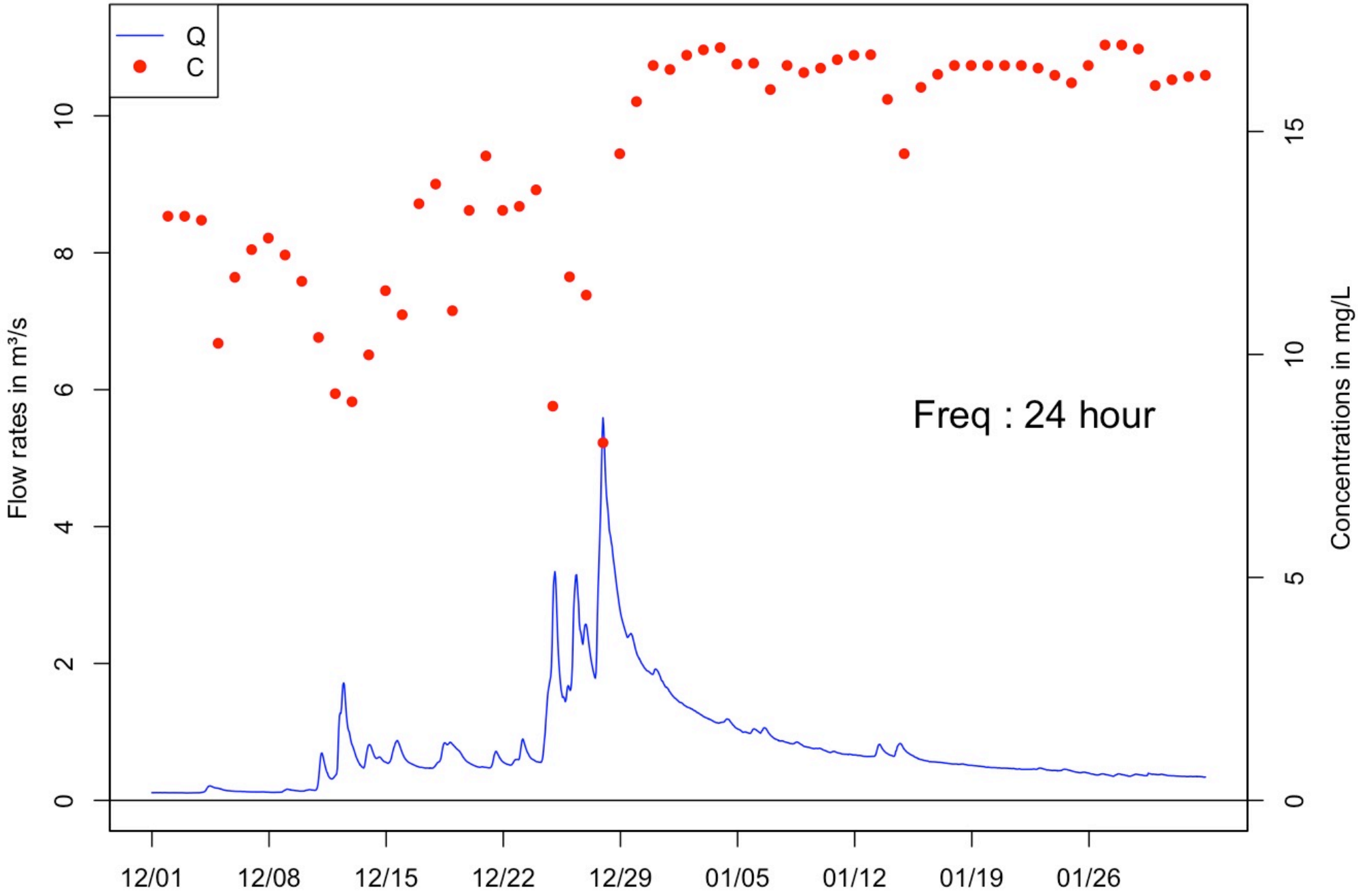
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C
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Flow rates in m³/s
Concentrations in mg/L
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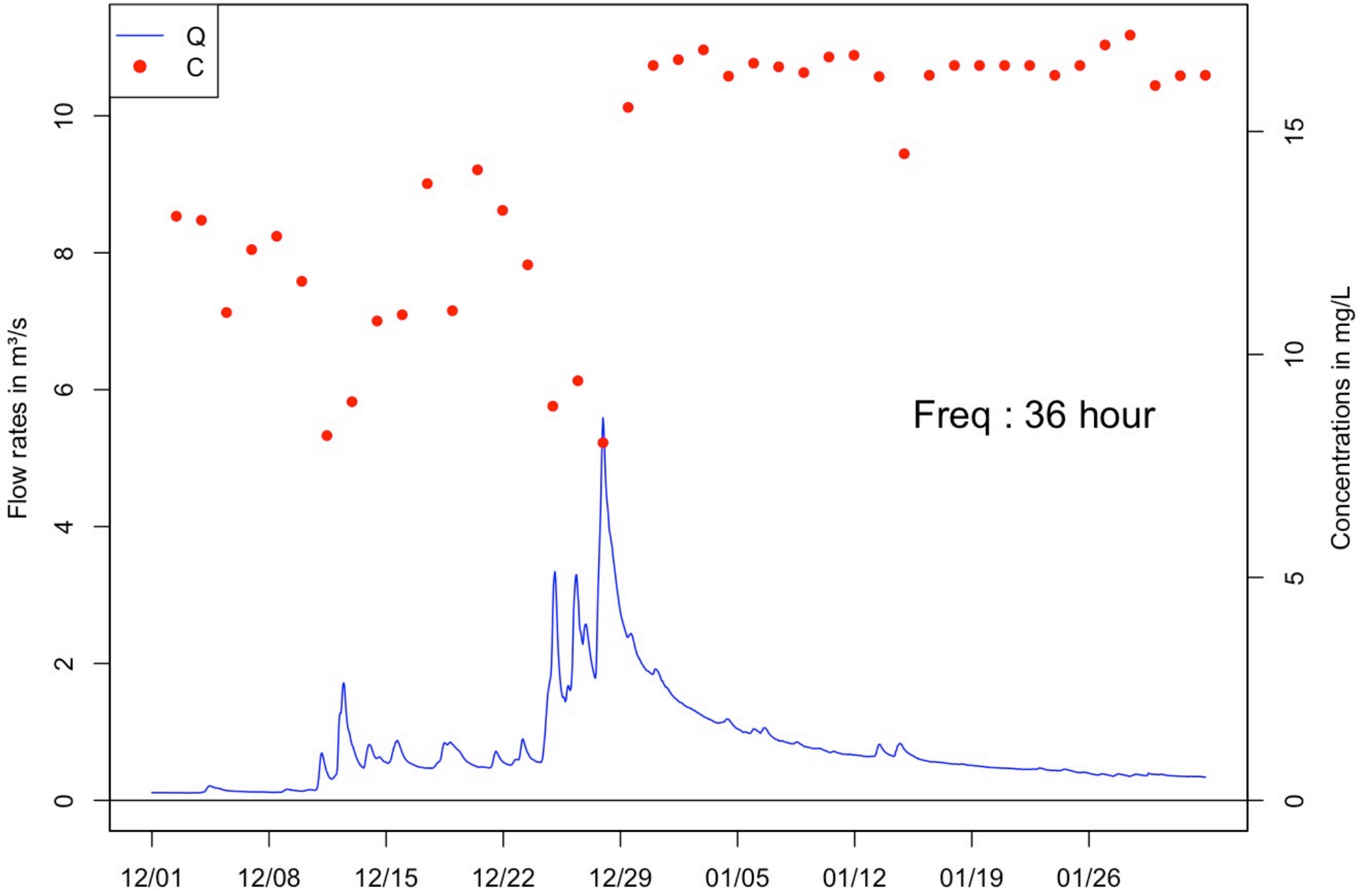
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C
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Flow rates in m³/s
Concentrations in mg/L
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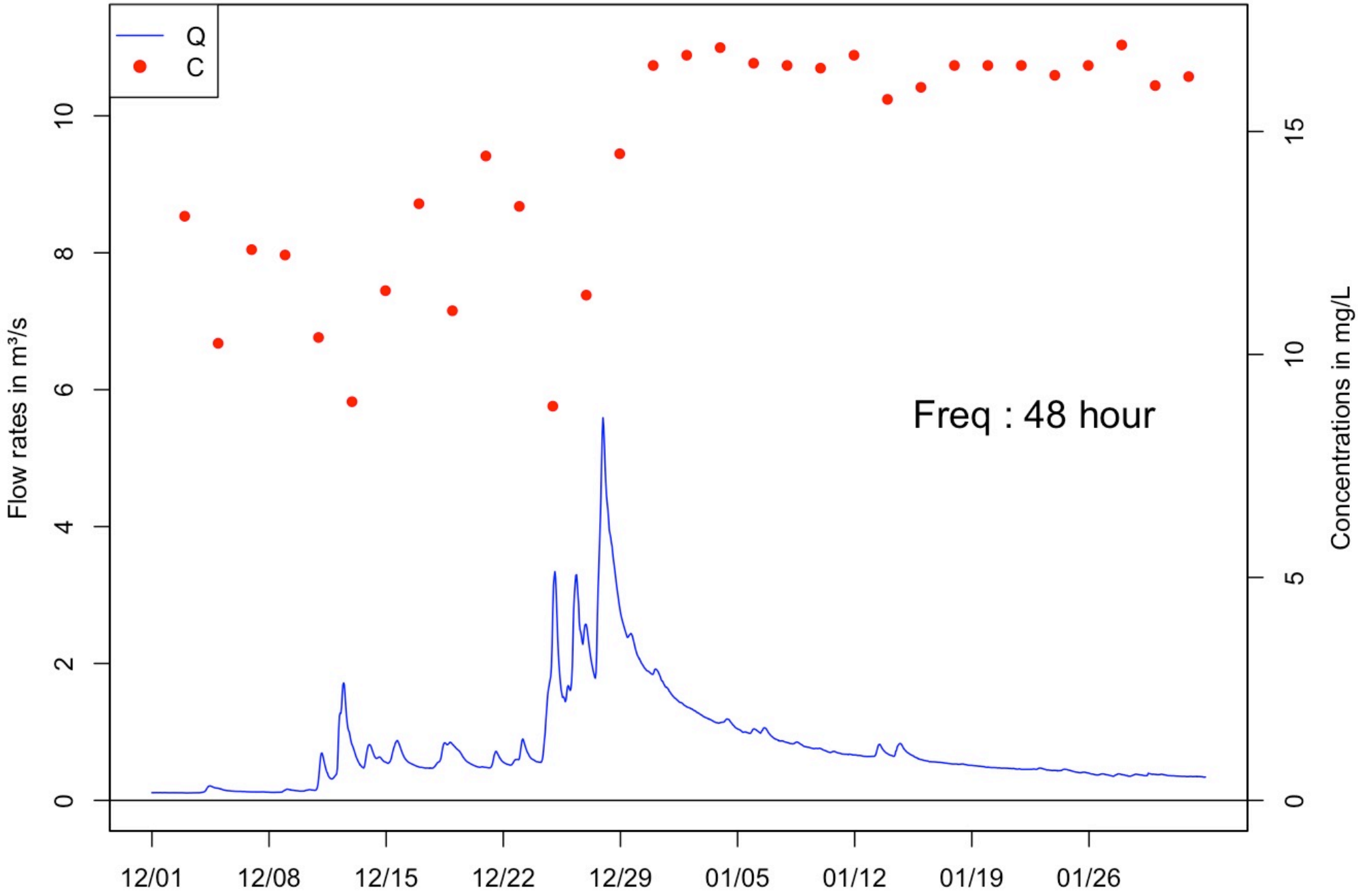
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Concentrations in mg/L
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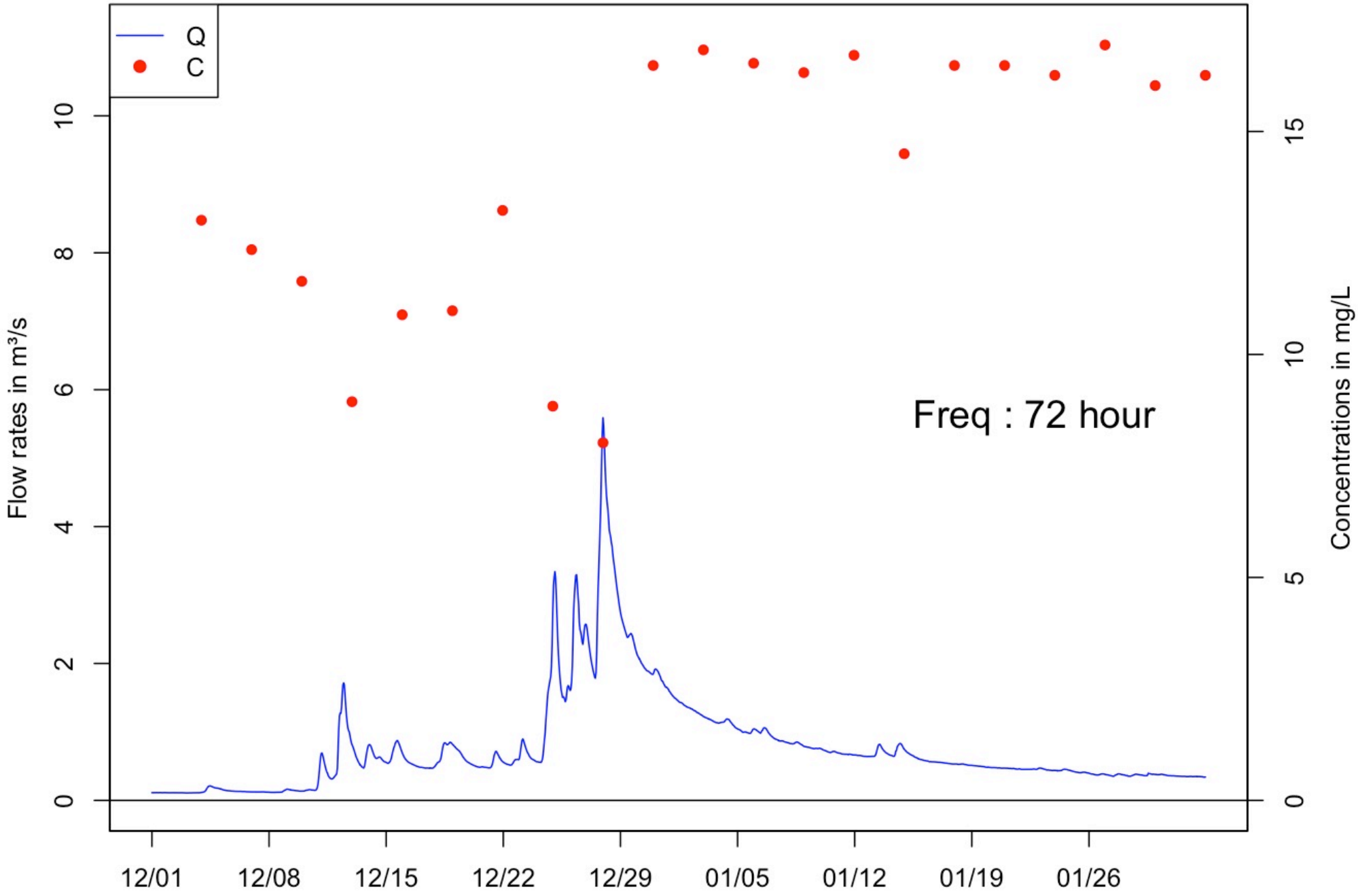
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C
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Flow rates in m³/s
Concentrations in mg/L
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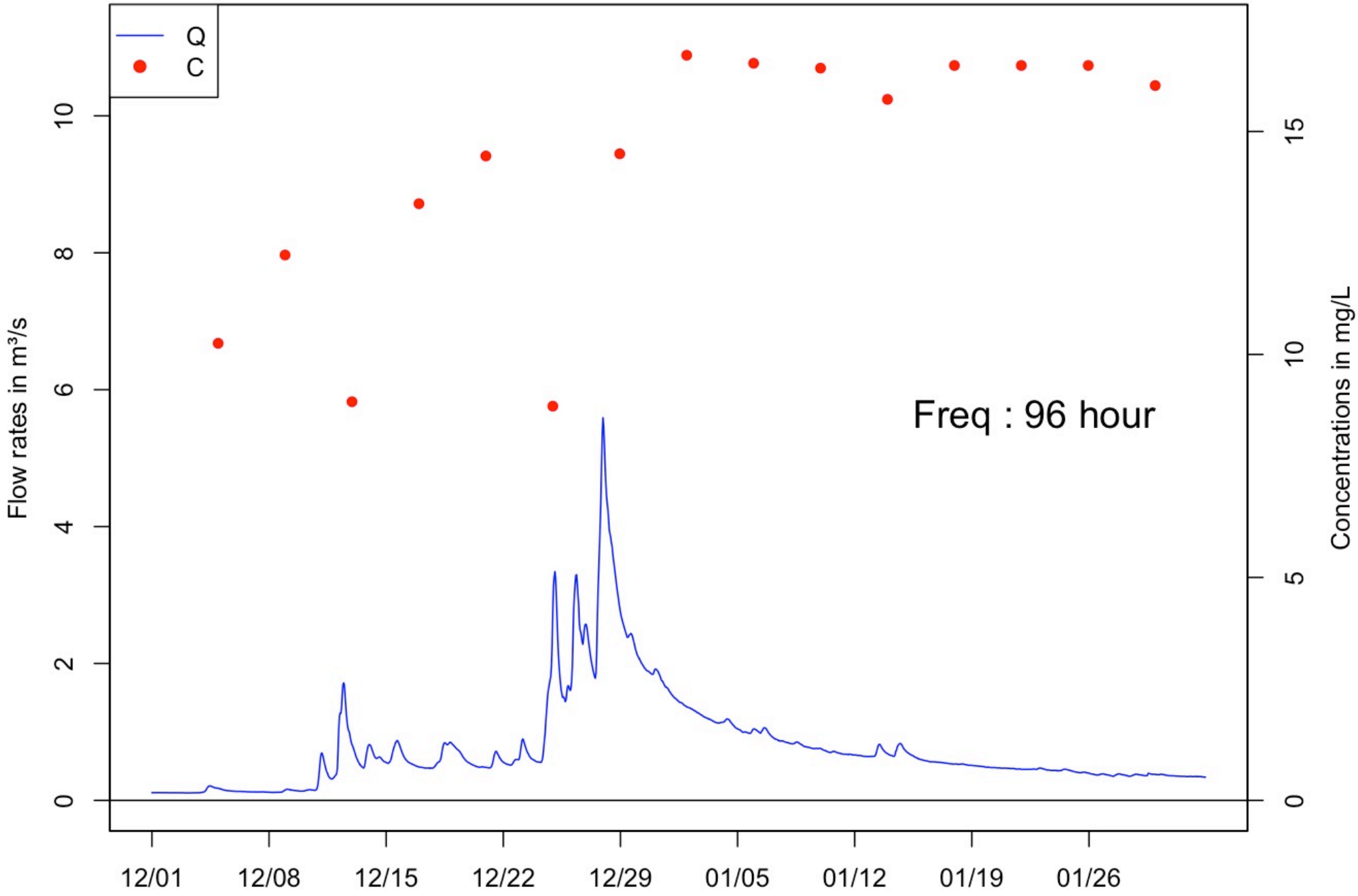
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C
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Flow rates in m³/s
Concentrations in mg/L
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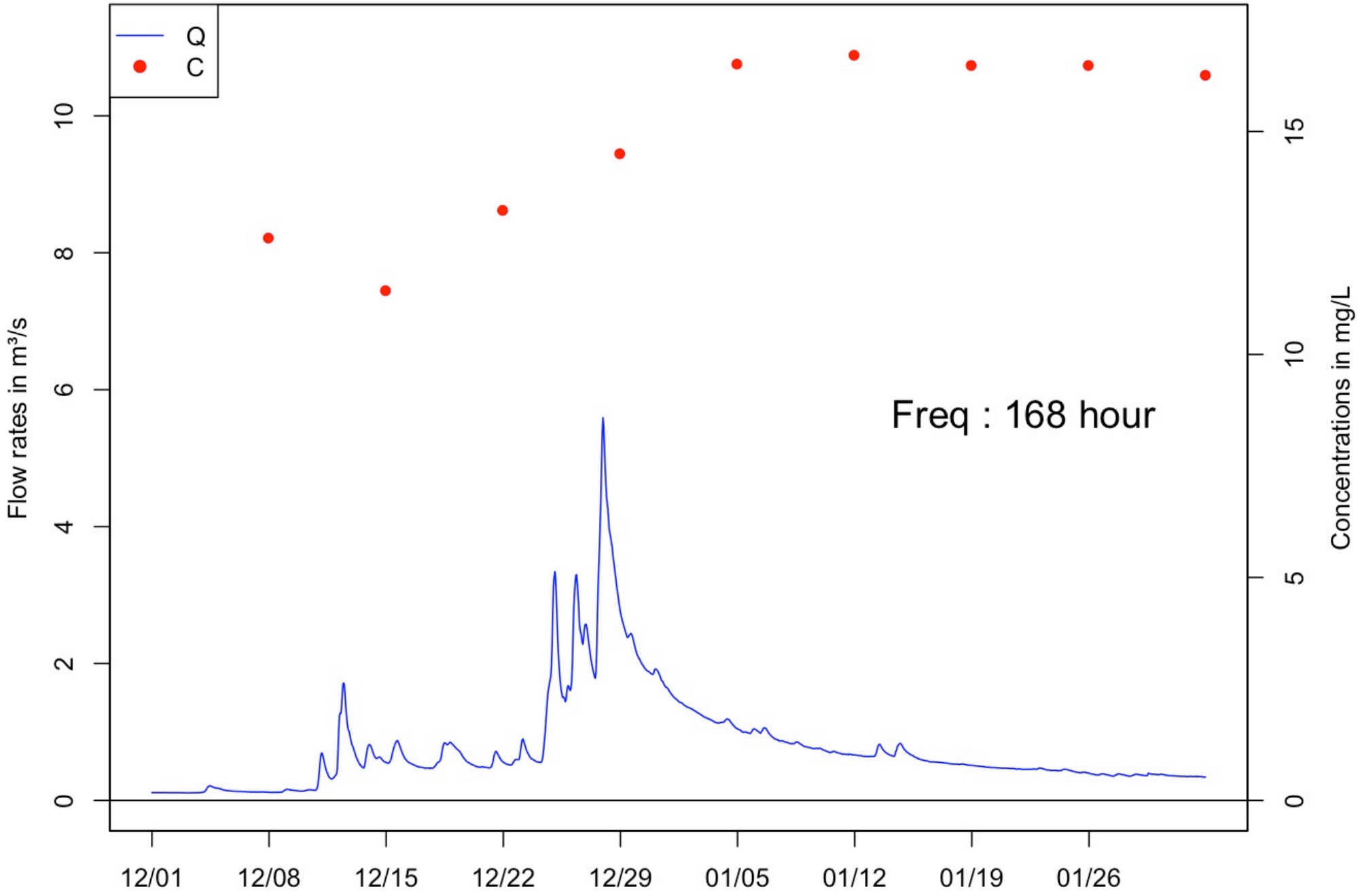
