15th Specialized Conference on
Small Water & Wastewater Systems

7th Specialized Conference on
Resources Oriented Sanitation

the international water association

# Dynamic membrane for particle removal with large pore size mesh in wastewater treatment

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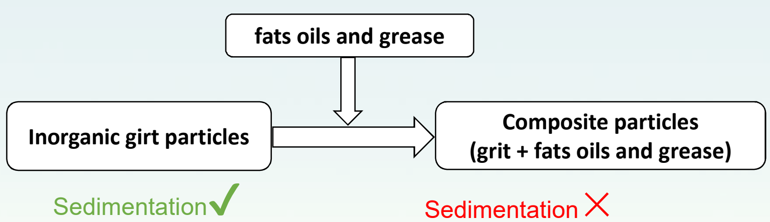
## Outline

1. Introduction
2. Material & Method
3. Results
4. Conclusion

# 1 Introduction

## Background—Problems in wastewater treatment

**Problems 1**: Undegradable composite particles

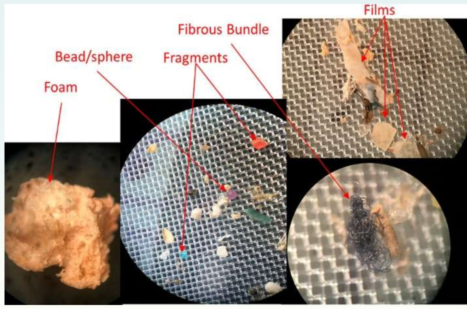


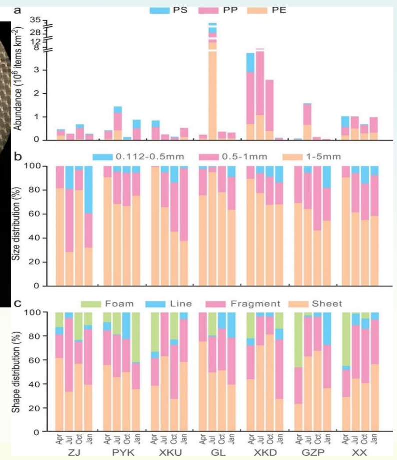

**New method**

Judd, S.J., Khraisheh, M., Al-jaml, K.L., Jarman, D.M., Jahfer, T., 2017. Influence of composite particle formation on the performance and economics of grit removal. Water Research, 108, 444-450.

# **Background**—Problems in wastewater treatment

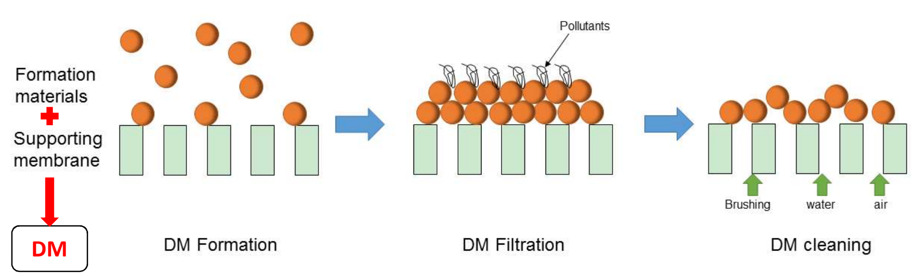
**Problems 2**: Microplastics in wastewater



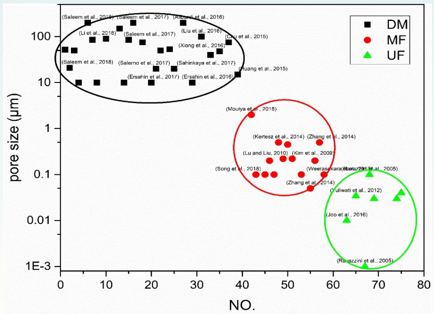

Tagg, A.S., Labrenz, M., 2018. Closing Microplastic Pathways Before They Open: A Model Approach. Environmental Science & Technology, 52 (6), 3340-3341.

