Sidestream Ozone Injection System Based on NETmix Technology for Water Treatment

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A sidestream ozone (O_3) injection system based on a novel design of a pressurized micro/meso-structured NETmix static mixer has been developed for the pre-oxidation of freshwater for human consumption. NETmix has an exclusive geometry and promotes a high intensity of O_3 gas-liquid mass transfer, which is essential for sidestream injection systems. A pilot-scale prototype was installed at Lever Water Treatment Plant (located in the north of Portugal), enabling the direct comparison with the full-scale sidestream system using a Venturi injector. O_3 doses ranging from 0.8 to 1.3 mgO$_3$ L^{-1} were tested unraveling a potential for lower O_3 dosage requirements to achieve appropriate water disinfection/oxidation and maximize the efficiency of the subsequent coagulation/flotation treatment unit.

Introduction

Sidestream injection (SSI) systems for ozone have been gaining popularity as one of the most promising techniques for upgrading water treatment plants (WTP). SSI involves splitting off a portion of the main water flow into a side stream. O_3 gas is injected into this side stream by a device such as a venturi or a static mixer and then the concentrated O_3 side stream is mixed back into the main flow. NETmix consists of a micro/meso-structured static mixer based on a network of unit cells formed by chambers interconnected by transport channels which generate a series of zones of complete mixing (chambers) and complete segregation (channels) [1]. It can be introduced as an alternative equipment in sidestream configurations for ozonation processes as it outperforms conventional devices [2]. Therefore, in this work, a sidestream ozone injection system based on a novel design of a pressurized NETmix reactor (NETmix SSI) has been developed aiming at the pre-oxidation of freshwater for human consumption. A pilot-scale prototype was installed in the oxidation/disinfection step at Lever WTP (north of Portugal), enabling a direct comparison with a full-scale sidestream system using a Venturi injector (Venturi SSI). In addition to analyzing the disinfection capabilities of the prototype, it was also evaluated the influence of the NETmix SSI on the downstream coagulation/flotation process.

Material and Methods

The NETmix (Figure 2) consisted of a network of unit cells including cylindrical chambers (diameter = 6.75 mm, depth = 3.0 mm) interconnected by prismatic half-channels (width = 1.0 mm, length=0.5 mm, depth = 3.0 mm). The reactor was made of a stainless-steel structure containing (i) a rear plate, (ii) a middle plate where the network of channels and chambers is imprinted on the front side, and a heat exchanger filled with fins is contained at the back side, and (iii) a frontal plate with a window of borosilicate.

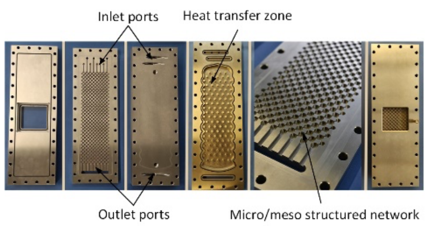

Figure 2. Micro/meso-structured NETmix reactor.

The pilot-scale prototype with the O_3 sidestream contacting train is displayed in the Graphical Illustration. In a typical test (Figure 3), 38 dm^3 h^{-1} of the main water flow was diverted from the main pipeline (operated at 1250 dm^3 h^{-1}) and directed into the NETmix for efficient mixing with an O_3-gas stream. An O_3-enriched liquid sidestream was rapidly established (3 sec) and continuously blended into the main water flow in the pipeline utilizing opposite-facing re-entrant nozzles and a static mixer device (Kenics). Subsequently, the recombined main water flow was directed to a 4-chamber reaction tank (equipped with vertical baffles, V_T = 225 dm^3, and HRT = 8 min) to provide the residence time for the oxidation/disinfection. O_3 gas was generated using a BMT 803 N O_3 generator with concentrations ranging from 84 to 136 g Nm^{-3} and gas flowrate of 12 Ndm^3 h^{-1}.