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C
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Flow rates in m³/s
Concentrations in mg/L
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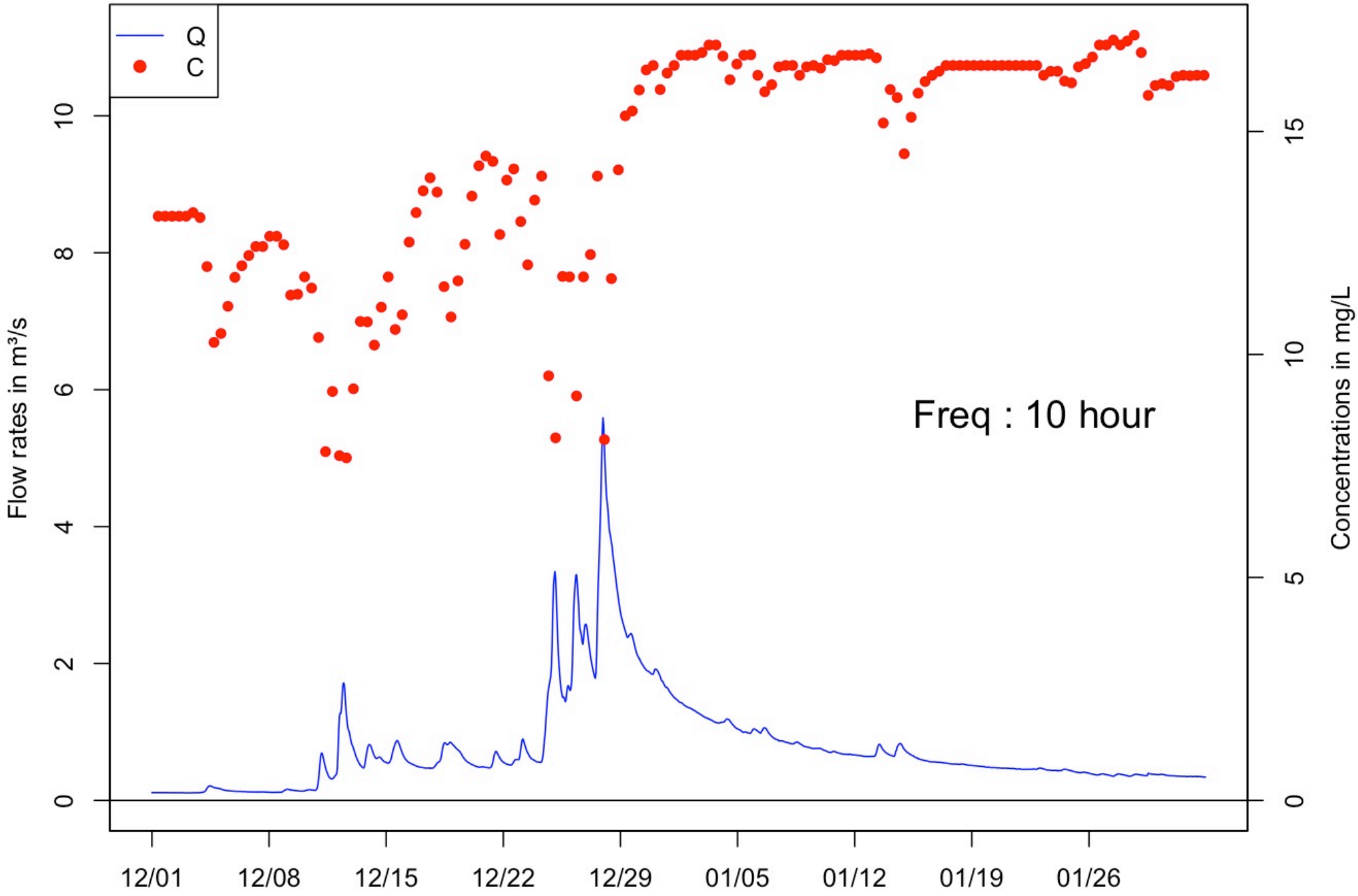
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Freq : 10 hour
Flow rates in m³/s
Concentrations in mg/L
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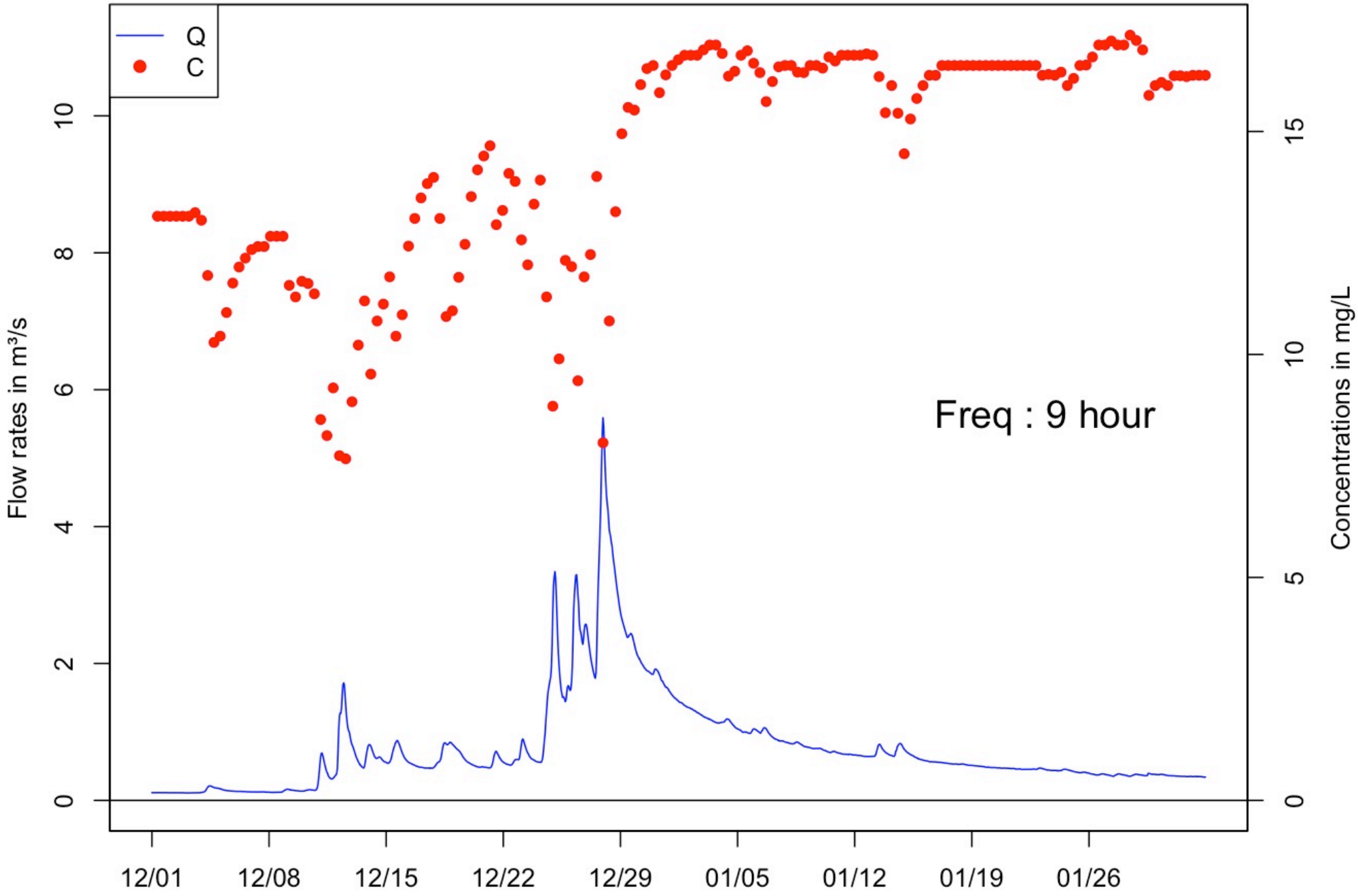
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Concentrations in mg/L
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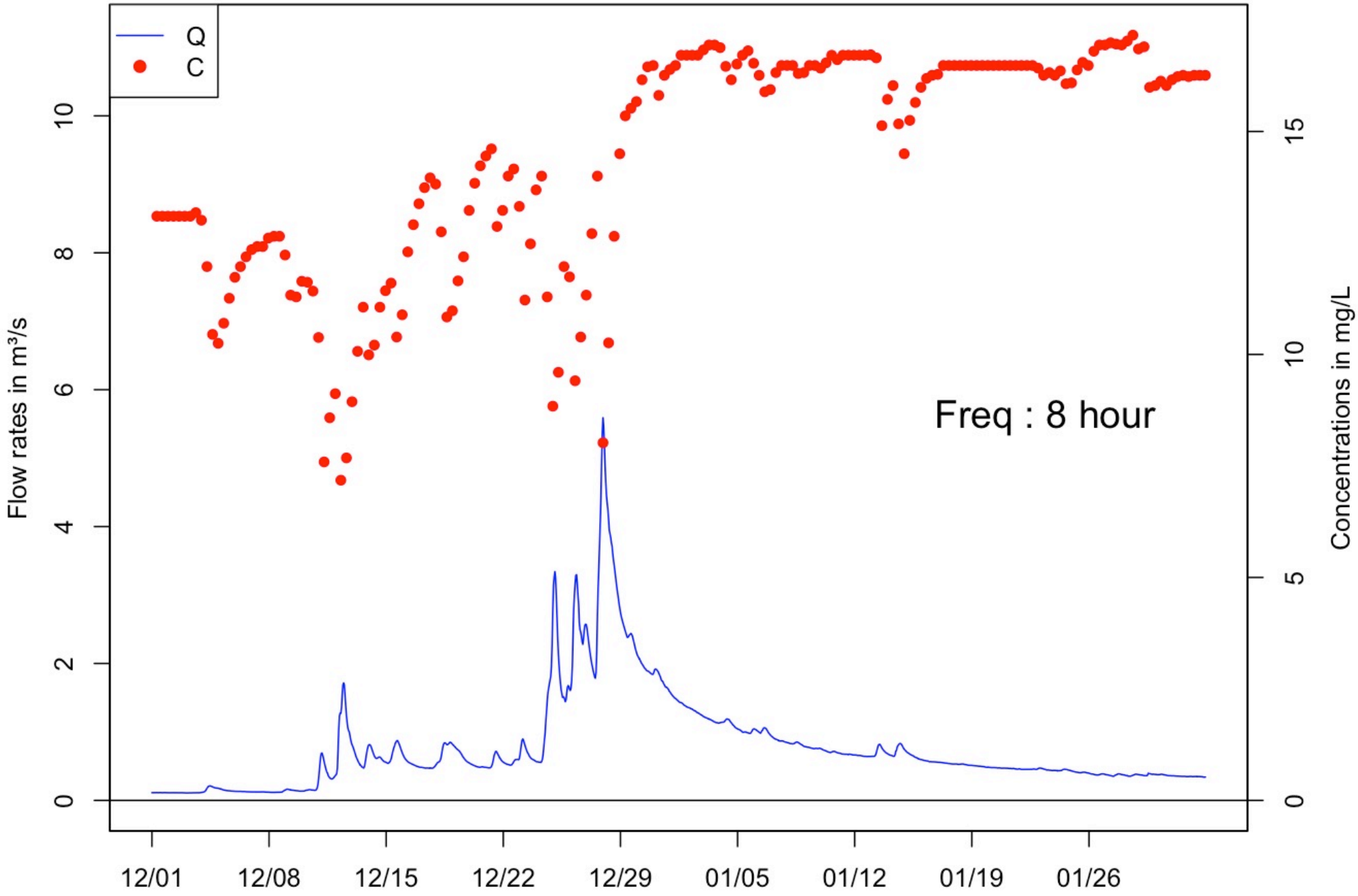
Q
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Freq : 8 hour
Flow rates in m³/s
Concentrations in mg/L
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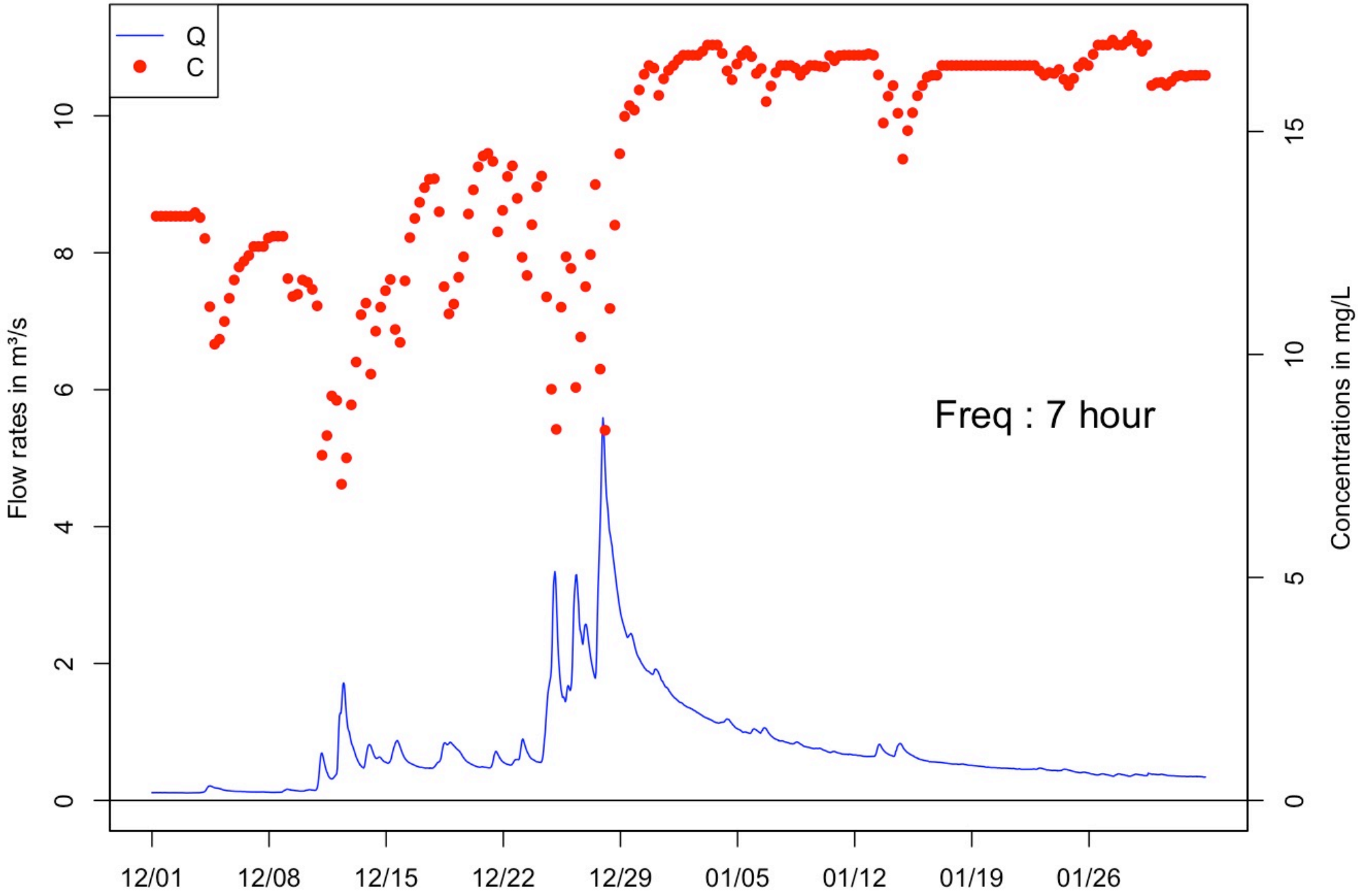
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Freq : 7 hour
Flow rates in m³/s
Concentrations in mg/L
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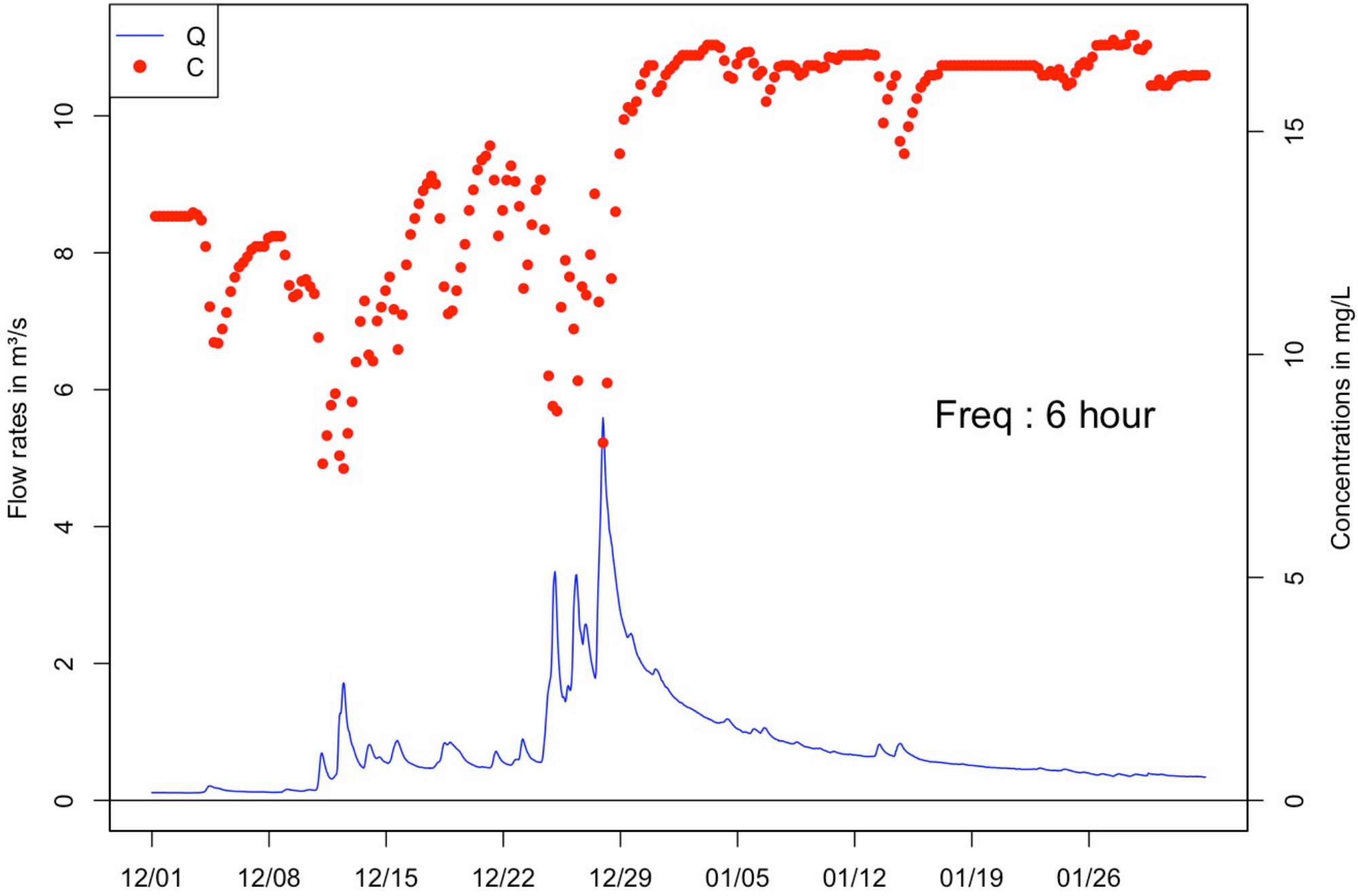
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Concentrations in mg/L
