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Pilot field comparison of traditional alum flocculation, chlorination, and combined flocculation-chlorination point-of-use water treatment on drinking water quality in Western Kenya

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Abstract

Background. The World Health Organization estimates that 1.1 billion persons do not have access to improved water supplies. Many of these persons rely on highly turbid surface waters for drinking. Currently available methods for disinfection of unimproved source water include the addition of dilute sodium hypochlorite, and solar water treatment. However, organic matter in highly turbid water may render sodium hypochlorite less effective and interfere with ultraviolet light. We evaluated a combined flocculation and chlorination product designed to render turbid source water clean and safer for drinking, and compared it with traditional and existing point-of-use water treatments in a pilot study. Waters in Western Kenya were selected because of their high turbidity and importance as drinking water sources. Furthermore, the Western Kenya site is well suited for a subsequent intervention study because of the limited range of improved water sources.

Methods. The pilot study was conducted in Asembo and Gem districts, Nyanza Province, Western Kenya. Asembo and Gem districts are located on the north of Winam Gulf, Lake Victoria. Thirty drinking water sources were sought to represent a range of water source turbidities. Samples were collected from 15 through 25 October 2002. Available water sources included Lake Victoria, rivers, streams, excavated ponds and earth pans, springs, and boreholes. At each water source, six locally purchased plastic buckets were filled with 10 liters of untreated source water. Water from each source was either untreated, or treated with a high-dose and low-dose formulation of combined flocculation and chlorination product (hereafter referred to as Pûr® A and Pûr® B) (Procter & Gamble Company, Cincinnati, OH); 5mL of locally available 1.0% sodium hypochlorite solution for water disinfection (Klorin, Jet Chemical Industries Ltd, Nairobi, Kenya, batch 01290902); 100 g alum block mixed gently for 60 seconds; or 100 g alum block mixed gently for 60 seconds and 5mL of locally available 1.0% sodium hypochlorite solution for water disinfection (Klorin, Jet Chemical Industries Ltd, Nairobi, Kenya, batch 01290902). Large stainless steel spoons were used for mixing all buckets. In each, case water was poured into a second bucket after a 30-minute treatment period. Turbidity was determined in the field using a Hach 2100P Portable Turbidimeter (Hach Company, Loveland, CO). Free residual and total chlorine levels were measured in the field using a Hach Portable DR/890 Colorimeter (PermaChem, Hach Company, Loveland, CO). Water samples collected using sterile technique in 150 mL sterile plastic containers with thiosulfate (IDEXX Laboratories Incorporated, Westbrook, ME) were transported on ice to the CDC/KEMRI water bacteriology laboratory for processing within 8 hours of collection with the Colilert Quantitray 2000 system (IDEXX Laboratories Incorporated, Westbrook, ME) to determine total coliform and *Escherichia coli* concentrations. All water bacteriology samples were tested undiluted and at 1:10, 1:100, and 1:1,000 dilutions to provide broad range of possible values.

Results. Mean (range) values for untreated water were *E. coli* concentration 3,937.6 (0.0-43,900.0) colony forming units per 100 mL (CFU/100mL), turbidity 331.9 (0.3-1,724.0) nephelometric turbidity units (NTU), and pH 7.19 (5.66-8.72). After treatment, mean (range) *E. coli* concentrations were 0.0 (0.0-1.0) for Pûr A; 4.8 (0.0-124.6) for Pûr B; 0.5 (0.0-10.9) for Klorin; 159.4 (0.0-2,490) for alum; and 0.0 (0.0-1.0) CFU/100mL for alum and Klorin. After treatment, mean (range) pH was 6.64 (4.56-7.46) for Pûr A; 6.67 (5.61-7.32) for Pûr B; 7.41 (5.83-8.85) for Klorin; 4.04 (3.71-4.93) for alum; and 4.14 (3.71-6.83) NTU for alum and Klorin. After treatment, mean (range) turbidity was 24.3 (0.6-341.0) for Pûr A; 33.9 (0.5-504.0) for Pûr B; 273.4 (0.5-1,570.0) for Klorin; 30.7 (1.5-357.0) for alum; and 25.8 (1.4-273.0) NTU for alum and Klorin. When stratified by turbidity (high >100 NTU, n=10; medium 10-100 NTU, n=10; low <10 NTU, n=10), the number (%) of high turbidity water sources meeting World Health Organization guideline of <1 *Escherichia coli* cfu/100mL with Pûr A was 10 (100%), Pûr B was 6 (60%), Klorin was 6 (60%), alum was 0 (0%), and alum with Klorin was 9 (90%). Results from treatment of medium turbidity water sources were Pûr A 9 (90%), Pûr B 10 (100%), Klorin 10 (100%), alum 3 (30%), and alum with Klorin 10 (100%). The number (%) of low turbidity water sources with < *E. coli* cfu/100mL for Pûr A was 10 (100%), Pûr B was 8 (80%), Klorin was 9 (90%), alum was 6 (60%), and alum with Klorin was 10 (100%).