The prototype NETmix SSI was operated on different days with O_3 doses of 0.8, 1.1, and 1.3 mgO_3 L^{-1} while the full-scale Venturi SSI was operated at 1.4, 1.1, and 1.2 mgO_3 L^{-1}, respectively. Water temperature and pH were kept in ambient (12±1 °C) and circumneutral (7.1±0.3) conditions, respectively. The bacterial inactivation (Coliform bacteria–COLI B; *Clostridium perfringens*–CLOST; *Enterococci*–ENC and *Escherichia coli*–E. COLI), turbidity, and Specific UV absorbance ($SUVA_{254}$, absorbance at 254 nm per mg DOC) were evaluated. Samples were taken at steady-state conditions. Thereafter, coagulation/flotation tests with 40 mg $Al_2(SO_4)_3$ L^{-1} were carried out.

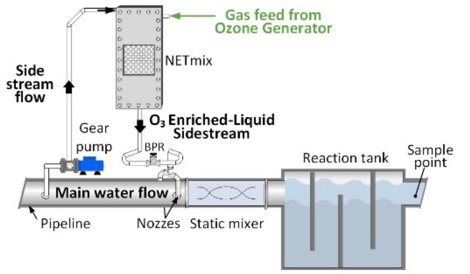

Figure 3. Scheme of the low-footprint O_3 sidestream prototype.

Results and Discussion

NETmix SSI presented an effective bacterial inactivation (Figure 4) of COLI B, ENC, and E. COLI at an applied O_3 dose of 0.8 mgO_3 L^{-1}, when compared to Venturi SSI with a O_3 dose of 1.4 mgO_3 L^{-1} and HRT of 10 min (based on the same raw water conditions). Additionally, complete bacterial inactivation was reached with a O_3 dose of 1.1 and 1.3 mgO_3 L^{-1} applying NETmix SSI. CLOST was the most resistant bacteria towards O_3 for both sidestream injection systems evaluated. Previous works [3] reported an O_3 dose ≥3.0 mgO_3 L^{-1} requirement to attain 99% CLOST inactivation. Moreover, O_3 was used to change the structure of the organic matter in the raw water and enhance subsequent coagulation/flotation efficiency (Figure 5). However, although the ozonation accomplished only a slight decrease in turbidity and $SUVA_{254}$, the dosage of applied O_3 influenced the characteristics of dissolved organic matter (DOM), especially with NETmix SSI. At low ozone dosages (0.8 and 1.1 mgO_3 L^{-1}), O_3 produced hydrophobic, neutral, intermediate molecular weight DOM, which was beneficial for the subsequent coagulation/flotation processes. Consequently, lower turbidity and $SUVA_{254}$ values were attained. On the other hand, at a larger O_3 dosage (1.3 mgO_3 L^{-1}), the DOM was further oxidized into more hydrophilic and lower molecular weight DOM, which hampered the turbidity and $SUVA_{254}$ reduction efficiencies [4].

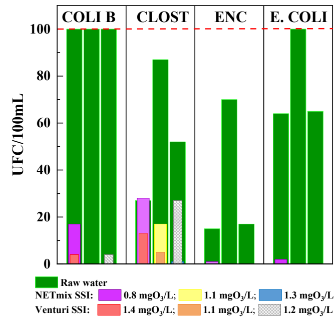

Figure 4. Effect of O_3 dose on bacterial inactivation. The red dash line indicate the upper limit of quantification.

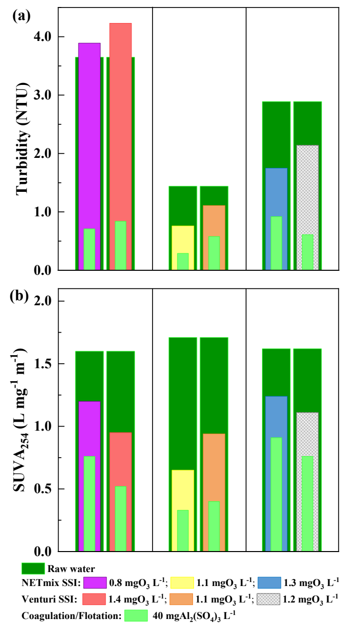

Figure 5. Effect of ozonation and coagulation/flotation on **(a)** turbidity and **(b)** $SUVA_{254}$ removal.

Conclusions

The prototype O_3 sidestream contacting train, based on a novel design of a pressurized micro/meso-structured NETmix technology, revealed a great potential to reduce O_3 dosage requirements to achieve appropriate water disinfection/oxidation and maximize the efficiency of the subsequent coagulation/flotation treatment unit.

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