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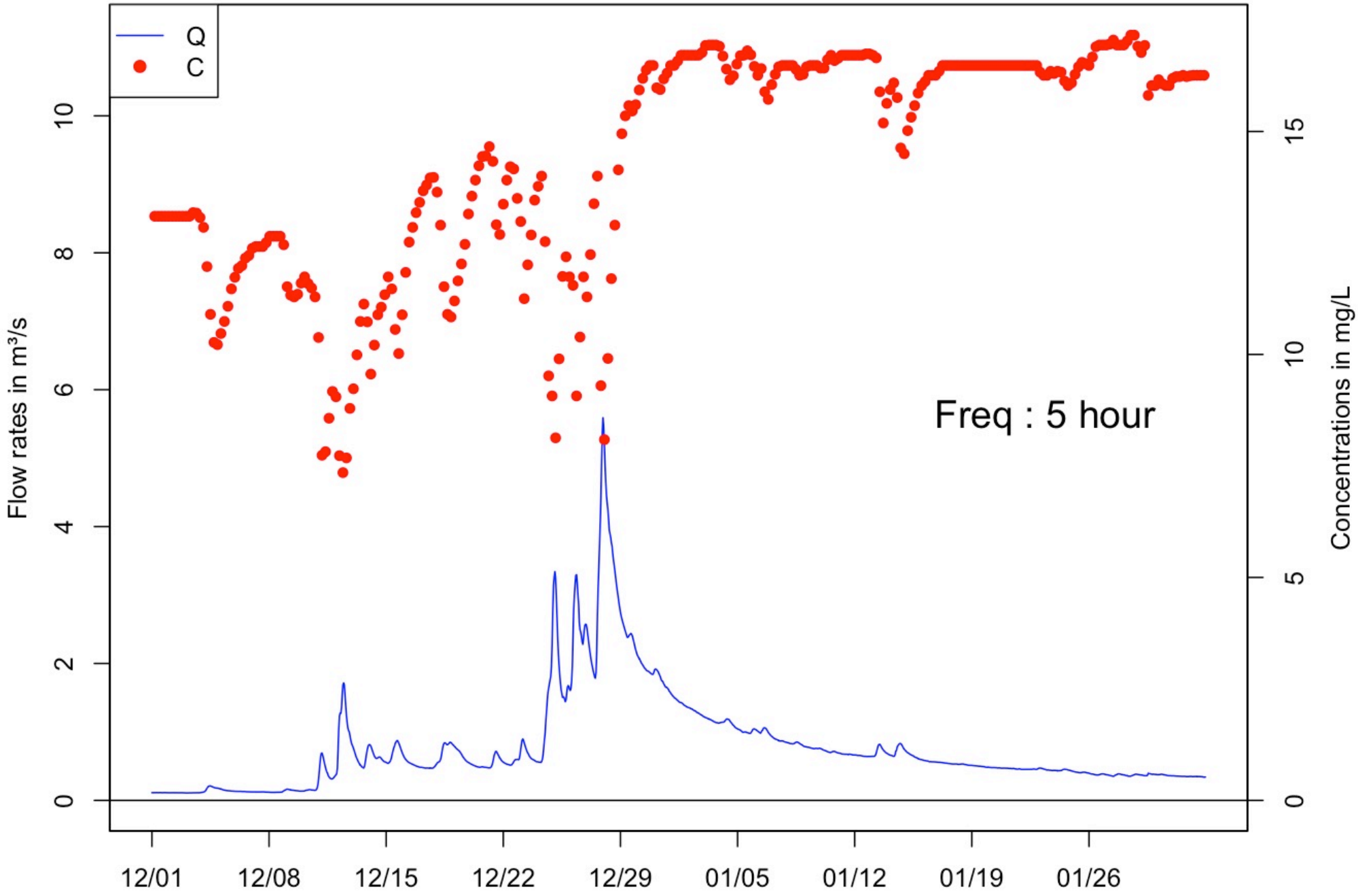
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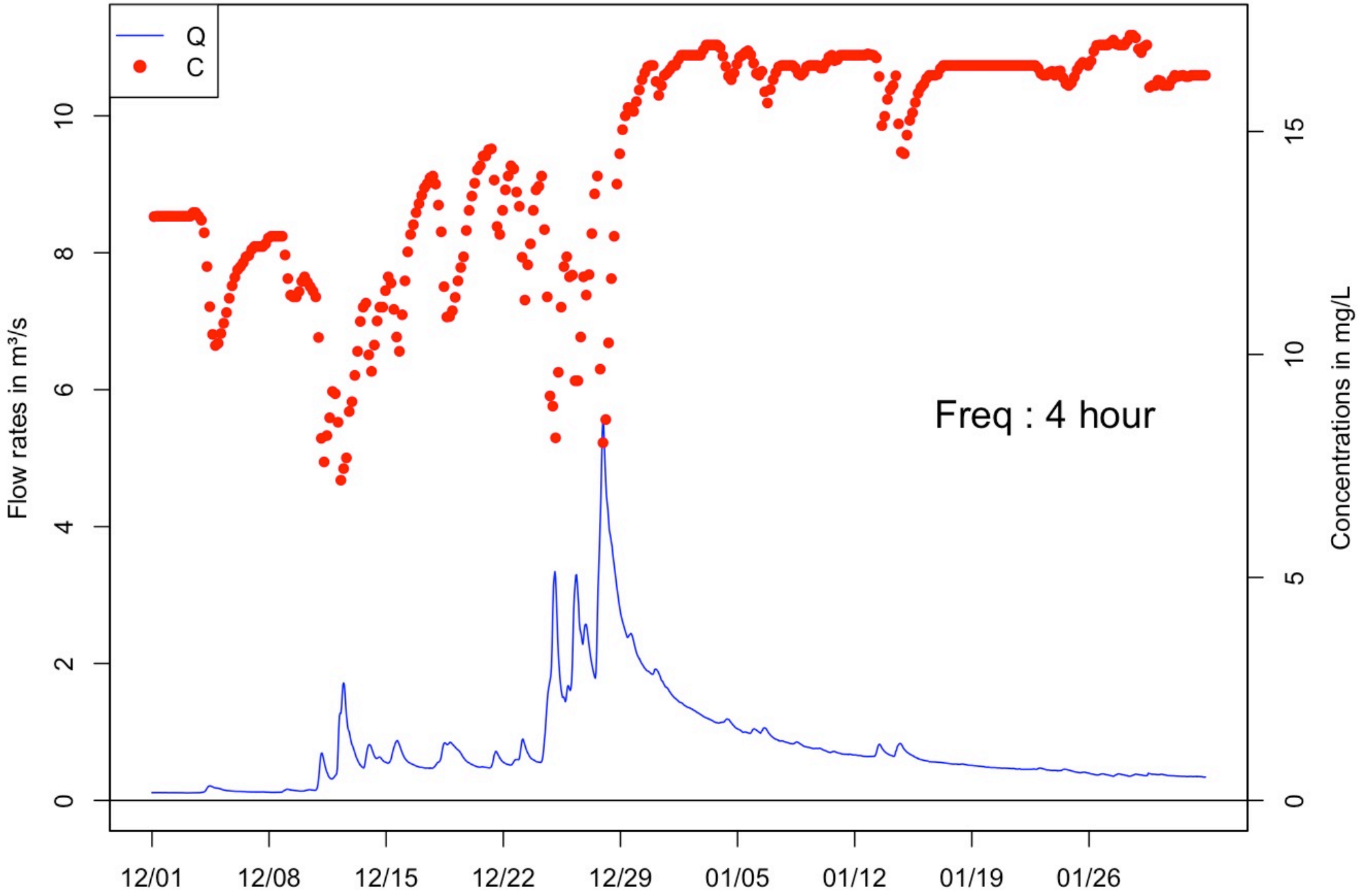
Q
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Freq : 4 hour
Flow rates in m³/s
Concentrations in mg/L
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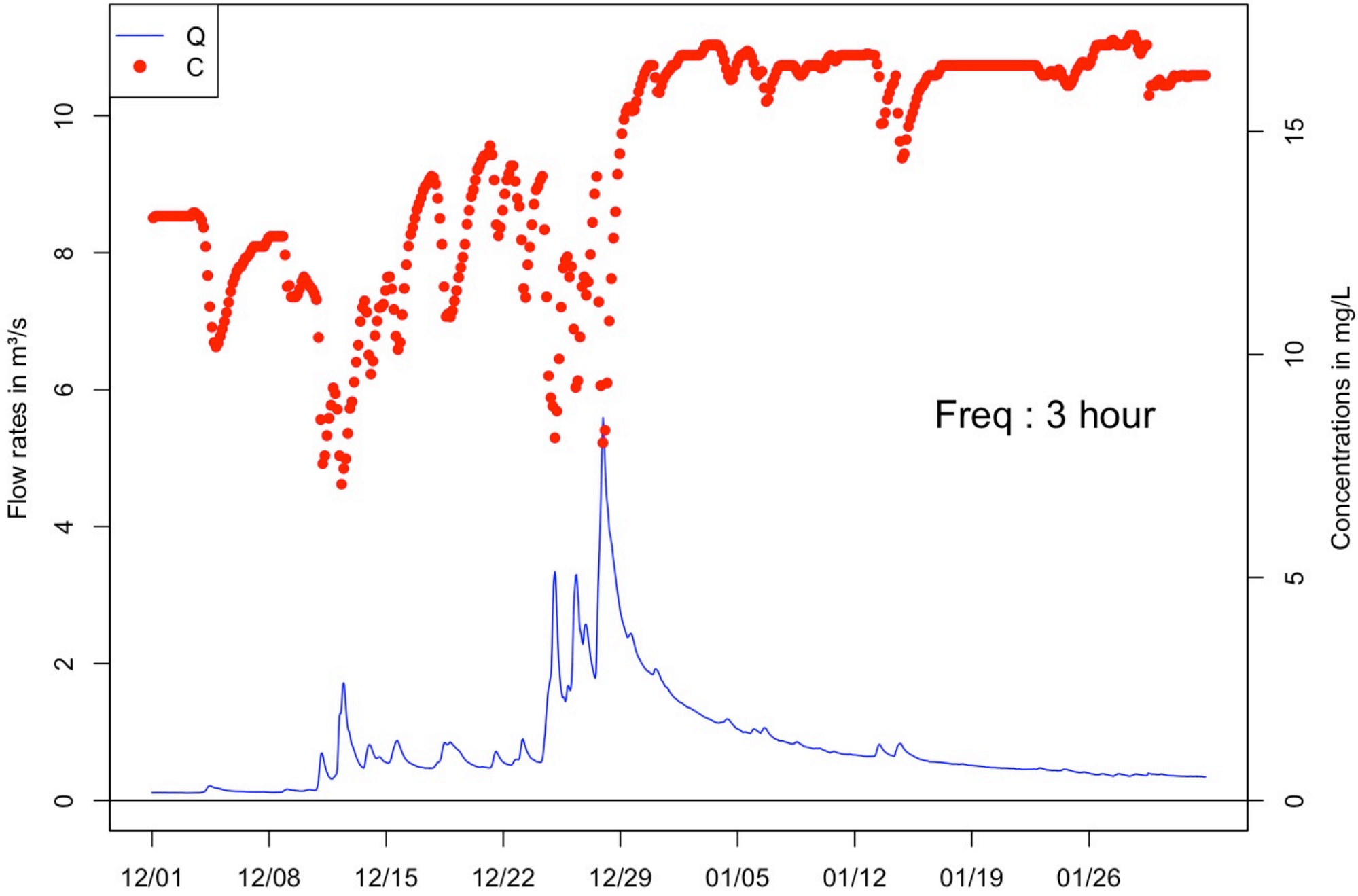
Q
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Freq : 3 hour
Flow rates in m³/s
Concentrations in mg/L
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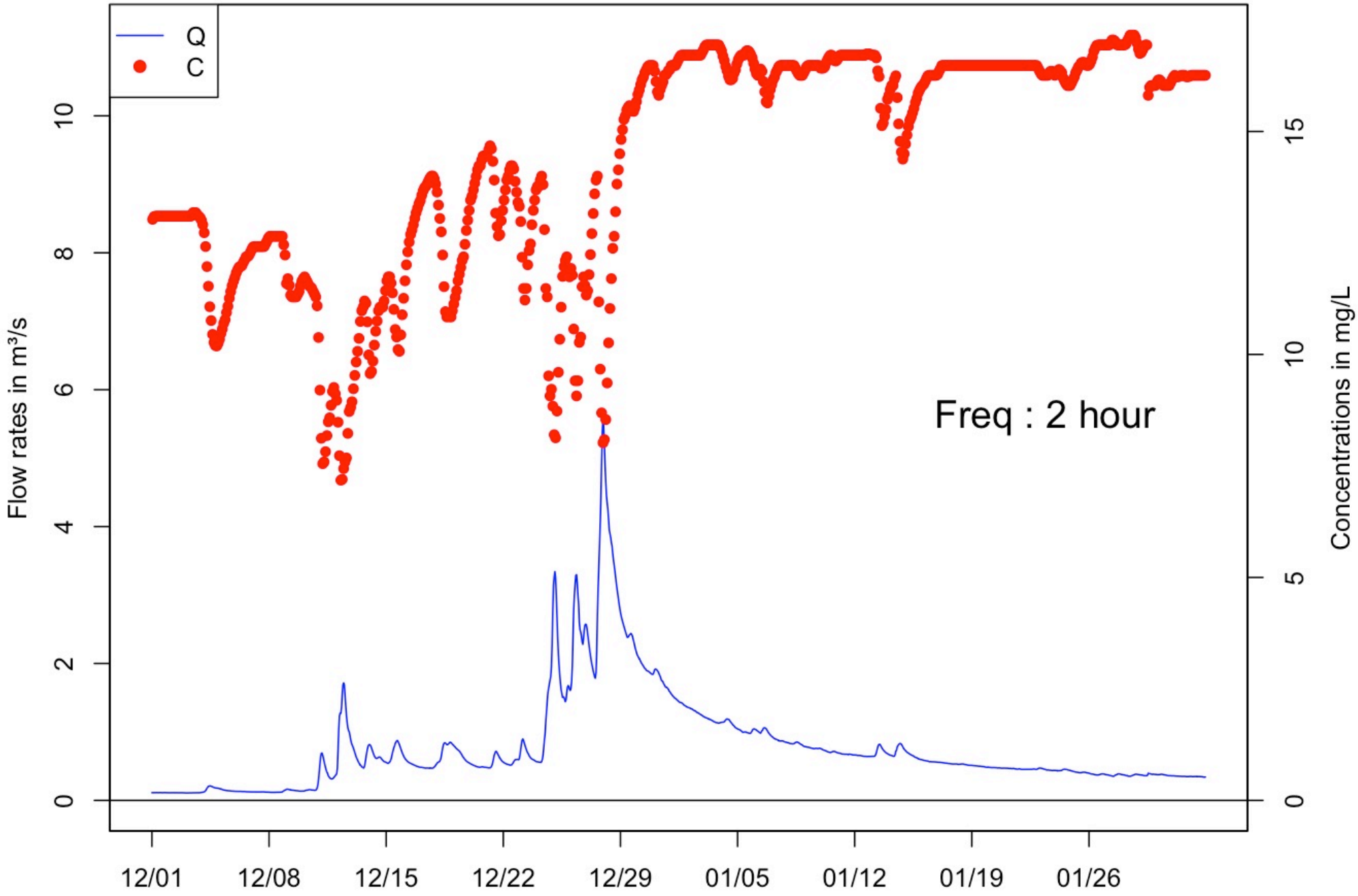
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Flow rates in m³/s
Concentrations in mg/L
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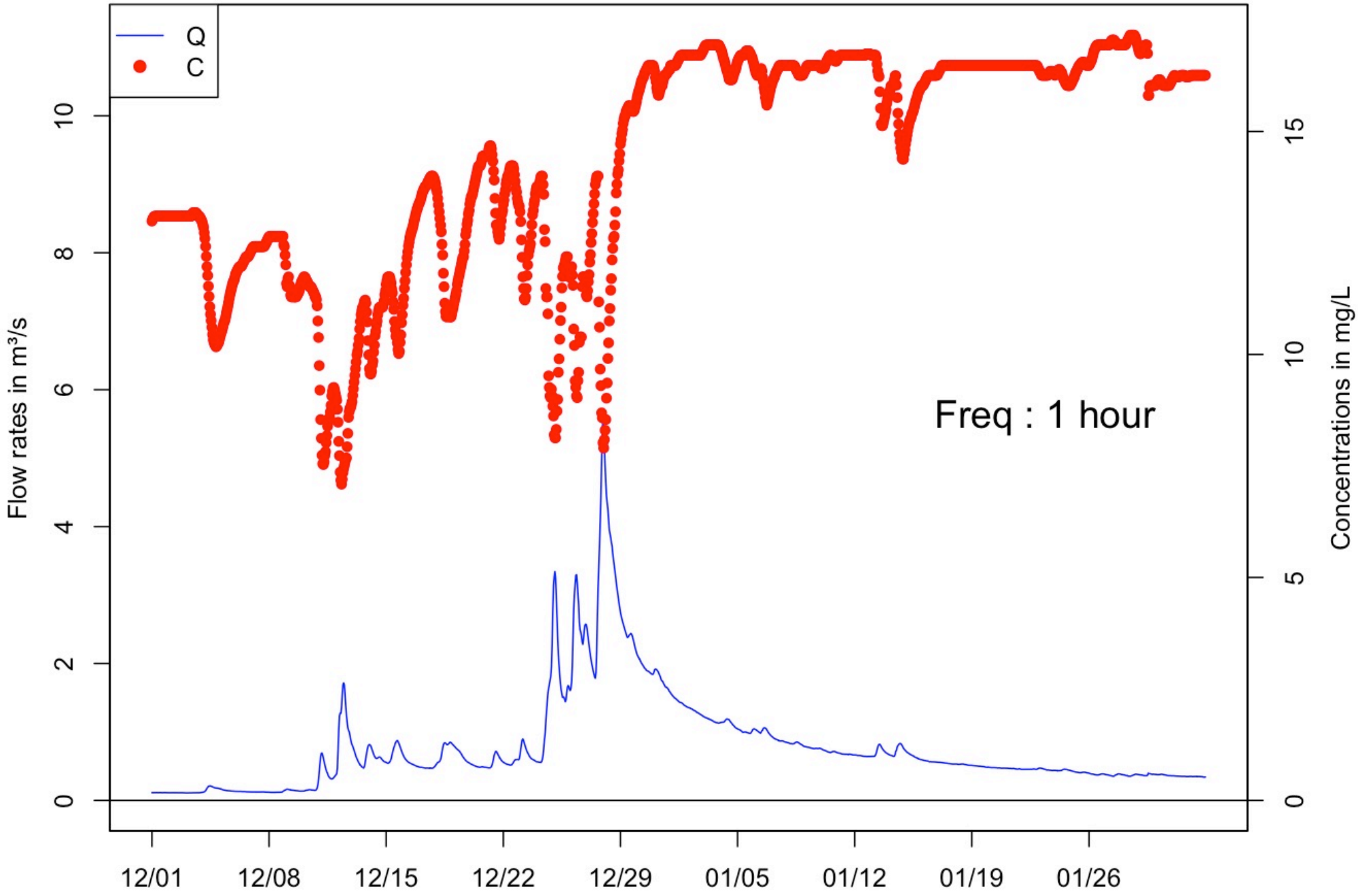
Q
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Freq : 1 hour
Flow rates in m³/s
Concentrations in mg/L
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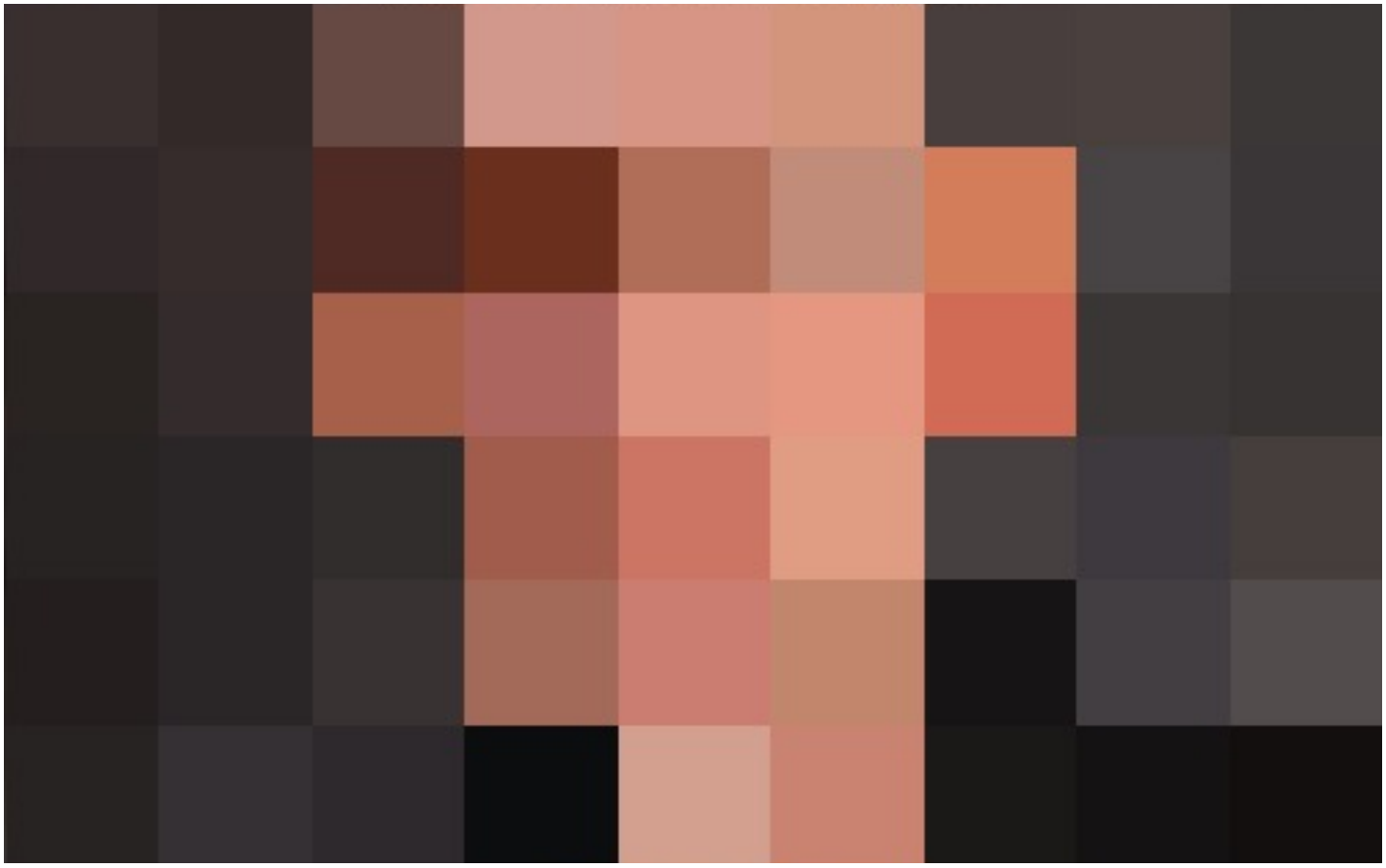
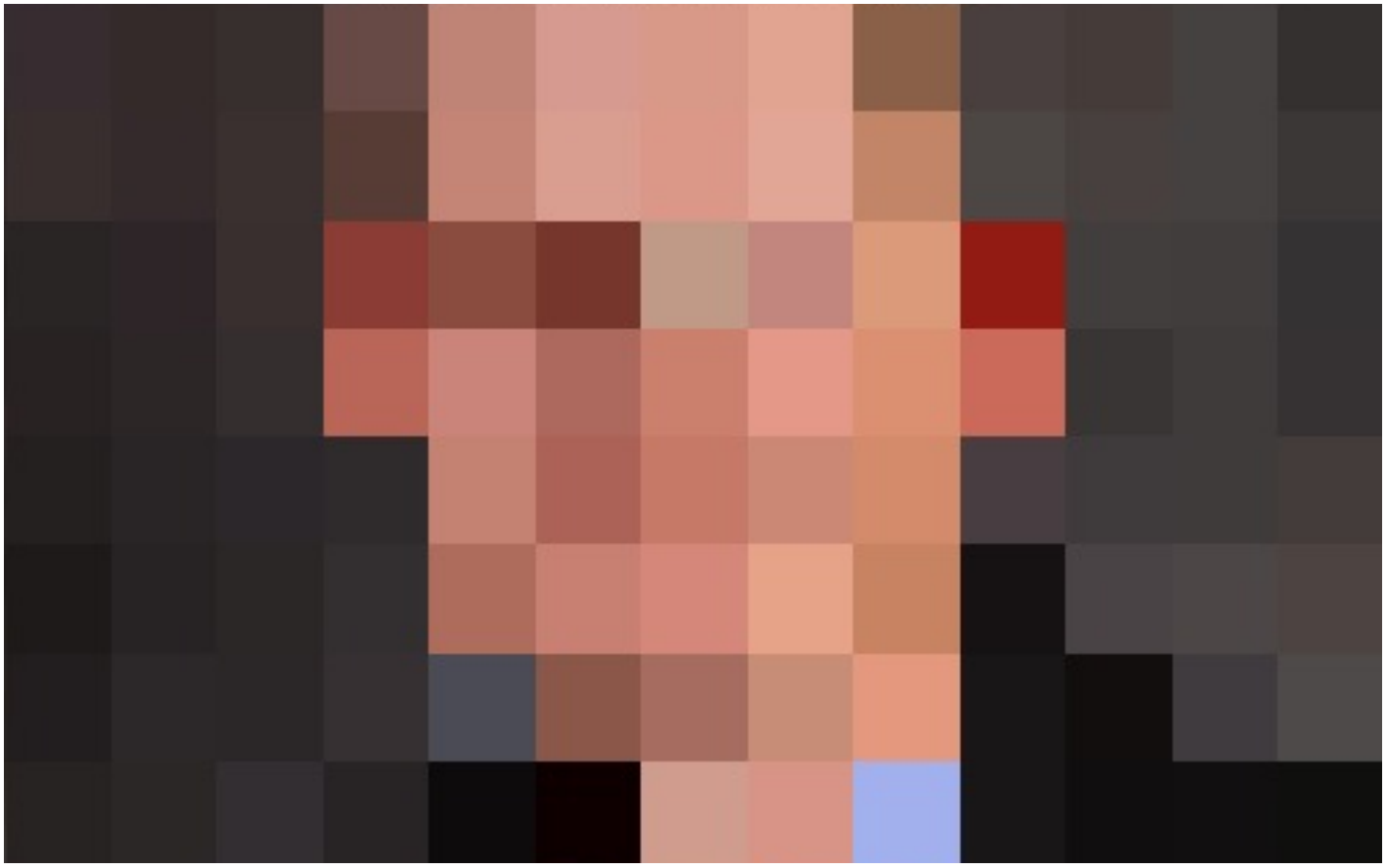
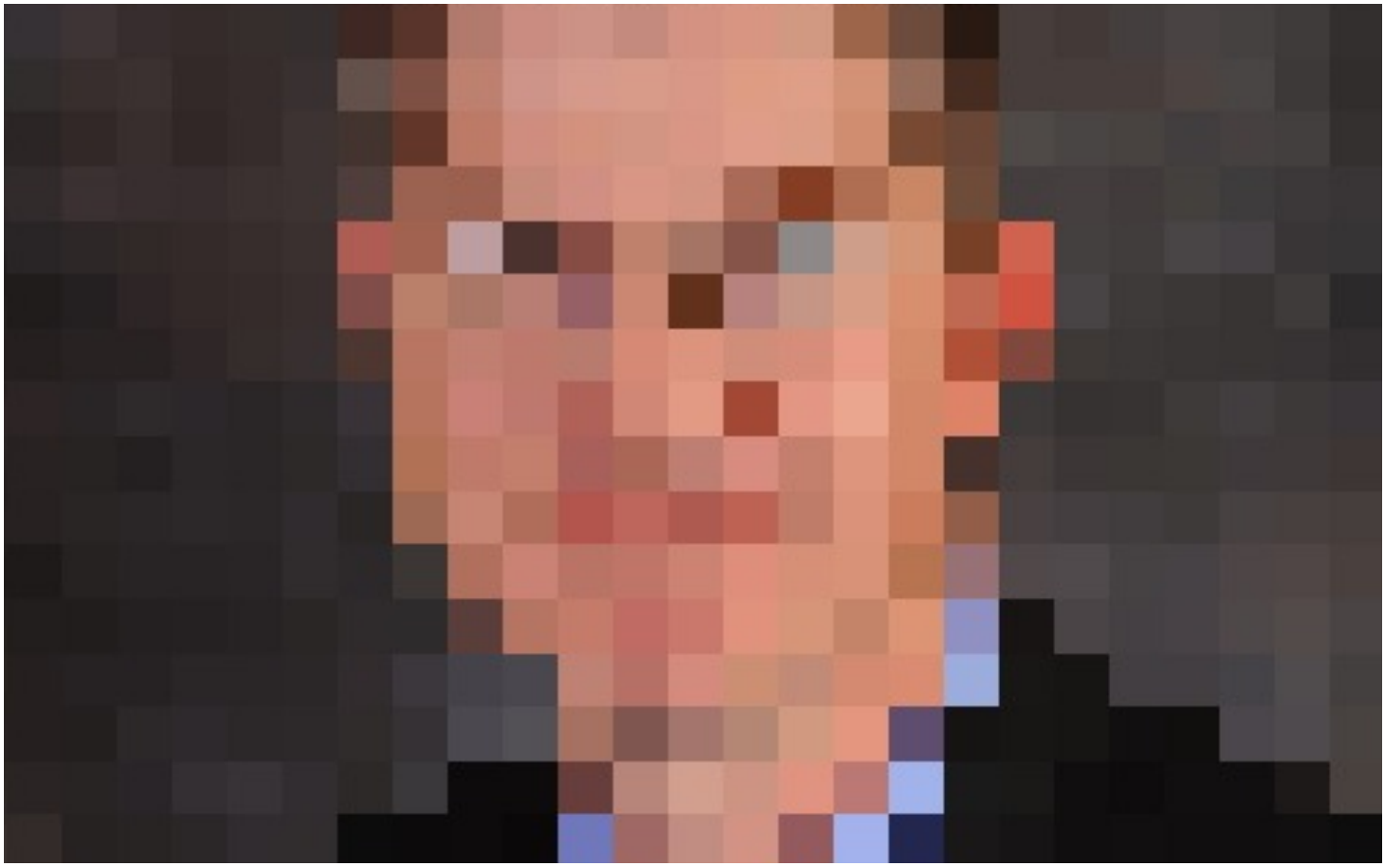
- Without high frequency data, our view of reality is blurred…