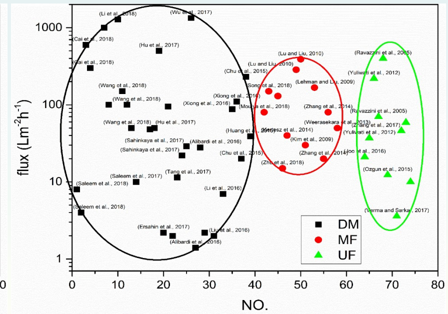
# **Background**—Dynamic membrane technology



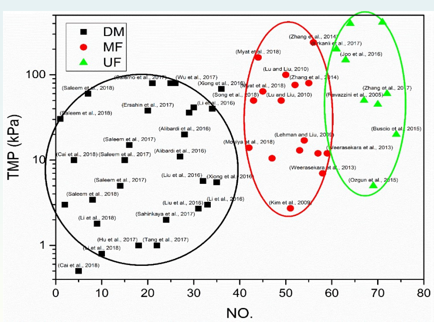

**Li, L., Xu, G., Yu, H., 2018. Dynamic Membrane Filtration: Formation, Filtration, Cleaning, and Applications. Chemical Engineering & Technology, 41 (1), 7-18.**

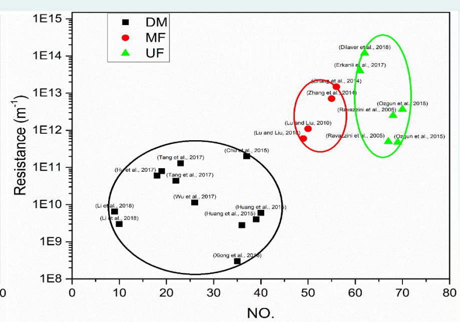
## Background—Comparison of DM, MF, UF



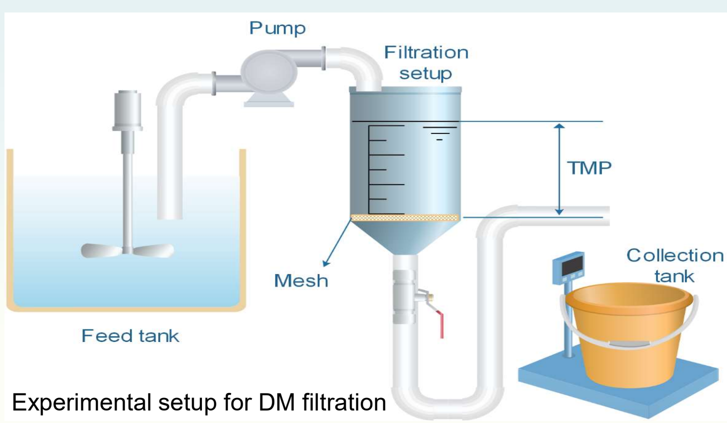

## Background—Comparison of DM, MF, UF



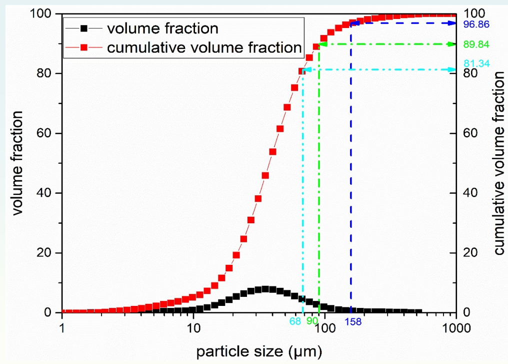
# 2 Materials & Methods

## Materials & Methods




Experimental setup for DM filtration

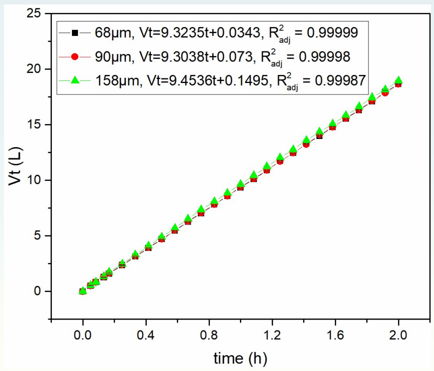
# Materials & Methods



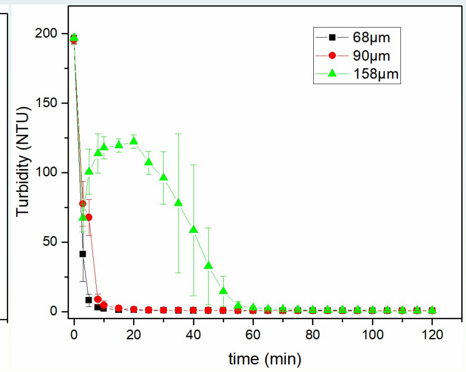

The relationship between particle size distribution and mesh pore size

# 3 Results

# Results—Effluent volume

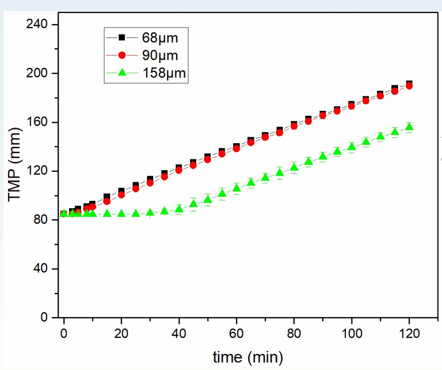



Variation of effluent volumes with different pore size meshes

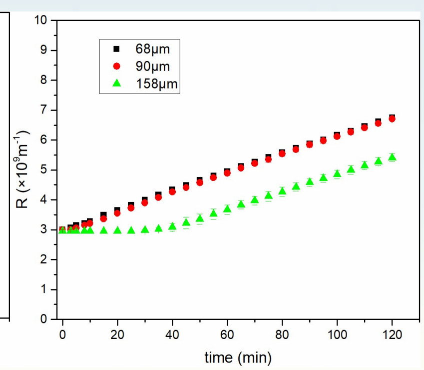



