Effects of suspended and dissolved particles through UV light exposure: an approach to the user's vulnerability based on water source quality

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Highlights:

- Suspended and dissolved particles affect UV penetration, influencing bacterial inactivation efficacy, especially in challenging scenarios.
- UV disinfection performance varies with water quality, crucial for ensuring safe drinking water in diverse community settings.
- The bacterial inactivation (1.35 ± 0.20 log) under extreme conditions raised questions on UV radiation stand-alone suitability.

Keywords: *Escherichia coli*; turbidity; total organic carbon

INTRODUCTION

Waterborne pathogens pose significant risks to public health, requiring effective disinfection strategies in water treatment processes. Ultraviolet (UV) radiation is recognized as a powerful technique for microbial inactivation due to its ability to disrupt microbial DNA, without promoting disinfectant-resistance bacteria or contributing taste and odor to the water (USEPA, 2006). However, one of the key factors to achieve successful disinfection results is the optical characteristics of water, because the presence of suspended and dissolved particles in water may alter the penetration, absorption, and scattering of UV light, impacting the damage in microbial cells (Baldasso et al., 2021).

According to the WHO, it is recommended to apply an UV in water with turbidity and total organic carbon below 1 NTU and 1 mg/L, respectively (WHO, 2018). In decentralized treatment scenarios, it is common to use supply sources with different qualities that can often exceed these standards. Additionally, users may change their choice of water source based on demand and availability. Therefore, predicting the effect of these different water qualities is a key knowledge for an efficient application of UV disinfection.

Understanding how suspended and dissolved particles affect bacterial inactivation through UV light exposure is essential for optimizing disinfection protocols and ensuring the delivery of safe drinking water to communities worldwide. Based on this, our study extrapolated the optimal conditions to evaluate the behavior of bacterial inactivation in these extreme situations.

METHODOLOGY

This study aimed to evaluate the effect of suspended and dissolved particles in water samples on the *E. coli* inactivation when exposed to an UV_{lamp} collimated-beam device ($\lambda = 254$ nm, 0.209 mW/cm²). For that, six lab-made water samples were produced, using two levels of turbidity (1 and 20 NTU) and three levels of total organic carbon (1, 7.5 and 15 mg/L). Turbidity (A2 fine test dust, ISO 12103-1) and TOC (tannic acid, Sigma-Aldrich) were utilized to measure suspended and dissolved particles, respectively (WHO, 2018). All samples were inoculated with 5.5×10^4 CFU/mL of *E. coli* (ATCC® 11229).

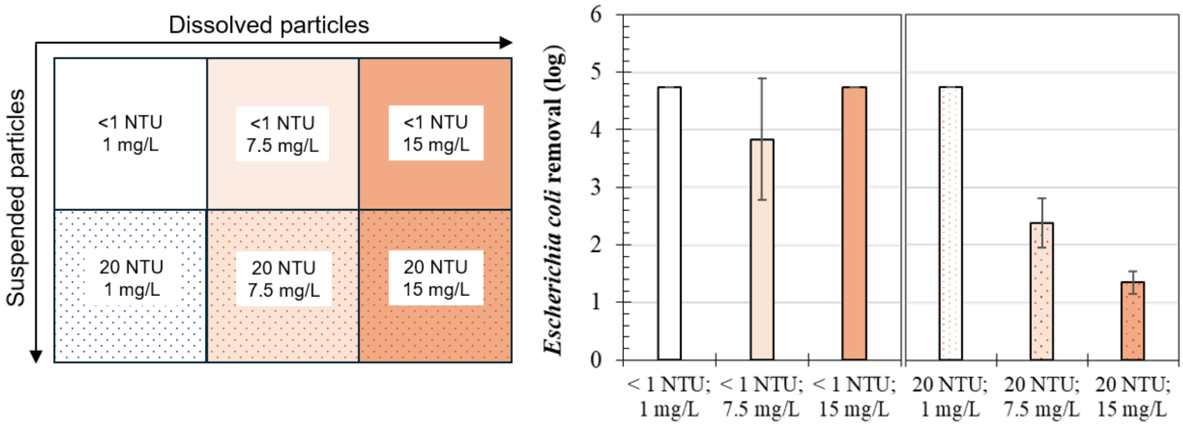
The inactivation experiments were conducted with 20 mL samples with *E. coli* under constant agitation at a UV dose of 30 mJ/cm² (2 min and 11 seg). All experiments were replicated three times. Blank and disinfected samples were analyzed by counting *E. coli* colonies in Chromocult® Coliform Agar at 37°C for 21 ± 3h. The detection limit (DL) was 67 UFC/100mL.

Normality distribution was evaluated by Shapiro-Wilk test and hypothesis tests by Kruskal-Wallis test. All statistical analyses were performed on PAST 4.03 software (PAlaeontological Statistics) considering a significance level of 5% (p-value < 0.05).

RESULTS AND CONCLUSIONS

Figure 1 shows the *E. coli* inactivation achieved in experiments conducted with the six lab-made water samples.

Figure 1 – Effects of suspended and dissolved particles on *E. coli* inactivation through UV light exposure



Samples falling below the detection limit were obtained in 58% of the tested conditions (14 out of 24), particularly in samples with turbidity and total organic carbon of (< 1 NTU and 1.0 mg/L), (< 1 NTU and 7.5 mg/L), (< 1 NTU and 15 mg/L), and (20 NTU and 1 mg/L).

As expected, water with optimal UV conditions inflict greater bacterial damage and water characterized by extreme turbidity and TOC levels result in less bacterial damage ($p = 0.0009$, Kruskal-Wallis test). Baldasso et al (2021) also observed this effect of both suspended and dissolved particles in experiments conducted with less contamination (up to 5 NTU and 3.5 mg/L), demonstrating that the linear effect continues to occur even in extreme situations. However, interestingly, water with high turbidity (20 NTU and 1 mg/L) or high TOC (< 1 NTU and 15 mg/L) also does not appear to induce harmful effects, showing that there was no isolated effect of these particles on bacterial inactivation (DL = 67 UFC/100mL).

While employing UV in extreme conditions, as found in this study, it is not the most recommended approach, such challenging conditions are still real and can be experienced in vulnerable and small settings with little or no access to other treatment technologies. In the face of challenging conditions, UV technology only demonstrated bacterial inactivation of 1.35 (± 0.20) log. This underscores that implementing the UV technology, as a stand-alone solution, should be pondered based on water quality and questioned when this solution is implemented in communities with frequent changes in supply sources.

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