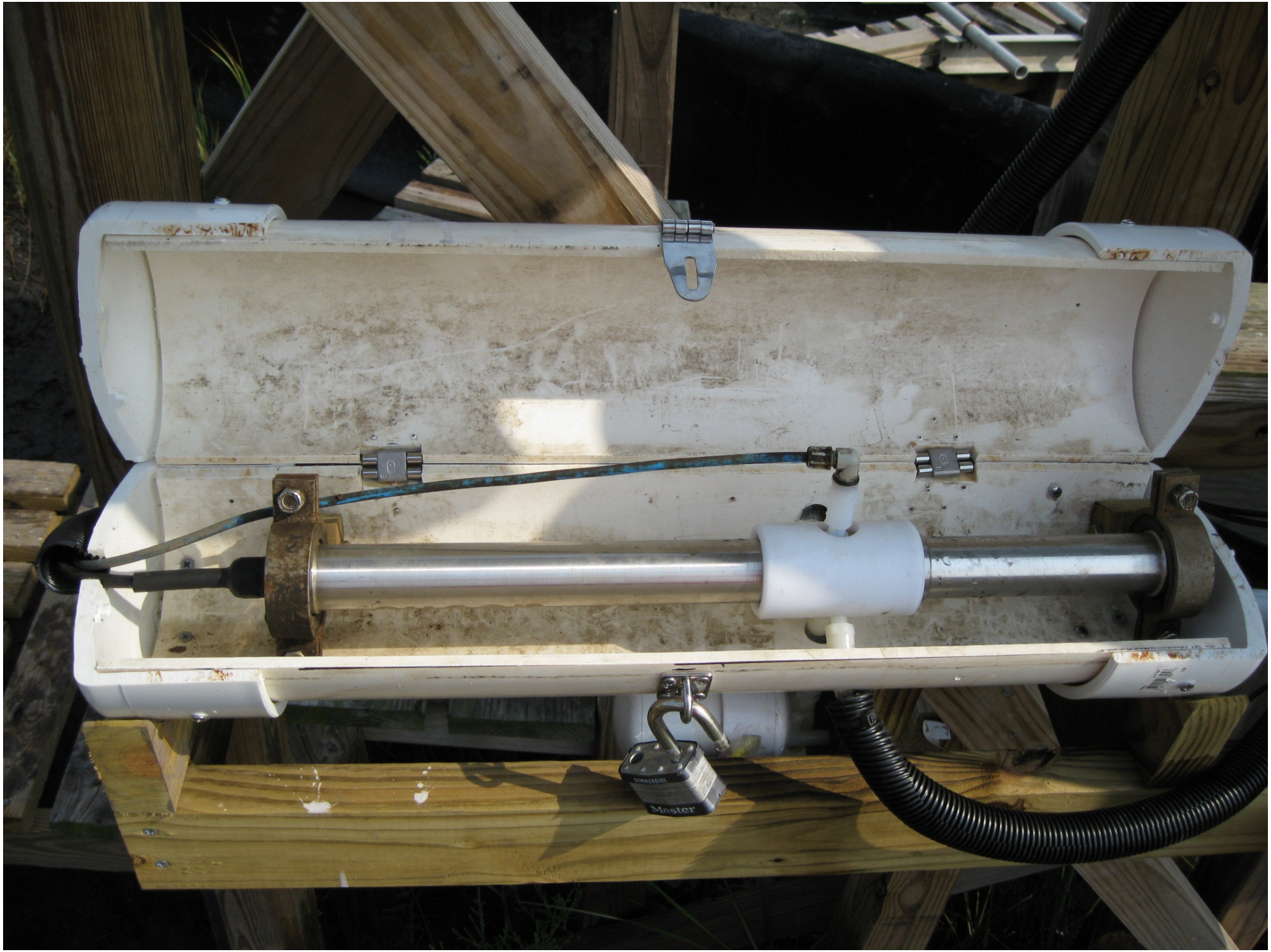
- Without high frequency data, our view of reality is blurred…
- … and so is (possibly!) our understanding…
- … and so are our conclusions about how the world functions…
- … and so are our solutions…