Variation of effluent turbidity with different pore size mesh

# Results—TMP & filtration resistance

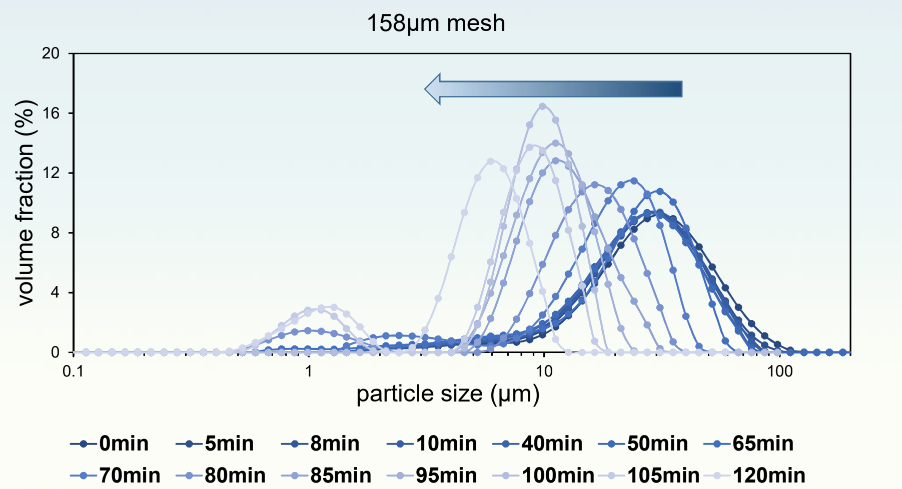



Variation of TMP with different pore size mesh

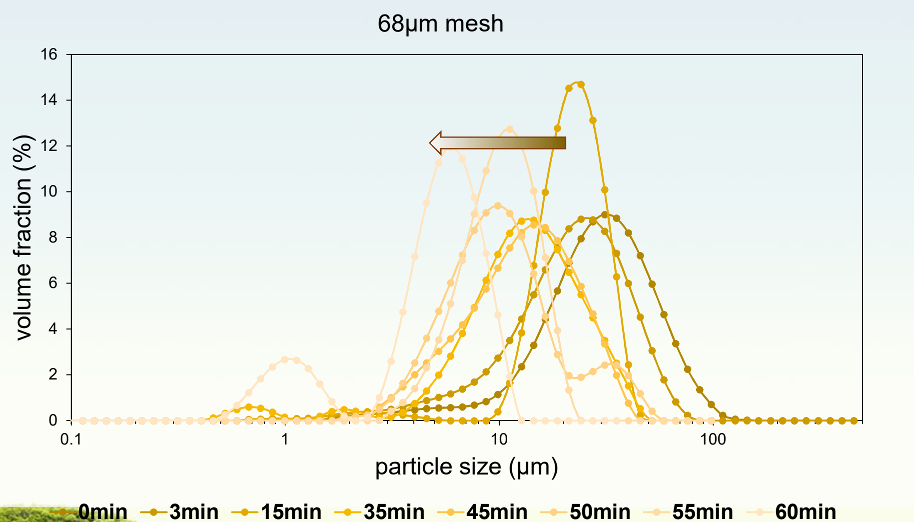



Variation of filtration resistance with different pore size mesh

# Results—Effluent particle size



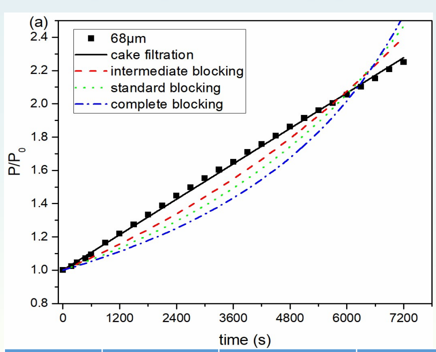

# Results—Effluent particle size



# Results—DM formation mechanism

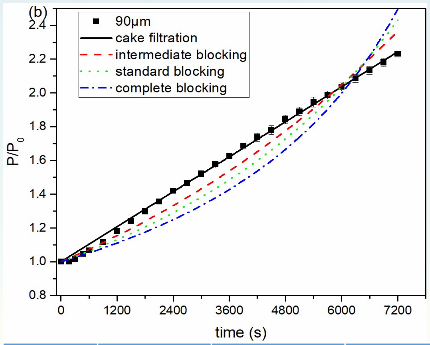
| Blocking mechanism | Model equation | Blocking constant |
|---|---|---|
| **Cake filtration** | $\frac{P}{P_0} = 1 + K_c J_0^2 t$ | $K_c$ |
| **Intermediate blocking** | $\frac{P}{P_0} = \exp(K_i J_0 t)$ | $K_i$ |
| **Standard blocking** | $\frac{P}{P_0} = (1 - \frac{K_s J_0 t}{2})^{-2}$ | $K_s$ |
| **Complete blocking** | $\frac{P}{P_0} = \frac{1}{1 - K_b t}$ | $K_b$ |
| **Cake-complete blocking** | $\frac{P}{P_0} = \frac{1}{(1 - K_b t)}\left(1 - \frac{K_c J_0^2}{K_b}\ln(1 - K_b t)\right)$ | $K_b, K_c$ |
