# Influence of interactions between NOM and zinc oxide nanoparticles on ultrafiltration membrane fouling

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## Abstract

Natural organic matter (NOM) fouling has been known as a significant challenge in membrane applications. In this work, Zinc oxide (ZnO) nanoparticles were utilized as nano-absorbent to mitigate the NOM fouling in ultrafiltration. The main objective of this work is to investigate the influence of interaction between NOM and ZnO nanoparticles on membrane fouling propensity. In this context, ZnO was added into an ultrafiltration system used to treat flower soil surrogate extract rich in NOM. Additional run of ultrafiltration with ZnO suspension and flower soil extract each alone as feed solution were also performed. This was intended to study the membrane fouling behavior caused by single pollutants as well as their combination. It was observed that fouling was mitigated with the addition of ZnO, probably due to the interaction between NOM and ZnO nanoparticles.

Keywords: Fouling; Ultrafiltration; Zinc oxide; Natural organic matter, Zeta potential

## 1. Introduction

Membrane filtration process has been proven to play an important role in water treatment due to its flexibility, effectiveness plus easy and economical operation [1]. However, one major drawback of membrane applications is that membranes are easily fouled by organic matters present in the source water. Ultrafiltration (UF) has been implemented extensively in surface water treatment because of their ability to remove organic and inorganic particulate matter in water incl. microorganism. However, colloidal NOM present as well in natural surface waters and with similar size as membrane pores can cause adverse effect on membrane performance. It can cause irreversible fouling by forming a strong adherent deposit on the membrane surface [2] and in the membrane pores. To address this challenge, several strategies such as modification of membrane surface [3,4] as well as pre-treating the feed water with ozonation [5] and/or coagulation [6] have been reported to mitigate the fouling propensity and prolong membrane lifespan.

Recent development of nanomaterial has shown as a great potential of promising technology in wastewater treatment. In this context, the utilization of nanomaterial as adsorption material have been studied extensively in wastewater treatment [7,8]. ZnO is a common nanomaterial that has been applied successively in photocatalysis as well as in adsorption. In terms of adsorption process, Fan

Zhang and co-workers has proven that ZnO is capable in dyes adsorption and shows high reusability [9]. However, it was found that current development of nano-absorbent that focus on influence of interaction between NOM and ZnO nanoparticles on UF membrane process is not well-documented to date. Therefore, we tested the utilization of ZnO nano-absorbent in UF membrane fouling mitigation using NOM as targeted substance. Further, the focus was set on the behavior of ZnO when they are well-mixed with NOM aqueous solution and being filtered by a UF system.

## 2. Materials and method

Flower soil was obtained from Toom Baumarkt. The flower soil extraction technique is based on standard procedures of inge GmbH, Greifenberg, Germany. ZnO nanoparticles, VP ZnO 20 (CAS No. 1314-13-2) used in this work was supplied by Evonik Industries. The zeta potential of ZnO was determined using Zetasizer (Nano ZS, Malvern Instruments, Germany). ZnO nanoparticle suspensions with concentration of 100mg/l were titrated with HCl and NaOH solution using an auto-titrator. UF membranes used in this work were UH004P, UP005P and UP010P, which were supplied by MICRODYN-Nadir GmbH, Germany. The properties of membranes used are shown in Table 1. The hydrophilicity of membranes were determined using contact angle measuring system OCA15 (Dataphysics) using sessile-drop method. UF experiments were carried out in a flat sheet crossflow membrane unit (membrane area = 0.014 $m^2$, crossflow velocity = 8 $cms^{-1}$ and flux = 100 $L/hr/m^2$). Three different type feed solution were used to study the influence of ZnO on membrane fouling mitigation: (a) ZnO (0.5 g/l) only , (b) flower soil surrogate extraction (1:500 dilution) only and (c) ZnO well-mixed with the flower soil surrogate extract (1:500 dilution). The membrane performance and fouling propensity were assessed based on the rejection of flower soil extraction and transmembrane pressure (TMP) development over time in constant flux operation.

## 3. Results and discussion

Fig. 1 (a), (b), and (c) illustrate the normalized TMP of the three investigated membranes operated with the different feed solutions. A sharp increase of TMP can be observed for all the membranes when flower soil surrogate extract was employed for the experiments. The results also reveal that increment of TMP was the greatest for UP010P, which has the larger pore size and little higher contact angle compared to UH004P and UP005P membranes. Similar finding is described by Laîné et al. [10] as cited in Yuan and Zydney [2]. On the other hand, steady TMP was observed when ZnO suspension and mixture of flower soil surrogate extract-ZnO were feed into the UF system. This implies that addition of ZnO can assist in membrane fouling mitigation. Fig. 2 presents the ZnO zeta potential as a function of pH from pH 3 to pH 11. Point of zero charge ($pH_{PZC}$) of ZnO was measured at pH 7.7. The filtration experiments were performed at pH 8.5. This indicates that the surface charge of ZnO has become negative with a zeta potential of about -10 mV and Z- average diameter of about 1,200 nm. ZnO nanoparticle is considered unstable with zeta potentials in between +30 mV and -30 mV. ZnO tend to aggregate and form agglomeration with the organic matter present in flower soil surrogate extraction [11]. In turn, these agglomerates cause less adhesive and dense foulant layer on the membrane and cannot penetrate into membrane pores. Fig.3 illustrates the membrane foulant morphology of UP005P using flower soil surrogate extract with/without ZnO.

## 4. Conclusion

A series of UF experiments were successfully conducted using different type of feed solutions for the purposes to investigate the influence of interactions between NOM and ZnO nanoparticles on UF membrane fouling behaviour. ZnO was found to be able to mitigate the UF fouling when treating NOM rich water.

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Paper prepared for: *17. Aachener Membran Kolloquium (AMK); 13. - 15.11.2018; Aachen*

**DOI:** 10.17185/duepublico/49399
**URN:** urn:nbn:de:hbz:464-20201126-130256-8