Are there solutions ?

Continuous sensors

- Field UV-vis spectrophotometers

- Spectro::lyser from S::CAN, Austria


Master

What parameter can we measure?

- Most manufacturers advertise for Nitrate
- Some add DOC and Turbidity

First challenges

- These sensors are currently rather expensive…
- $20k+
- A big egg in one basket…

Expanding the capabilities of these sensors

Lab **micro**volume MPS

Field **macro**volume MPS

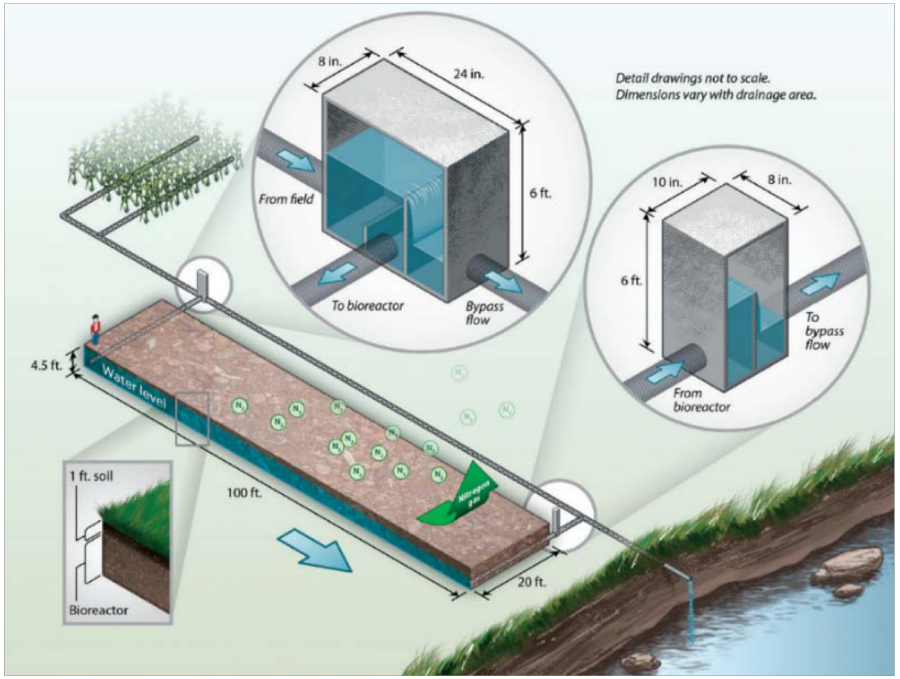
What do we get?

Unveiling the inside of a black box:

- Woodchip bioreactors

What are woodchip bioreactors?