| **Cake-intermediate blocking** | $\frac{P}{P_0} = \exp(K_i J_0 t)\left(1 + \frac{K_c J_0}{K_i}(\exp(K_i J_0 t) - 1)\right)$ | $K_i, K_c$ |
| **Complete-standard blocking** | $\frac{P}{P_0} = \frac{1}{(1 - K_b t)(1 + \frac{K_s J_0}{2K_b} ln(1 - K_b t))^2}$ | $K_b, K_s$ |
| **Intermediate-standard blocking** | $\frac{P}{P_0} = \frac{\exp(K_i J_0 t)}{(1 - \frac{K_s}{2K_i}(\exp(K_i J_0 t) - 1))^2}$ | $K_i, K_s$ |
| **Cake-standard blocking** | $\frac{P}{P_0} = (1 - \frac{K_s J_0 t}{2})^{-2} + K_c J_0^2 t$ | $K_s, K_c$ |

# Results—Single blocking model



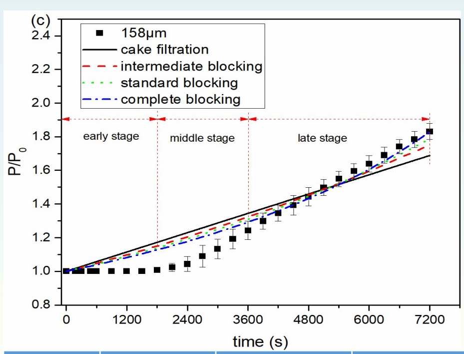

| Mesh | Parameters | Cake filtration | Intermediate blocking | Standard blocking | Complete blocking |
|---|---|---|---|---|---|
| **68μm** | K | 1448.11 | 0.35 | 0.29 | 8.41×$10^{-5}$ |
| | Standard error | 5.51 | 0.00539 | 0.00551 | 1.78×$10^{-6}$ |
| | $R^2_{adj}$ | 0.99876 | 0.96094 | 0.91466 | 0.84543 |
| | RMSE | 0.01418 | 0.07969 | 0.1178 | 0.15853 |

