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Microbial quality of drinking water in rural Kenyan and Ethiopian households – impacts of defluoridation filters

Rachel Künzle[1,2], Nina Küng[1,2], and Richard Johnston[1*]
[1]EAWAG [2]ETH Zurich *Corresponding Author: richard.johnston@eawag.ch

Background

Geogenic fluoride contamination of drinking water affects the health of 100s of millions worldwide, The Great Rift Valley in Eastern Africa is particularly affected.

In Ethiopia and Kenya, bone char with calcium phosphate pellets (the "Nakuru process") is used to remove fluoride from drinking water in household and community defluoridation filters [1, 2], but little is known about filter impacts on microbial water quality.

Methods

Compact Dry plates (Nissui) were used to measure microbial water quality among Ethiopian and Kenyan households using defluoridation filters. *E. coli* (EC), Total Coliforms (TC), and Enterococci (ETC) were measured. 1 mL samples were added directly to the plates, while larger volumes (10-100 mL) were filtered through cellulose membranes (0.45 µm), which were then incubated on plates at 37 °C unless otherwise noted.

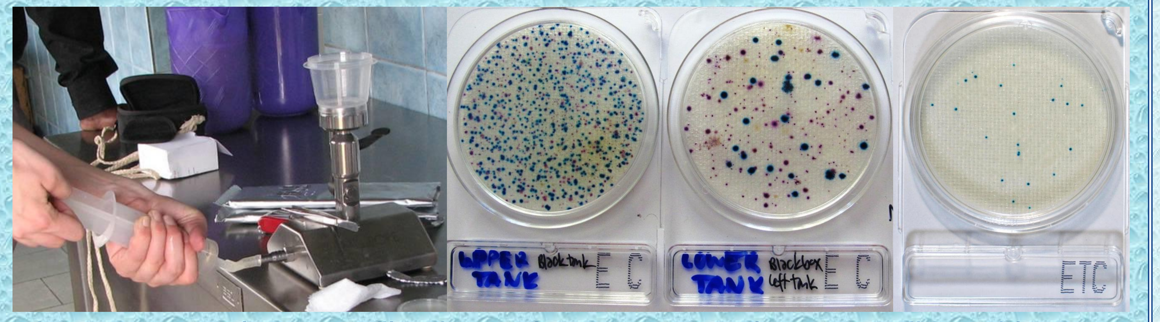

Figure 1: Manual vacuum filtration and Compact Dry plates. *E. coli* form blue colonies and other coliforms develop red colonies on EC plates (left and center), while Enterococci form blue-green colonies on ETC plates (right).

Laboratory validation studies showed that *E. coli* colonies on the plates matched expectations based on dilutions from pure stocks measured with flow cytometry (Figure 2). Compact Dry plates showed good reproducibility for all three bacterial indicators, with counts generally within 0.2 log units of mean values.

Incubation of replicates under variable temperatures showed that Total Coliform counts were highly temperature-dependent, but *E. coli* counts after 24 hours were consistent between 30 and 40 °C. At 20, 25, and 42 °C, counts reached the expected level after 48 hours, but at 10 and 45 °C, growth was inhibited.

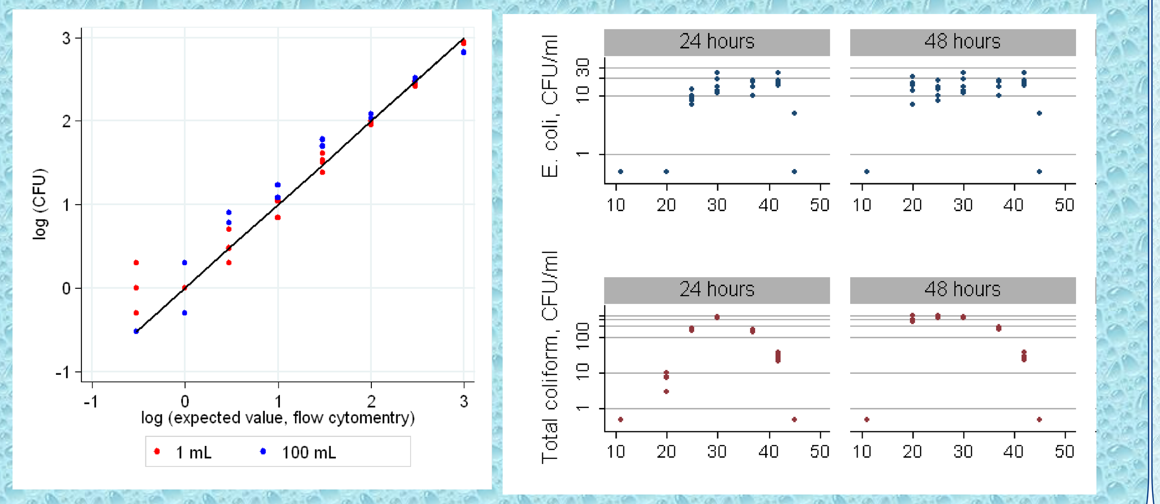

Figure 2: (a) *E. coli* compared to flow cytometry [2] and (b) effect of different incubation temperatures on *E. coli* and Total Coliform growth. [1]

Kenya

The Catholic Diocese of Nakuru (CDN) has distributed thousands of household filters, and built more than 100 community filters. Some of the household filters use ceramic candle filters (Stefani) to remove microbial contamination.