- Agricultural BMP
- Intercept tile drainage
- Targets nitrate removal
- ~20 year lifespan
- NRCS approved
- 2-22 g N m^{-3} d^{-1} in field
- Mainly seen in Midwest



Christianson and Helmers, 2011

From the literature

- Reported nitrate removal efficiencies varying from less than 10% to more than 90%

- Decrease of removal efficiency within one to several years from >60% to <20%

Research questions

- Why are there so much discrepancies in the reported removal rates?
- What are the factors driving the nitrate removal efficiencies, and its decrease over time?
- What can we do to 'rejuvenate' bioreactor and maintain removal efficiency?
- Can we provide guidelines for maintaining and increasing nitrate removal efficiencies?

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4. Effect of wetting and drying cycles to rejuvenate bioreactors: replicated column experiment in the lab

What are drying-rewetting cycles?

- Cycle between dry/wet conditions
- Gradient of conditions

- Based on literature:
  - Stimulates respiration
  - Increases mineralization of C & N
  - Changes in microbial community

Experimental Hypothesis

Do drying-rewetting cycles in woodchip bioreactors significantly improve treatment performance by increasing nitrate removal rates?

denitrification…

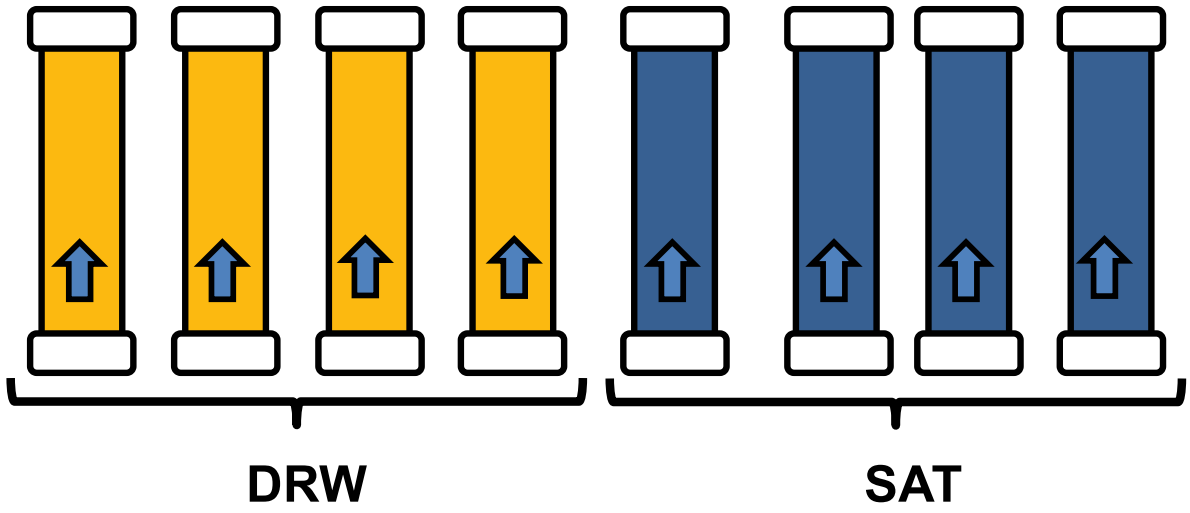
Aerobic breakdown increases available carbon

DENITRIFICATION!!!

Methods

- Lab experiment with 8 woodchip-filled columns

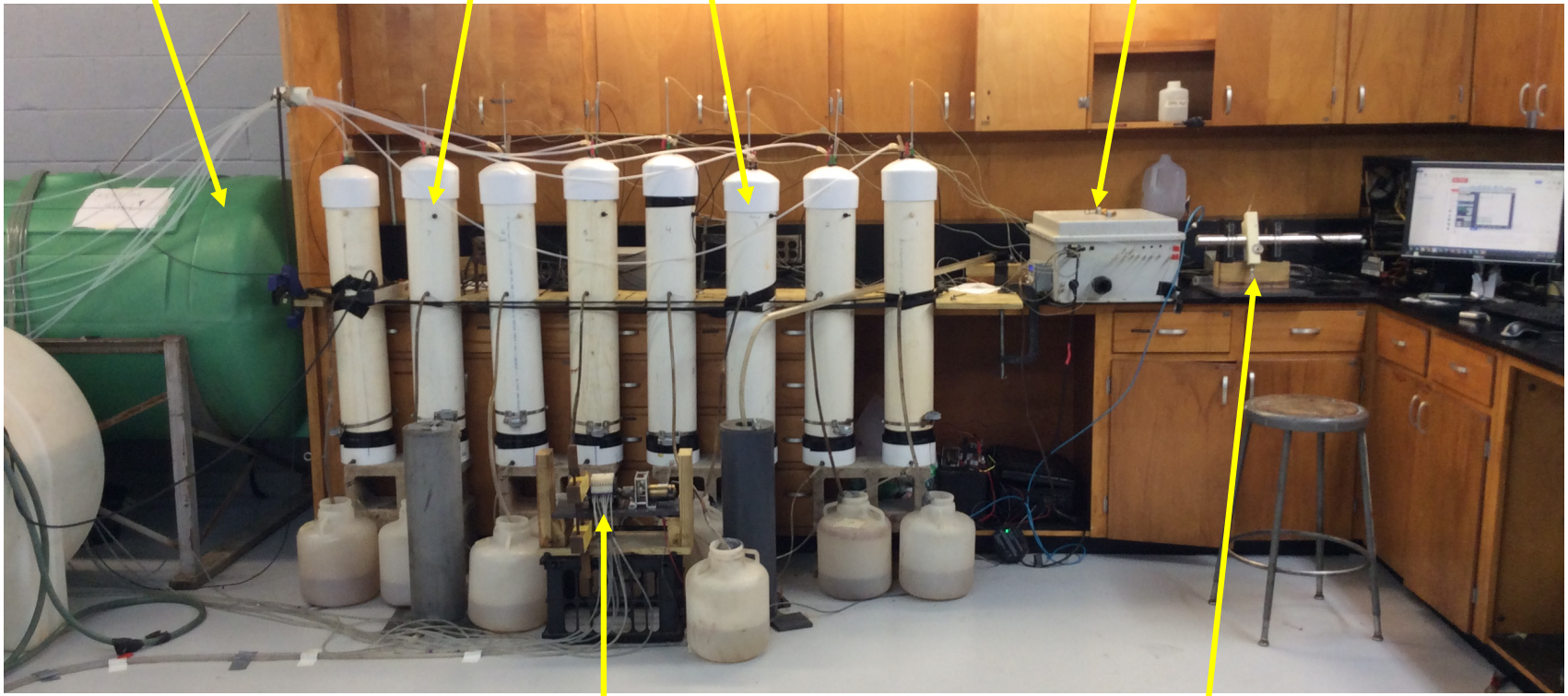
- Continuous upflow (~8 hr HRT) for 10 months, ~20 mg NO3-N/L
- Two treatment groups
  - **DRW** – Drained once a week, unsaturated for 8 hr
  - **SAT** – Continuously saturated
  - Both columns received SAT treatment for first 3 weeks



Stock tank

Upflow columns

Multiplexed water pumping system (MPS)