# Results—Single blocking model



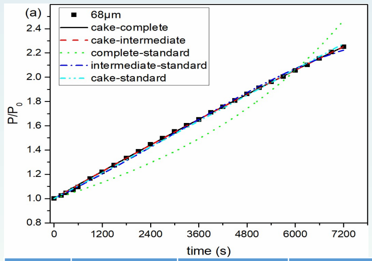

| Mesh | Parameters | Cake filtration | Intermediate blocking | Standard blocking | Complete blocking |
|---|---|---|---|---|---|
| 90μm | K | 1409.34 | 0.34 | 0.28 | 8.33×10$^{-5}$ |
| | Standard error | 7.18 | 0.00456 | 0.00491 | 1.63×10$^{-6}$ |
| | $R^2_{adj}$ | 0.99794 | 0.97318 | 0.93579 | 0.87715 |
| | RMSE | 0.01847 | 0.06657 | 0.10301 | 0.142 |

# Results—Single blocking model



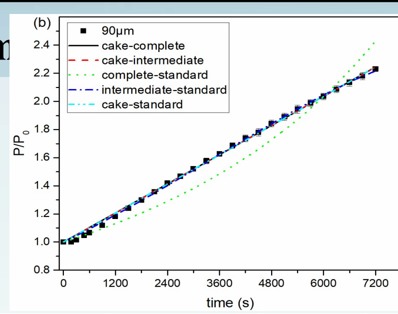

| Mesh | Parameters | Cake filtration | Intermediate blocking | Standard blocking | Complete blocking |
|---|---|---|---|---|---|
| 158μm | K | 780.67 | 0.22269 | 0.20036 | 6.29×10$^{-5}$ |
| | Standard error | 41.21 | 0.00745 | 0.00515 | 1.22×10$^{-6}$ |
| | $R^2_{adj}$ | 0.8684 | 0.91495 | 0.93458 | 0.94992 |
| | RMSE | 0.10604 | 0.08525 | 0.07477 | 0.06542 |

# Results—Combined blocking model



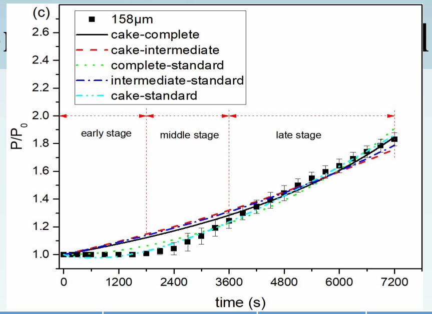

| Mesh | Parameters | Cake-complete | Cake-Intermediate | Complete-Standard | Intermediate-standard | Cake-standard |
|---|---|---|---|---|---|---|
| 68μm | Kc | 1611.86 | 1607.84 | | | 1448.10 |
| | Standard error | 18.88 | 17.85 | | | $2.19\times10^{6}$ |
| | Kb | $-8.02\times10^{-6}$ | | $3.3\times10^{-8}$ | | |
| | Standard error | $9.04\times10^{-7}$ | | 0.00254 | | Over Para-meterized |
| | Ki | | -0.02192 | | -0.60566 | |
| | Standard error | | 0.00234 | | 0.00758 | |
| | Ks | | | 0.29 | 1.06381 | $3.42\times10^{-6}$ |
| | Standard error | | | 7.24 | 0.01161 | 765.19 |
| | $R^2_{adj}$ | 0.9997 | 0.9997 | 0.91124 | 0.99865 | 0.99871 |
| | RMSE | 0.00701 | 0.00698 | 0.12013 | 0.01484 | 0.01446 |

# Results—Com l




| Mesh | Parameters | Cake-complete | Cake-Intermediate | Complete-Standard | Intermediate-standard | Cake-standard |
|---|---|---|---|---|---|---|
| 90μm | Kc | 1399.06 | 1398.91 | | | 1541.36 |
| | Standard error | 48.42 | 48.60 | | | 202.69 |
| | Kb | $5.20\times10^{-7}$ | | $8.9\times10^{-7}$ | | |
| | Standard error | $2.42\times10^{-6}$ | | 0.00476 | | Over Para-meterized |
| | Ki | | 0.00151 | | -0.56786 | |
| | Standard error | | 0.00696 | | 0.00794 | |
| | Ks | | | 0.28218 | 1.0025 | -0.0495 |
| | Standard error | | | 13.58 | 0.01194 | 0.08144 |
| | $R^2_{adj}$ | 0.99786 | 0.99786 | 0.93322 | 0.99874 | 0.99786 |
| | RMSE | 0.01882 | 0.01882 | 0.10505 | 0.01444 | 0.0188 |

