# Hybrid Coagulation-ultrafiltration Process for Drinking Water Treatment

Ultrafiltration allows for compact, effective and low-cost water treatment plants to be installed in developing countries. However, membrane fouling remains an overriding obstacle. This article highlights the performance of a pilot coagulation-ultrafiltration study in Kampala. Samuel Gyebi Arhin[1,2], Noble Banadda[2], Allan Komakech[2], Sara Marks[1]

## Introduction

Worldwide, the numerous challenges associated with inadequate access to safe drinking water are well-known: 1.8 billion people use water contaminated with faecal pathogens [1] and 3 900 children die daily from diseases transmitted through unsafe water [2]. In Uganda, although piped water coverage has increased over the years, treatment of piped supplies is not guaranteed, and only 5 % of the population have access to a tap on their premises [3]. Residents without access to piped water use untreated sources, which are prone to contamination with enteric pathogens (Photo 1). As a result, 29 300 children die annually in Uganda from diarrhoeal diseases [4].

Ultrafiltration (UF) is a promising technology for decentralised water treatment in developing countries; yet, a major hindrance to long-term operation of UF is membrane fouling. This leads to permeate flux losses, increased membrane cleaning routines and high operating costs. Several researchers have studied coagulation pre-treatment of feed water to overcome fouling, but no study has been done on surface water sources characterised by concentrated organic and inorganic matter content in Uganda. This study examined the performance of a UF system for drinking water treatment, using polyaluminium chloride (PACl) coagulant for fouling control.

## Methods

Preliminary batch experiments, aimed at obtaining the optimum conditions for coagulation pre-treatment, were done on raw water samples taken from Lake Victoria at the Ggaba II Water Treatment Plant inlet. PACl doses ranging from 10 – 20 mg / L were tested under flocculation retention time (FRT) of 5 – 20 mins in a bench-scale in line coagulation / ultrafiltration process. The optimum PACl dose and FRT were selected based on conditions resulting in higher removal of turbidity and $UV_{254}$, while retaining a high hydraulic permeability.

Two sets of pilot-scale UF experiments were performed. In the first, the optimum PACl dose and FRT were used to pre-treat the feed water prior to the filtration process (system A). In the second, the feed water was filtered without PACl (system B). The efficiency of the treatment process was assessed based on the removal of turbidity, colour, $UV_{254}$ absorbance, dissolved organic carbon (DOC), pathogen count (*Escherichia coli* and total coliforms), and fouling rate of the UF membranes.

## Results

The optimum PACl dose and FRT were 20 mg / L and 14 min respectively. It was observed that PACl dose(s) and FRT(s) that formed very small flocs had lower hydraulic permeability. The study further revealed that with smaller flocs, tiny particles were able to permeate through the UF membranes leading to lower permeate quality.

In the pilot-study, less fouling was observed in system A compared to system B because coagulation pre-treatment was effective in removing natural organic matter from the feed water. As shown in Table 1, 77.8 % removal of $UV_{254}$ absorbing organics was attained in system A whereas in system B, only 28.6 % of $UV_{254}$ organics were removed.


Photo 1: People fetching water from an unprotected spring in a slum in Kampala.

Aside from $UV_{254}$, system A also contributed to high removal of DOC.

## Conclusion

The relatively high removal of turbidity, colour, $UV_{254}$, DOC, *E. coli* and total coliforms from the permeate of system A and the ability of the system to control membrane fouling indicate that integrating PACl coagulation with the UF process is potentially an effective and sustainable technique for producing safe drinking water in Uganda. Further long-term research, however, is needed to provide insight into the overall feasibility of implementing this hybrid system in Uganda.

| Parameter | System A (%) | System B (%) |
|---|---|---|
| Turbidity | 99.2 ± 0.2 | 98.1 ± 1.0 |
| Colour | 100.0 ± 0.0 | 97.5 ± 0.8 |
| $UV_{254}$ | 77.8 ± 8.3 | 28.6 ± 6.9 |
| DOC | 35.3 ± 7.2 | 11.8 ± 3.3 |
| *E. coli* [a] | > 3.3 ± 0.1 | > 3.3 ± 0.1 |
| Total coliforms [a] | > 3.8 ± 0.1 | > 3.6 ± 0.1 |

Table 1: Percentage removal of water quality parameters in systems A and B.
[a] $Log_{10}$ reduction.


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