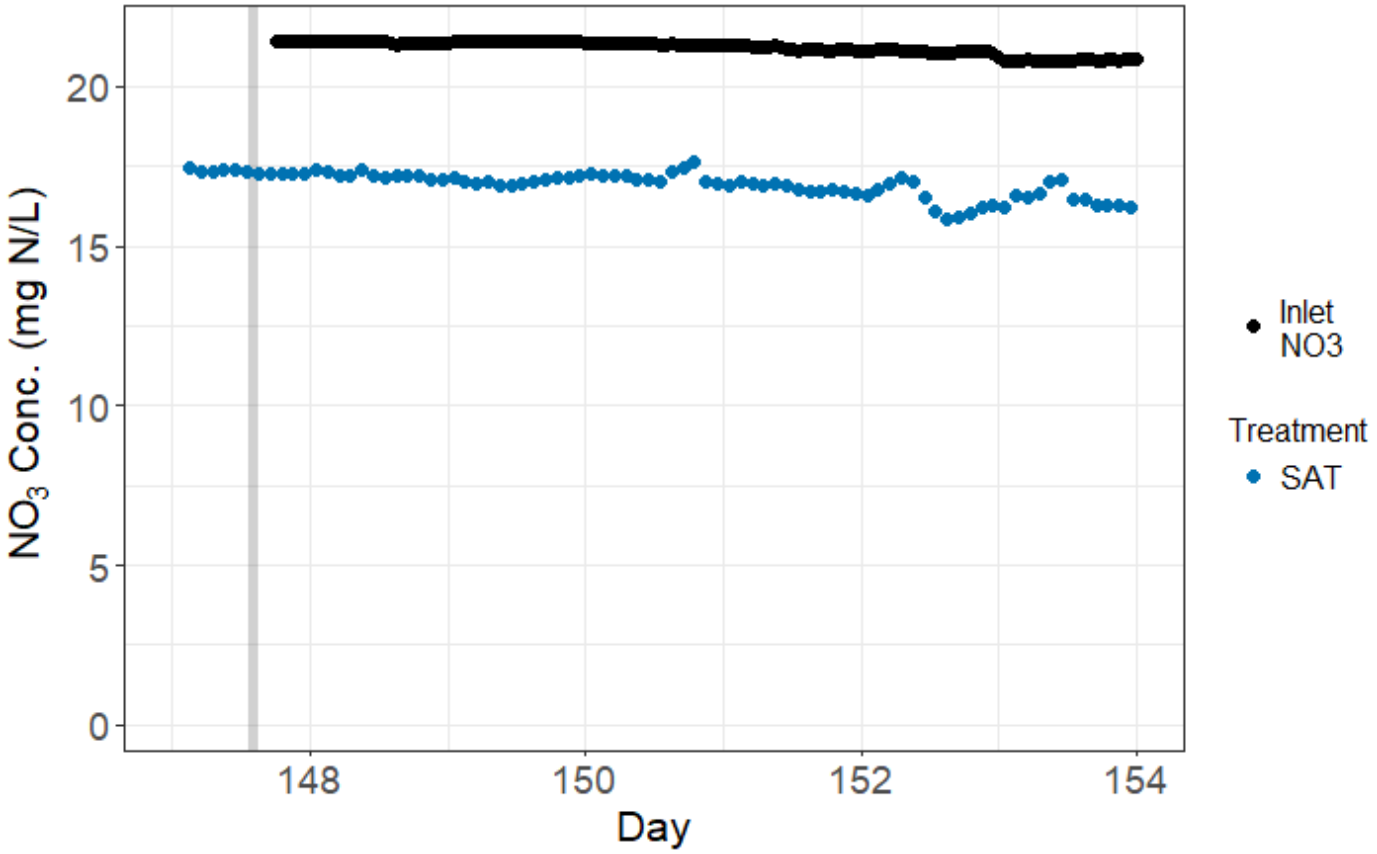


8-channel peristaltic pump

High frequency Water quality sensor

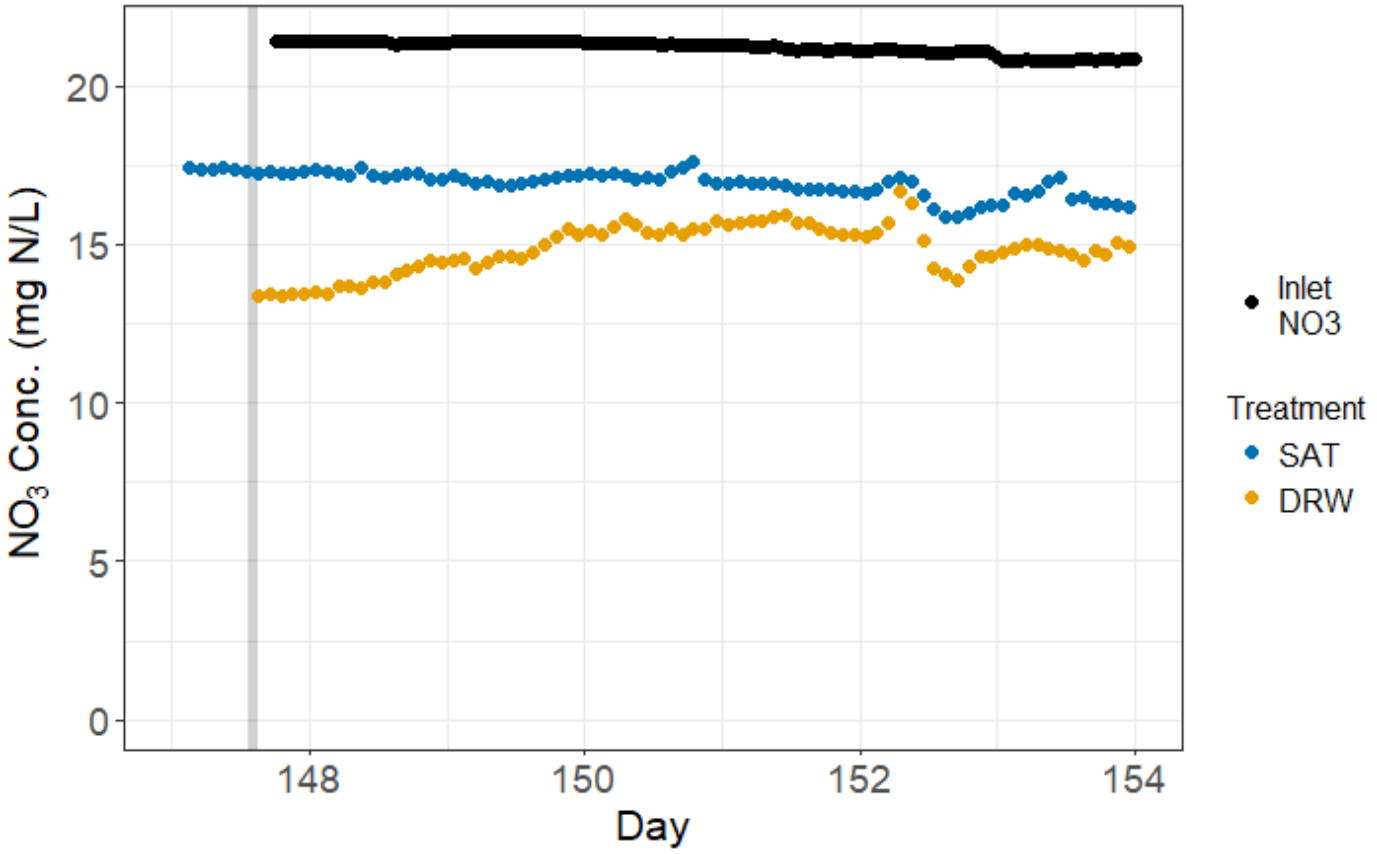
Results : High frequency data

84 measurements per column per week



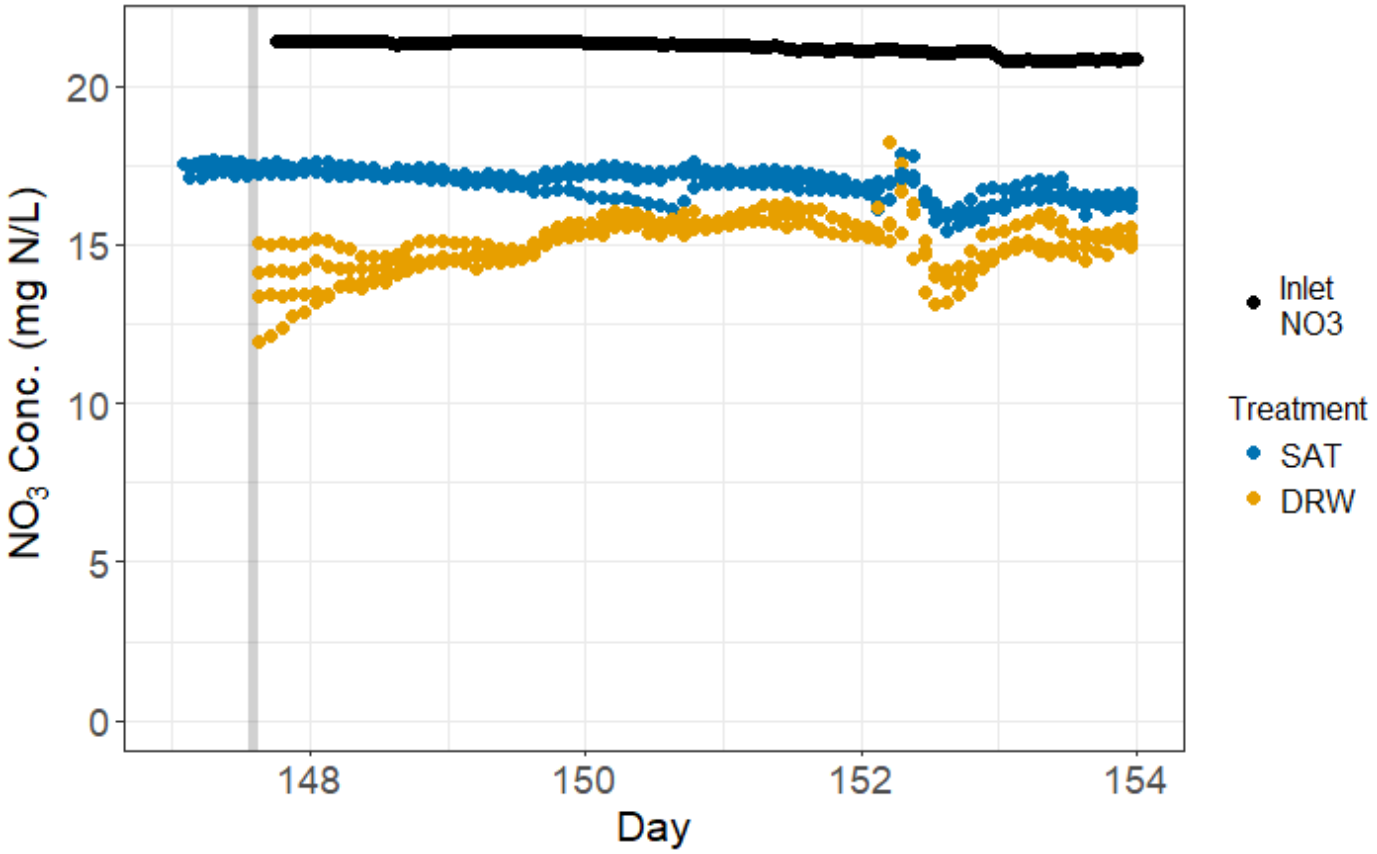
Results : High frequency data

84 measurements per column per week

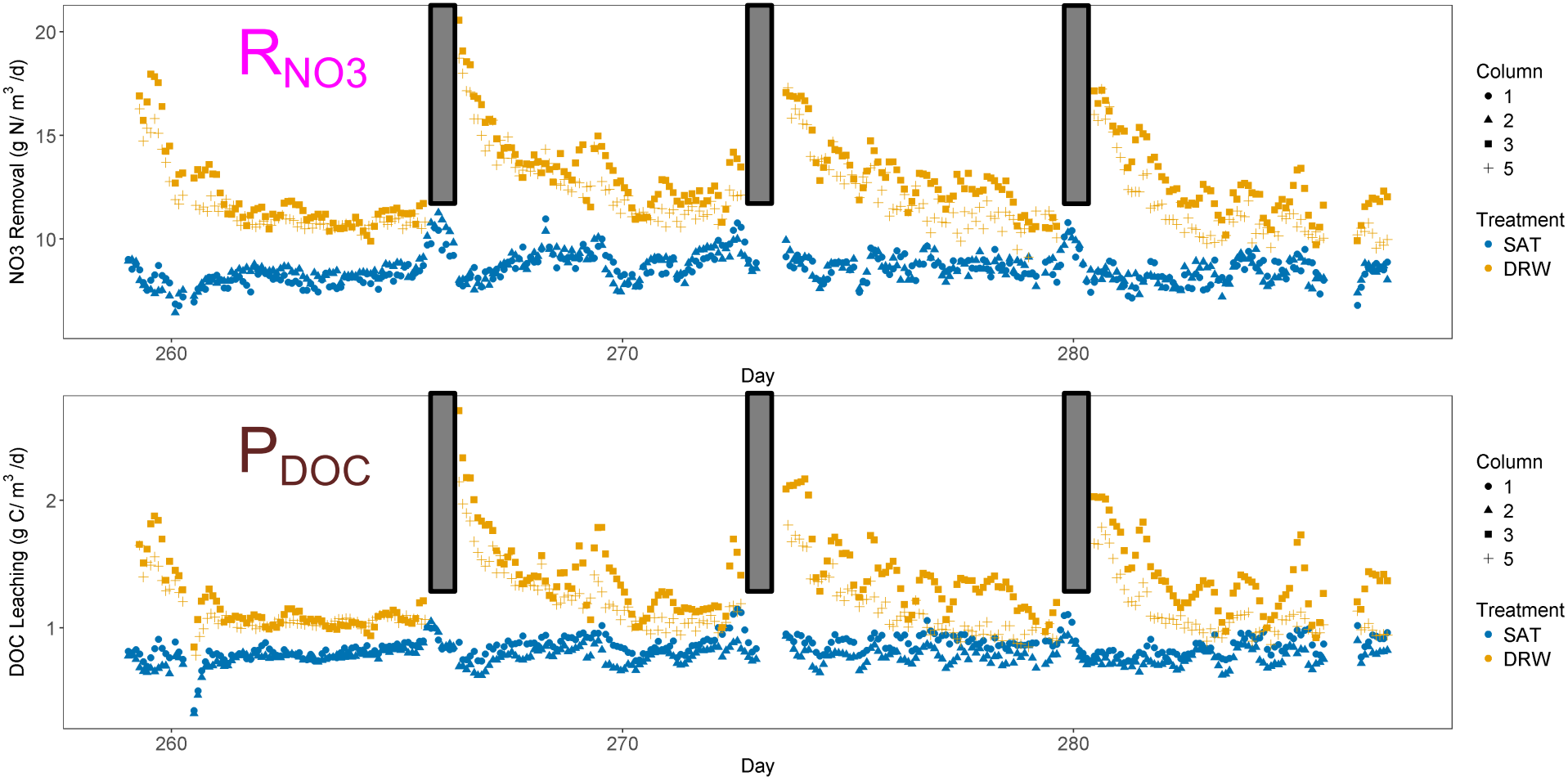


Results : High frequency data

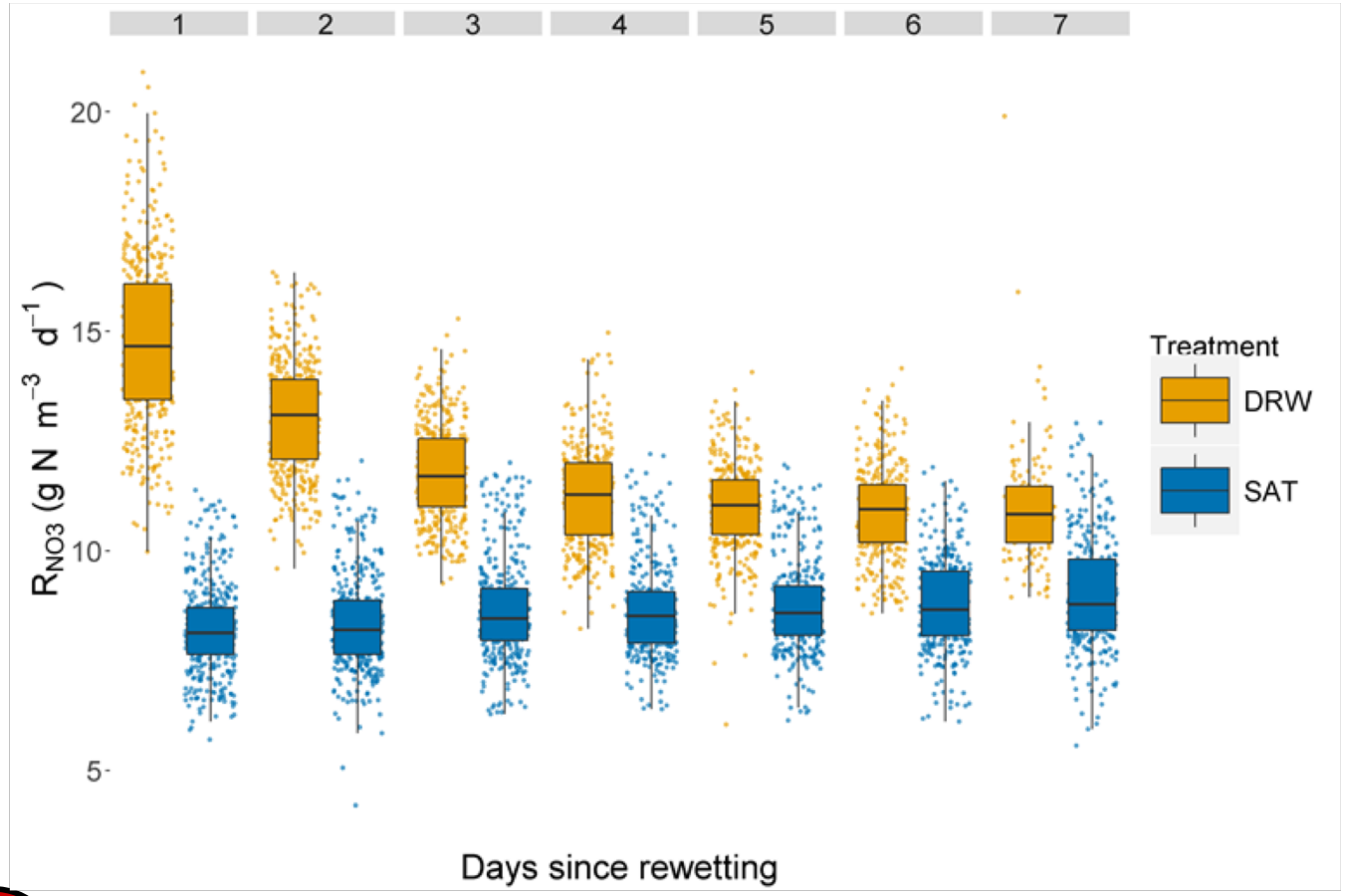
640 measurements per week for all columns



Rapid and Large response to DRW cycles

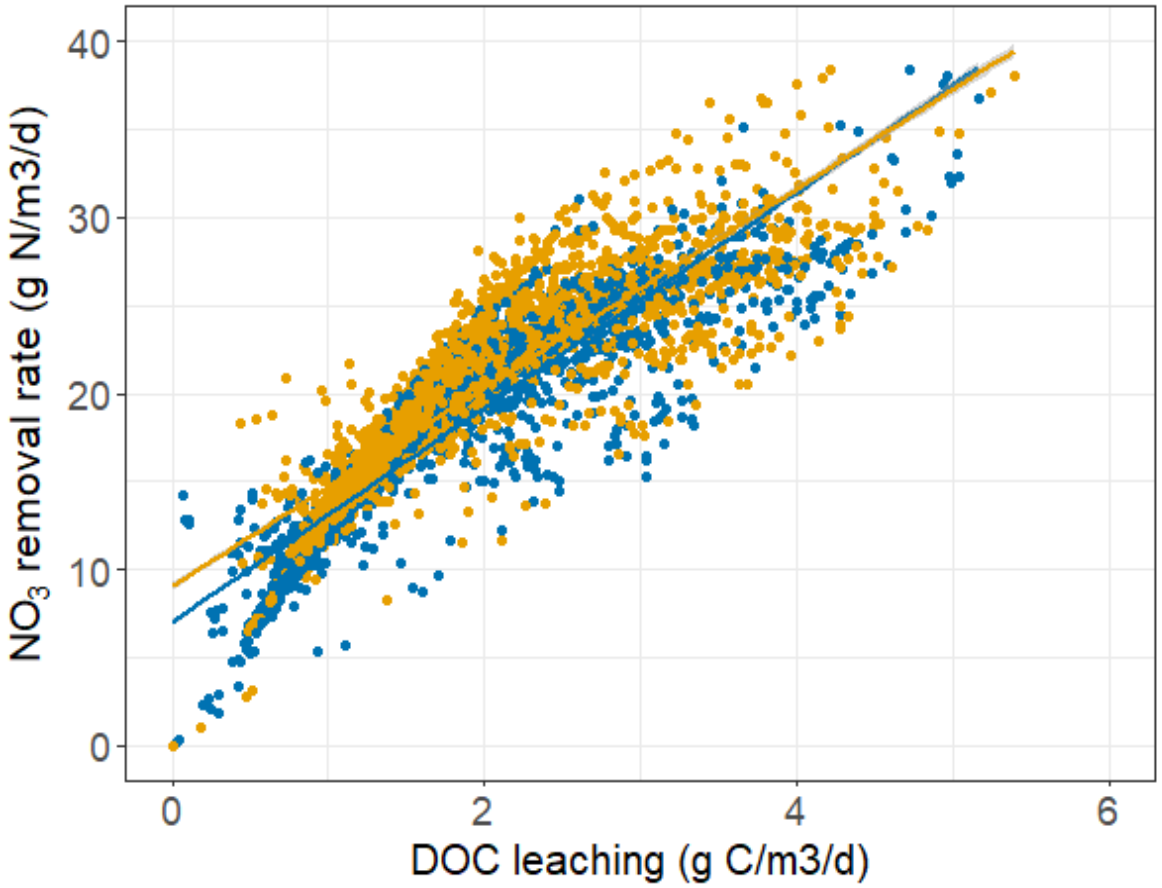


A big reward: Nitrate removal responds to DRW cycles!



Removal rates in DRW columns decreased quickly within 3 days of rewetting, and were still significantly higher 7 days later

Does DOC production explain NO3 removal?