Conclusions. For water sources in Western Kenya, high dose formulation of combined flocculation and chlorination product, and traditional alum flocculation plus chlorine, effectively mitigate turbidity and render water potable. Alum flocculation alone mitigates turbidity and lowers *E. coli* concentration, but does not reliably render water potable. In addition, traditional alum-based treatments substantially reduce pH that may lead to lower acceptability and use in field studies. Sodium hypochlorite alone does not substantially reduce turbidity and more often renders low and medium turbidity water than highly turbid water potable. Overall, combined flocculation and chlorination shows promise as an acceptable point-of-use treatment for rendering highly turbid source water clear and safe for drinking. Comparative field studies of this product are planned with infant diarrhea incidence and acceptability as the primary outcomes

Background

- 1.1 billion persons lack access to improved water
- Diarrheal disease kills >2 million persons annually
- 'Point-of-use' approaches to improving drinking water
  - Require little infrastructure
  - Are suited to rural settings
  - Empower individuals to make water safe for their families
- 'Point-of-use' disinfectants (e.g., sodium hypochlorite) are likely to perform poorly for highly turbid source water

Woman collects drinking water from a turbid pond Asembo, Western Kenya

Aim

To compare the effect on water quality indicators of traditional alum flocculation, chlorination, and combined flocculation-chlorination (Pûr A and Pûr B) point-of-use water treatment on drinking water quality in Western Kenya over a range of source water turbidities

Materials & Methods

- 30 water sources

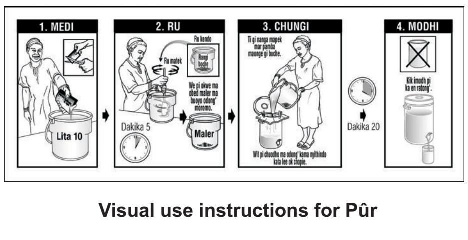
10 low turbidity (<10 NTU)
10 medium turbidity (10-100 NTU)
10 high turbidity (>100 NTU)

- Six treatments
  - Combined flocculation-chlorination product yielding ~3.5 mg/L free chlorine (Pûr A)
  - Combined flocculation-chlorination product yielding ~2.0 mg/L free chlorine (Pûr B)
  - Locally produced water disinfectant yielding ~5.0 mg/L free chlorine (Klorin)
  - Locally available alum flocculant ~100 g for 60 seconds
  - Alum + Klorin
  - Untreated control
- Outcomes
  - Turbidity measured by Hach 2100P Portable Turbidimeter (Hach Company, Loveland, CO)
  - Free and total chlorine concentration measured by Hach Portable DR/890 Colorimeter (Hach Company, Loveland, CO)
  - pH measured by IQ 150 Handheld pH Meter (IQ Scientific Instruments Inc, San Diego, CA)
  - *E. coli* concentration measured by Colilert Quantitray 2000 system (IDEXX Laboratories Incorporated, Westbrook, ME)

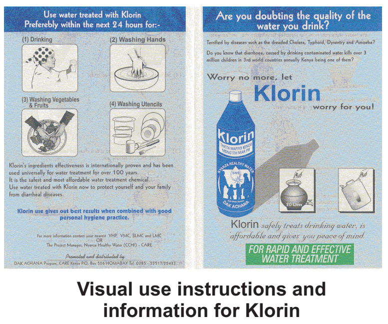
Point-of-use water treatments evaluated

Turbid water after treatment with Pûr

Scientist treating lake water, Asembo Pier, Lake Victoria



Visual use instructions for Pûr

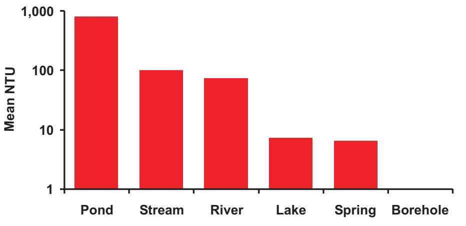


Visual use instructions and information for Klorin

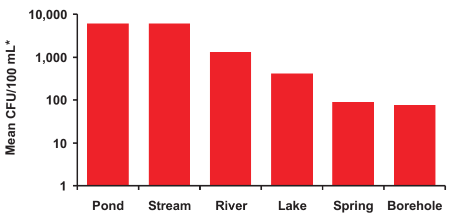
Results

Before treatment, turbidity and *Escherichia coli* concentrations were highest in pond water, followed by stream, river, lake, spring, and borehole water