# Results—Co … l




| Mesh | Parameters | Cake-complete | Cake-Intermediate | Complete-Standard | Intermediate-standard | Cake-standard |
|---|---|---|---|---|---|---|
| 158 µm | Kc | -210.62 | 140.81 | | | 1850.68 |
| | Standard error | 1175.24 | 20012.07 | | | 17.59 |
| | Kb | $8.54\times10^{-5}$ | | $-3.3\times10^{-4}$ | | |
| | Standard error | $1.43\times10^{-4}$ | | $3.5\times10^{-5}$ | | |
| | Ki | | 0.16766 | | -0.00196 | |
| | Standard error | | 7.05 | | 42.26 | |
| | Ks | | | 0.94301 | 0.20232 | -0.86 |
| | Standard error | | | 0.06636 | 42.26 | 0.03048 |
| | $R^2_{adj}$ | 0.95364 | 0.91697 | 0.98045 | 0.93196 | 0.9954 |
| | RMSE | 0.06294 | 0.08423 | 0.04087 | 0.07625 | 0.01983 |

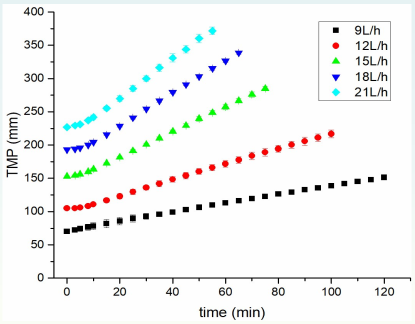
# Results—Model evaluation

| Mesh | Function | Status | AIC | BIC |
|---|---|---|---|---|
| 68µm | Cake-intermediate CF | Succeeded | -263.12658 | -260.28255 |
| | Cake-complete CF | Succeeded | -262.92686 | -260.08282 |
| | Cake filtration CF | Succeeded | -226.33783 | -224.24615 |
| | Intermediate-standard CF | Succeeded | -222.40509 | -219.56106 |
| | Intermediate CF | Succeeded | -133.11795 | -131.02627 |
| | Standard CF | Succeeded | -112.01331 | -109.92163 |
| | Complete-standard CF | Succeeded | -109.46979 | -106.62576 |
| | Complete CF | Succeeded | -95.97713 | -93.88546 |
| | Cake-standard CF | Failed | | |
| 90µm | Cake-intermediate CF | Succeeded | -223.8692 | -221.02517 |
| | Cake-complete CF | Succeeded | -212.07087 | -209.97919 |
| | Cake filtration CF | Succeeded | -209.57933 | -206.7353 |
| | Intermediate-standard CF | Succeeded | -209.5787 | -206.73467 |
| | Intermediate CF | Succeeded | -209.56119 | -206.71715 |
| | Standard CF | Succeeded | -142.8288 | -140.73713 |
| | Complete-standard CF | Succeeded | -119.2586 | -117.16693 |
| | Complete-CF | Succeeded | -116.71513 | -113.8711 |
| | Cake-standard CF | Failed | | |
| 158µm | Cake-standard CF | Succeeded | -158.68458 | -155.84055 |
| | Complete-standard CF | Succeeded | -148.85797 | -146.01393 |
| | Complete CF | Succeeded | -143.7763 | -141.68462 |
| | Cake complete CF | Succeeded | -144.37774 | -141.53371 |
| | Standard CF | Succeeded | -136.55993 | -134.46826 |
| | Intermediate standard CF | Succeeded | -134.01645 | -131.17242 |
| | Intermediate CF | Succeeded | -129.47622 | -127.38454 |
| | Cake-intermediate CF | Succeeded | -128.64064 | -125.79661 |
| | Cake filtration CF | Succeeded | -117.69099 | -115.59932 |

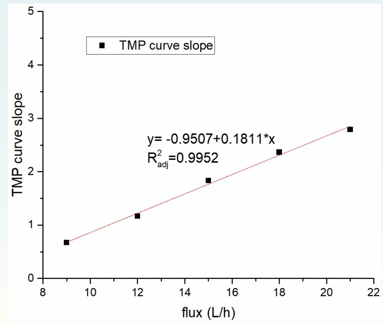
**AIC: Akaike information criterion**, an estimator of the relative quality of statistical models for a given set of data. Thus, AIC provides a means for model selection.