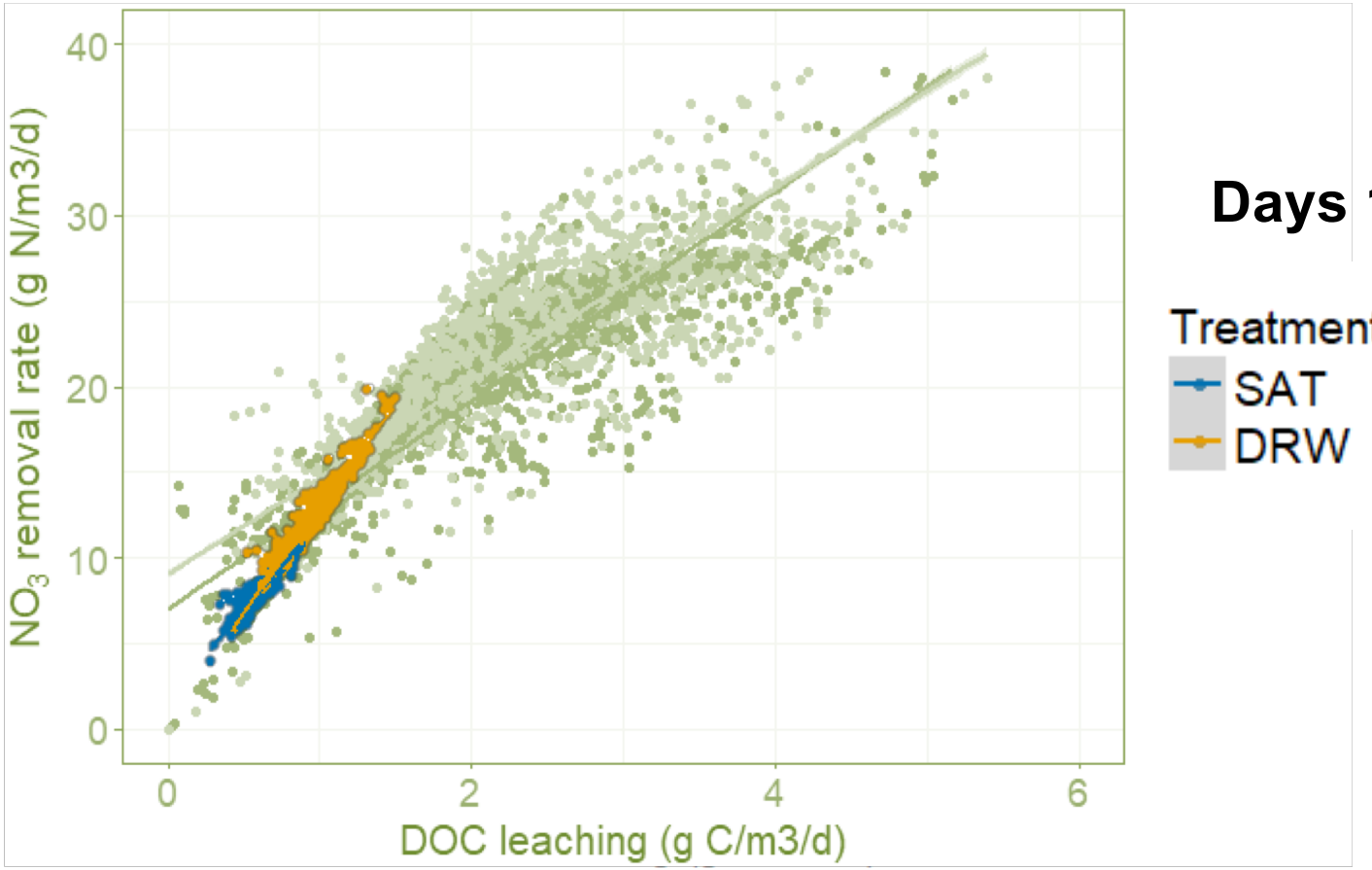


Days 20 - 100

Treatment
SAT
DRW

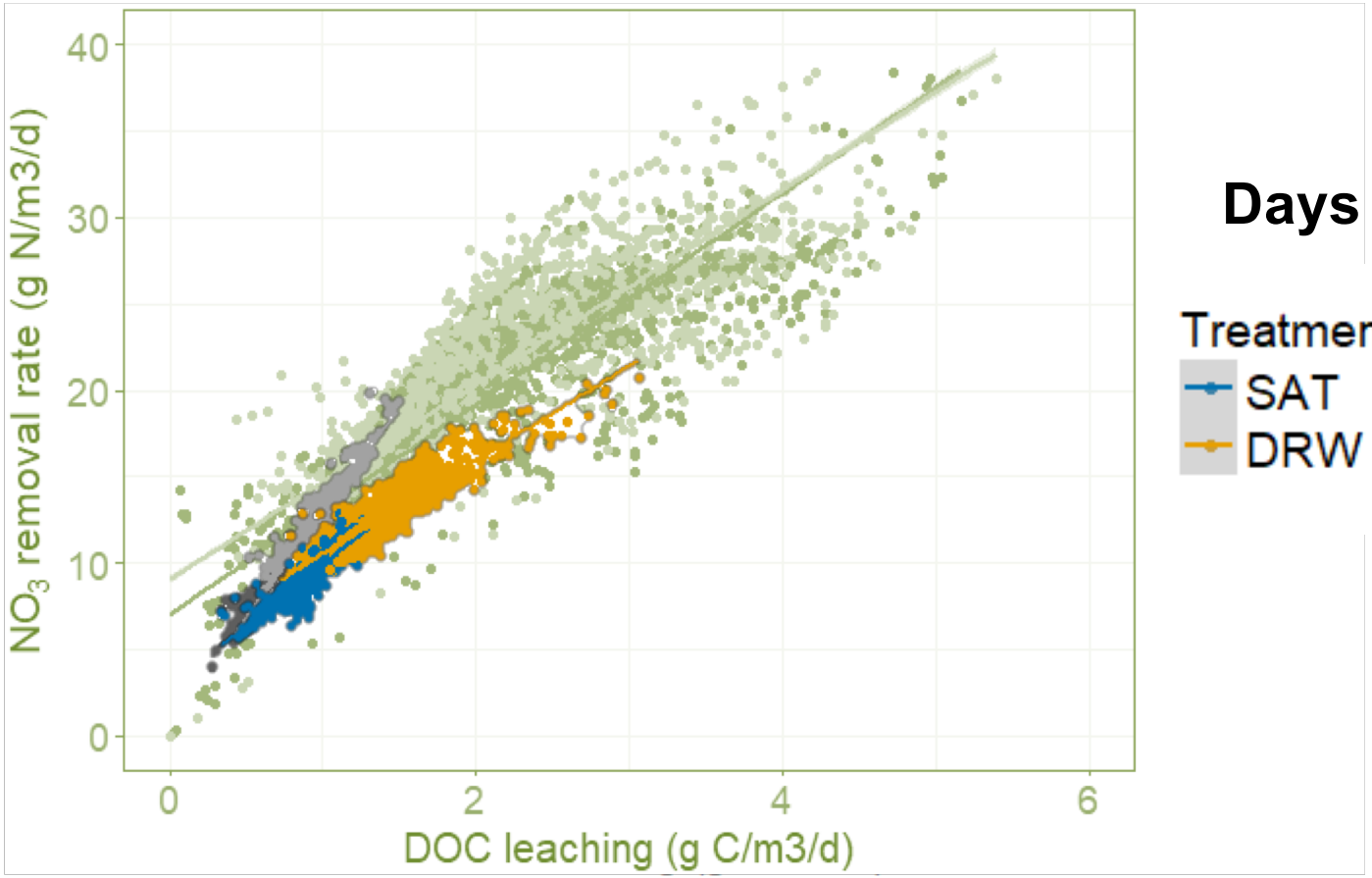
DOC production (leaching) rates explained most of variance in removal (R^2 : 0.90 – 0.97)

Does DOC production explain NO3 removal?



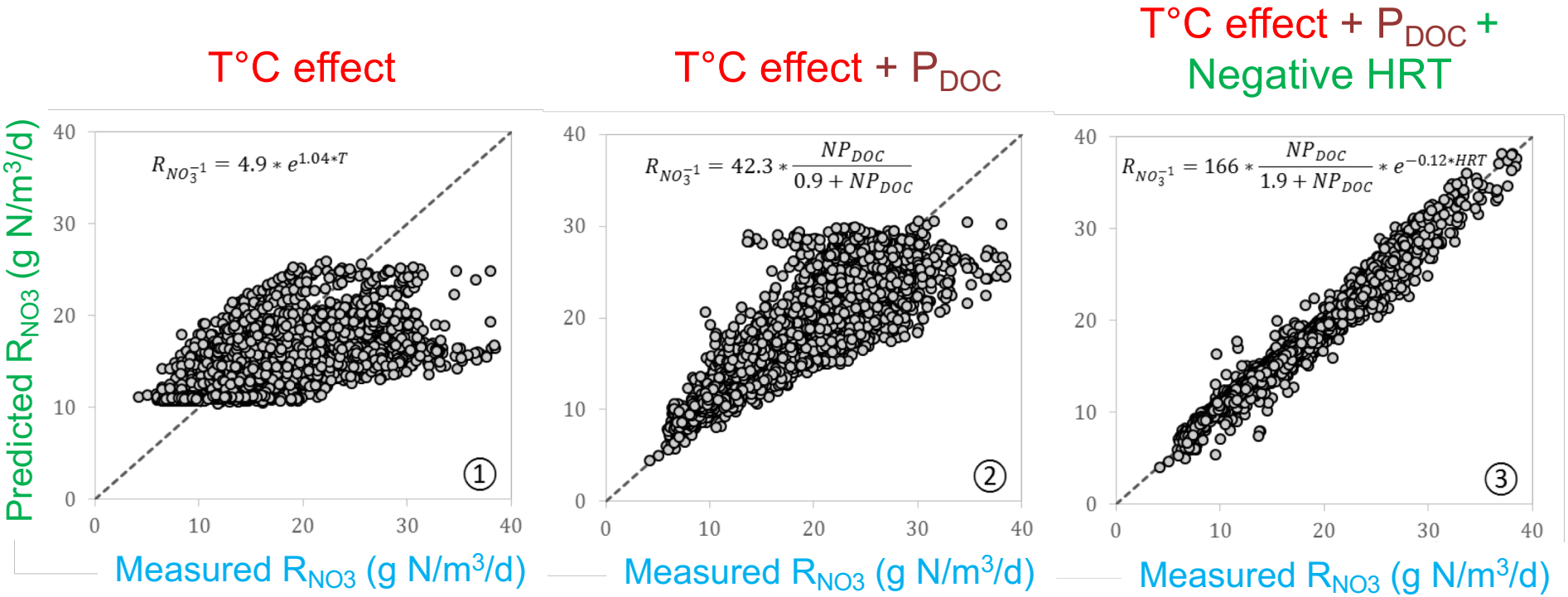
DOC production (leaching) rates explained most of variance in removal (R^2 : 0.90 – 0.97)

Does DOC production explain NO3 removal?



DOC production (leaching) rates explained most of variance in removal (R^2 : 0.90 – 0.97)

Column modeling insights

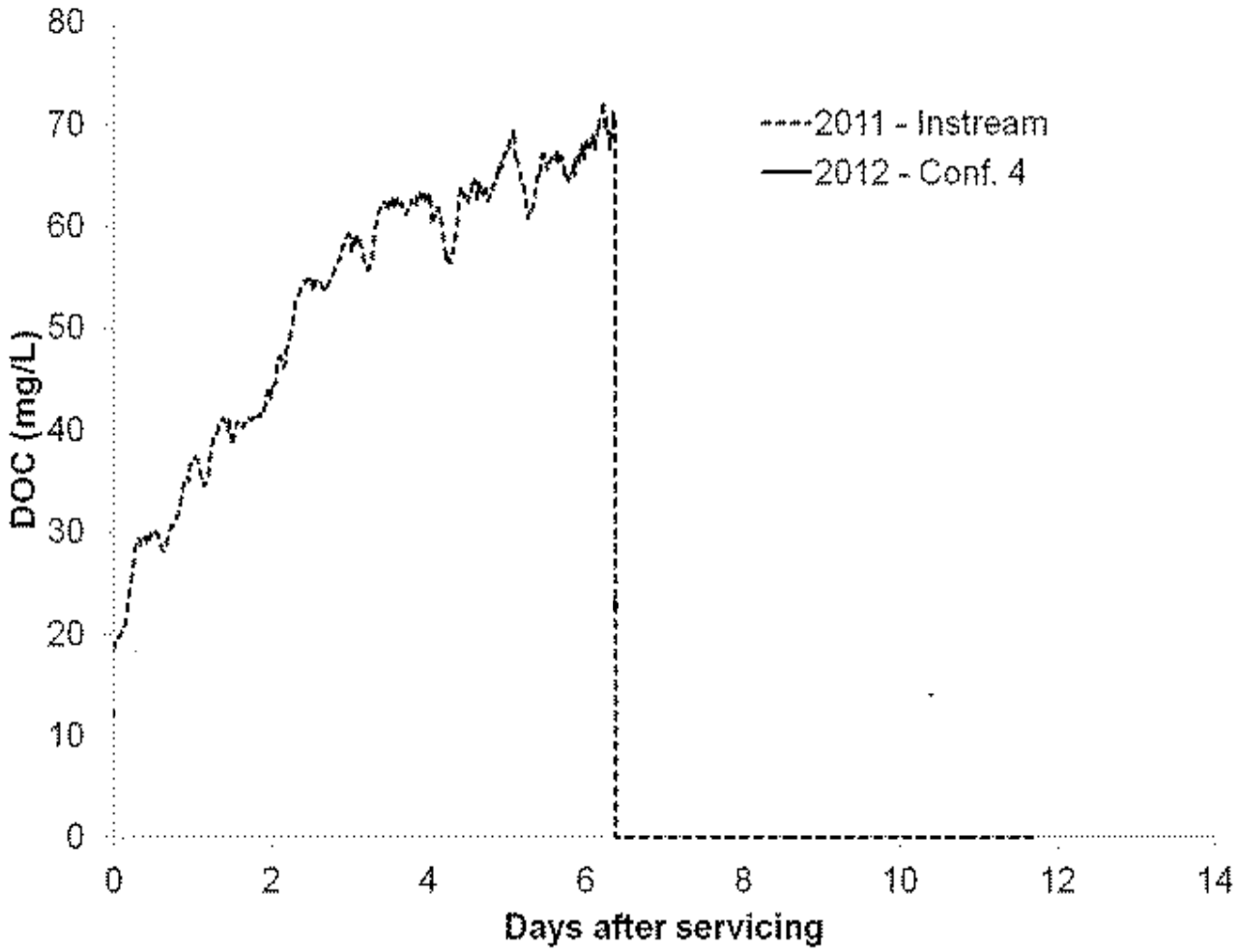


But all of this comes with a lot of challenges

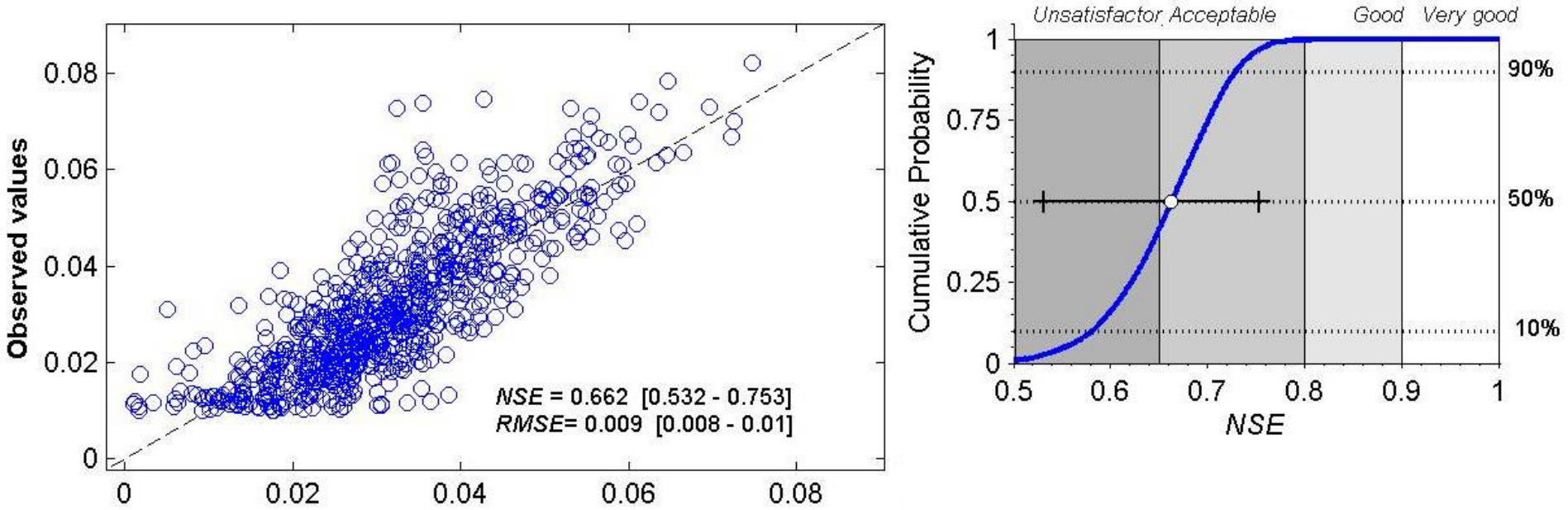
- Continuous water quality sensors require a lot of maintenance

Our dirty little secrets…

Fouling…


80
70
60
50
40
30
20
10
0
DOC (mg/L)
0
2
4
6
8
10
12
14
Days after servicing
2011 - Instream
2012 - Conf. 4

Detailed calibrations necessary: PO4 in a marsh



p = 0.41

(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

More challenges…

- A lot more information that comes with…
  - … A lot more maintenance work
  - … A lot more money
  - … A lot more data analytics work in uncharted territory!
- Little time and energy left for other valuable approaches

Team effort


François Birgand


Chip Chescheir


David Williams


Laura Christianson


Mohamed Youssef

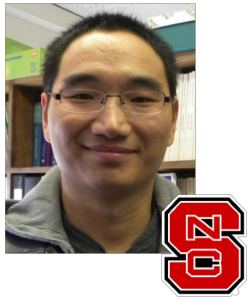

Matt Helmers


Louis Schipper


Bryan Maxwell


Wenlong Liu


Sam Garvey


Shying Tian


Thank you for your attention!
Questions?