

# Treatability of South African surface waters by enhanced coagulation

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## ABSTRACT

The majority of South African inland surface water sources are compromised due to a long-standing national policy of mandatory return flows. With renewed emphasis on the removal of organic carbon in the latest SANS 241 water quality standard, many South African water treatment managers may need to consider adoption of enhanced coagulation (EC) in the near future to achieve both turbidity and NOM removal. From the study of 4 South African inland waters, this paper demonstrates that UV<sub>254</sub> absorbance provides a more accessible, reliable and rapid way of monitoring NOM at treatment plant level. This report also provides a detailed procedure for determining the dosages for EC in terms of UV<sub>254</sub> absorbance at jar test level. Using ferric chloride as coagulant, a correlation was established to estimate the coagulant dosage for any desired level of UV<sub>254</sub> absorbance removal. This correlation enables a preliminary assessment of EC as a means of planned NOM removal. Should EC promise to be a candidate process for NOM removal, it should be verified at jar test level using the proposed procedure.

**Keywords:** Natural organic matter, enhanced coagulation, ferric chloride, jar test, UV absorbance, modelling

## INTRODUCTION

In conventional water treatment practice, coagulation is generally used for multiple objectives that include maximising particle and turbidity removal, maximising total organic carbon (TOC) and disinfection by-product precursor (DBP) removal, minimising residual coagulant, minimising sludge production and minimising operating costs (Edzwald and Tobiasson, 1999). Enhanced coagulation (EC), on the other hand, requires higher coagulant dosage to achieve the single objective of better removal of natural organic matter (NOM) (Edzwald and Tobiasson, 1999; USEPA, 1999; Xiao et al., 2013). With renewed emphasis on the removal of organic carbon (exemplified by the inclusion of dissolved organic carbon (DOC) in the latest water quality standard SANS 241), many South African water treatment managers may need to consider the adoption of EC in the near future to achieve both turbidity and NOM removal, a process deemed to be one of the best available technologies for the latter (Uyak and Toroz, 2007). Enhanced coagulation is a practical option only when appropriate coagulants are used. Organic polymeric coagulants, despite their advantages of being less pH-dependent, producing less sludge and lower costs, are not used for EC because they are not good at removing NOM; they may even increase the TOC level in water (USEPA, 1999; Nozaic et al., 2001; Bolto and Gregory, 2007). Inorganic coagulants such as aluminium sulphate (Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>·18H<sub>2</sub>O) and ferric chloride (FeCl<sub>3</sub>·6H<sub>2</sub>O) are much better at NOM removal. Although both these coagulants are effective at NOM removal, there is emerging consensus that ferric chloride is marginally more effective than aluminium sulphate (Crozes et al., 1995; Bell-Ajy et al., 2000; Uyak and Toroz, 2007; Wang et al., 2011). The decrease in NOM by EC is mostly determined by measuring (TOC), but other measures of NOM such as trihalomethane formation potential (THMFP) and

ultraviolet absorbance at 254nm (UV<sub>254</sub>) have also been used (USEPA, 1999; Bell-Ajy et al., 2000; Freese et al., 2007). Uyak and Toroz (2007), for example, found that conventional coagulation removes about 15% of TOC (range 9% – 20%) while EC removes up to 71% TOC with ferric chloride and 67% with alum. In terms of the THMFP, García (2011) found that the water after EC never exceeded the guidelines, contrary to water treated by conventional coagulation only.

Other than the choice of coagulant, the success of EC depends on a number of factors. The first is the coagulant dosage, with more coagulant providing more metal ions for complexation of organic compounds, which increases NOM removal (Edzwald, 2013). Uyak and Toroz (2007) found that, for 3 different waters, increasing the ferric chloride dosage from 40 mg·ℓ<sup>-1</sup> to 80 mg·ℓ<sup>-1</sup> resulted in an increase in DOC removal from about 18% (range 16% – 20%) to 36% (range 28% – 41%). The second is pH, with lower pH making NOM compounds more hydrophobic and adsorbable, thus increasing their removal (Crozes et al., 1995; Bell-Ajy et al., 2000; USEPA, 2001; Uyak and Toroz, 2007). At a constant dosage of 80 mg·ℓ<sup>-1</sup> of ferric chloride, Uyak and Toroz (2007) found that the DOC removal increased from 36% (range 28% – 41%) to 60% (range 43% – 71%) after adjusting the pH to 5.5. Crozes et al. (1995) found that decreasing the pH to 6 increased NOM removal by as much as 65% – with the corresponding UV<sub>254</sub> absorbance removal improving from 49% (range 32% – 61%) to 71% (range 47% – 84%). Other authors confirmed that the optimal pH of EC is between 5.0 and 6.5 (for example, Harrington et al., 1992; Bell-Ajy et al., 2000). The addition of more acidic coagulant and the lowering of pH are interrelated – more coagulant depresses the pH to a lower level. The alkalinity of the water, therefore, also comes into play. With high alkalinity, the addition of more coagulant only has a small effect on pH, which might inhibit NOM removal somewhat. In addition to coagulant dosage and pH, NOM removal is also a function of its initial concentration and the nature and composition of NOM in terms of charge, molecular weight and hydrophobicity (USEPA, 2001; Eikebrokk et al., 2006; Edzwald, 2013). The specific ultraviolet absorbance (SUVA) has proven to be a valuable and rapid

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