**BIC: Bayesian Information Criterions**, a criterion for model selection among a finite set of models; the model with the lowest BIC is preferred.

# Results—Influencing factors—influent flow

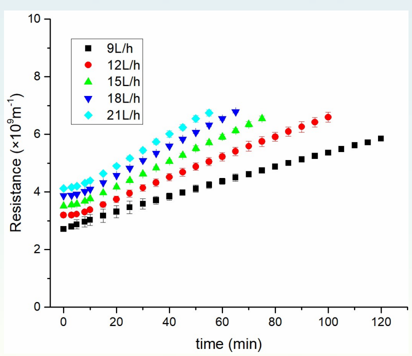



Variation of TMP with time under different influent flow

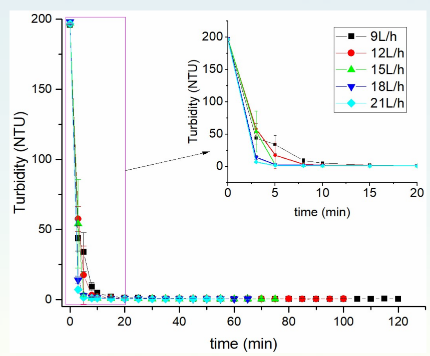



Variation of TMP curve slope with different influent flow

# Results—Influencing factors

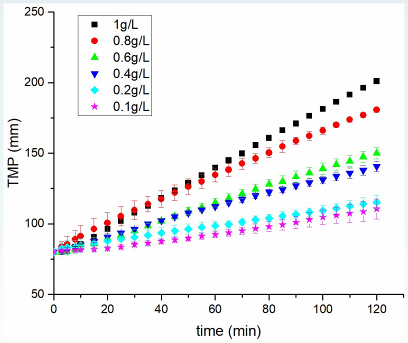



Variation of filtration resistance with time under different influent flow

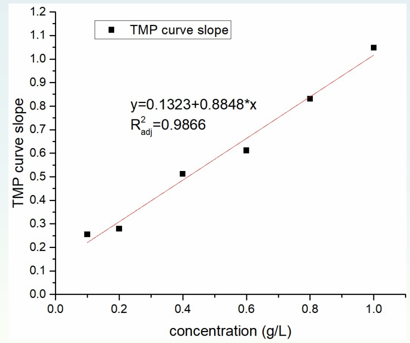



Variation of effluent turbidity with time under different influent flow

# Results—Influencing factors—influent particle concentration

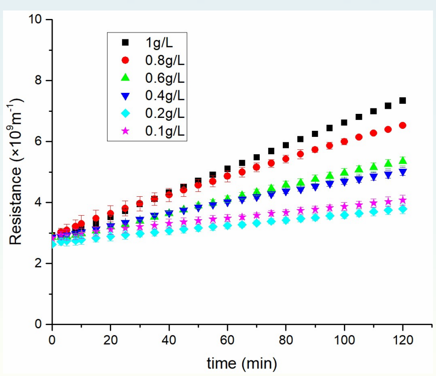



Variation of TMP with time under different influent particle concentration

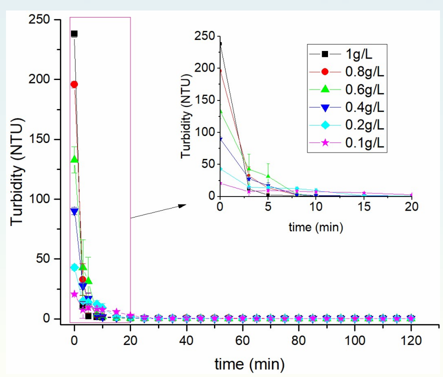



Variation of TMP curve slope with different influent particle concentration

# Results—Influencing factors




Variation of filtration resistance with time under different influent particle concentration




Variation of effluent turbidity with time under different influent particle concentration

# 4 Conclusion

## Conclusion

- **DM filtration technology** can remove the particles effectively, with low TMP, filtration resistance, and high filtration flux in the DM filtration process.

## Conclusion

- Single blocking model of **cake filtration** can explain the DM formation process with 68 μm and 90 μm mesh, while combined blocking model of **cake-intermediate blocking** performs better. For 158 μm mesh, **cake-standard blocking** model can explain the DM formation process reasonably.

## Conclusion

- **Influent flux** and **influent particle concentration** are found to be able to facilitate the formation of DM layer.


Thank
You!