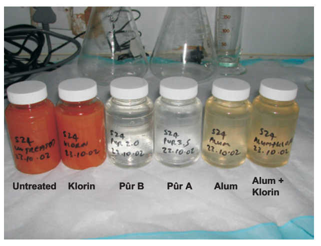
Turbidity by untreated source water type, Asembo and Gem, 2002



***E. coli* concentration by untreated source water type, Asembo and Gem 2002**

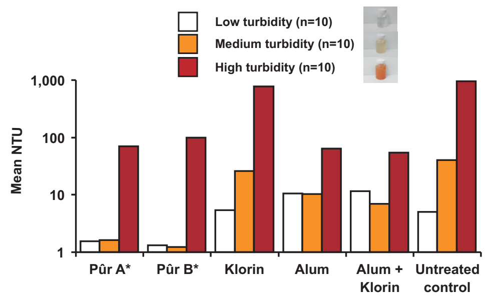


*WHO guideline <1 *E. coli* CFU/100 mL



Visual impact of water treatments on highly turbid source water

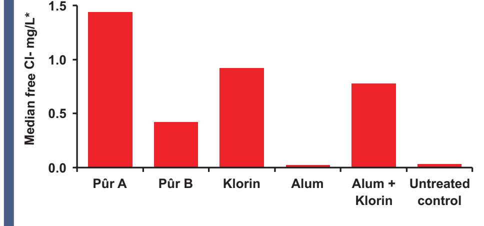
Effect of water treatments on turbidity by turbidity, Asembo and Gem, 2002



*Includes two water sources where one sachet of Pûr failed to form floc

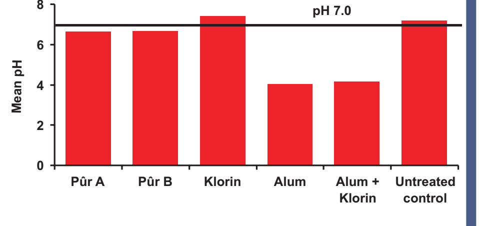
Although Klorin delivers a higher chlorine dose compared to Pûr A, free chlorine levels measured 30 minutes after water treatment were higher for Pûr A compared to Klorin alone

Effect of water treatments on free chlorine, Asembo and Gem, 2002



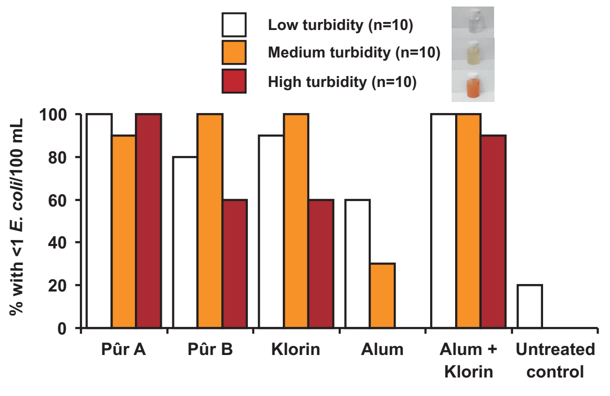
*Measured 30 minutes after treatment

Effect of water treatments on pH Asembo and Gem, 2002



Alum-based treatments lower pH substantially

Proportion waters with <1 *E. coli*/100 mL after treatment, Asembo and Gem, 2002



- Only treatments that combined flocculation and chlorination performed well in high-turbidity waters
- Treatments that included disinfectant performed well in low- and medium-turbidity waters

Conclusions

- Pûr A
  - Mitigates turbidity
  - Achieves <1 *E. coli*/100 mL in even high-turbidity water
  - Maintains neutral pH
- Pûr B
  - Mitigates turbidity
  - Achieves <1 *E. coli*/100 mL in low- and medium-turbidity water
  - Maintains neutral pH
- Alum alone
  - Mitigates turbidity
  - Lowers *E. coli* concentration, but not to <1/100 mL
  - Lowers pH
- Klorin alone
  - No impact on turbidity
  - Achieves <1 *E. coli*/100 mL in low- and medium-turbidity water
  - Does not render high-turbidity water potable
- Alum + Klorin
  - Mitigates turbidity
  - Achieves <1 *E. coli*/100 mL in high-turbidity water
  - Lowers pH

Combined flocculation and chlorination may perform better than chlorination alone in the households of people living with contaminated, highly turbid water

Effect on pH of alum may lower taste acceptability of alum-based treatments

Ongoing health outcome study

- Launched in Asembo and Gem, Western Kenya, 2003
- 600 homes (>6,500 persons) randomly assigned to use
  - Pûr A , or
  - Klorin, or
  - Traditional practices
- 20 week duration
- Main outcomes
  - Diarrhea prevalence (especially of children <2 years)
  - Intervention acceptability
  - Water quality

CDC
Centers for Disease Control and Prevention