Figure 3: Household, standard community, and remote community defluoridation filters in Kenya.

Microbial water quality was monitored in ten household filters and nineteen community filters over three months.

Standard community filters, using borehole sources, showed similar microbial counts before and after treatment. In remote areas where polluted surface water was used, filters reduced bacteria levels by about 90%. However, water quality in general deteriorated between the community filter and the point of consumption (samples collected from a household cup).

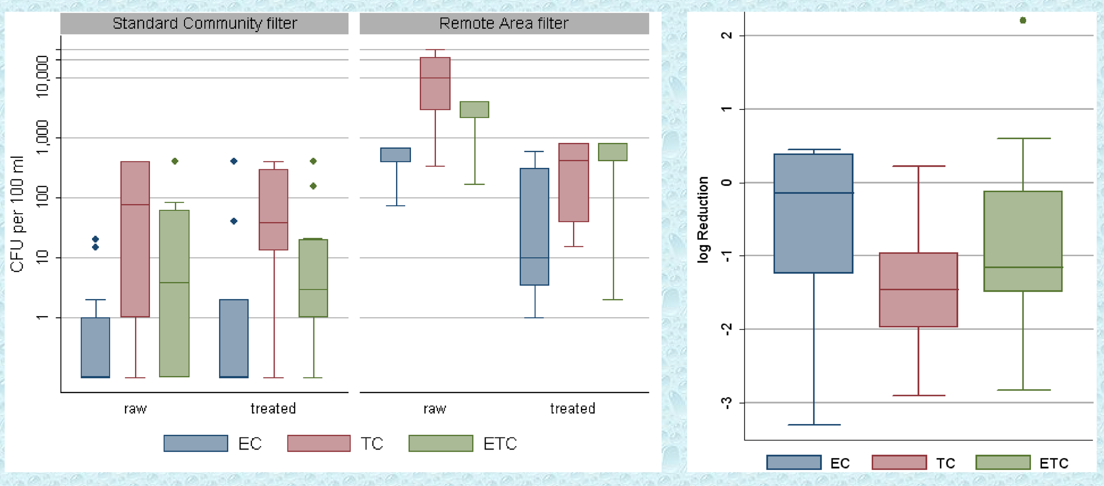

Figure 4: (a) Raw and treated water quality, conventional and remote filters (n=15 and n=4 respectively). (b) Water quality deterioration between community filter tap and point of consumption (n=20). Source: [1]

Water quality at the point of consumption was best for users of household filters, and worst for users of kiosk water. Ceramic candle filters did not significantly reduce bacteria counts in either household filters or laboratory experiments. Attempts to improve water quality by inserting copper wire coils into household filters were ineffective.

Source	n	E. Coli	Total Coliforms	Enterococci
Kiosk water	3	31.1	1340	380
Tap water	46	2.1	60	40
Community filters	17	2.5	1050	60
Household filters	27	1.8	15	15

Table 1: Household water quality at point of consumption. Bacterial counts are geometric means, CFU/100 mL [1].

Ethiopia

In collaboration with the Oromo Self-Help Organization (OSHO) and Swiss Interchurch Aid (HEKS), several hundred household filters and one community filter (Shibere) have been introduced to communities in the Rift Valley, where fluoride levels range from 3-18 mg/L.

Figure 5: Household filter distribution and training. Household filters consist of two buckets: the top filled with sand for particle removal, and the bottom filled with a mixture of bone char and calcium phosphate pellets.

46 household filters were tested from four villages over several months. Feed water was sampled from the upper bucket, and treated water from the filter tap. In four households of each village, water was also tested at the source, in between the two filter chambers, and at the point of consumption (from a household glass). Water quality deteriorated, most notably between the source and the filter inlet, due to unhygienic storage containers. Household filters marginally improved water quality for *E. coli* ($p<0.001$), but not for total coliforms or Enterococci.

Figure 6: (a) Water quality from source to tap [2]. (b) A typical water storage container.

Source	n	E. Coli	Total Coliforms	Enterococci
Community filter[1] (Shibere source)	34	1040	2130	1310
Household filter[2] (Shibere source)	38	440	2810	740
Household filter[2] (Lake source)	21	950	12800	5220
Household filter[2] (Groundwater source)	66	630	2240	950

Table 2: Household water quality at point of consumption[1] or filter tap[2]. Bacterial counts are geometric means, CFU/100 mL [2].

Conclusions

Compact Dry plates are robust and reproducible, and can be incubated at ambient temperatures (20-42 °C), though below 30 °C incubation should be made for 48 hours. These plates, along with simple filtration instruments, allow easy measurement of microbial water quality under challenging conditions. One positive feature of the plates is that they can be stored at room temperature for up to two years before use, in contrast with many other pre-formulated coliform testing materials.

Defluoridation filters on average have a modest positive effect on microbial quality, especially when source water is of poor quality. Neither the sand pre-filter used in Ethiopia nor the ceramic candle filters used in Kenya significantly reduced bacteria counts. Simple addition of copper coils to treated water reservoirs did not result in significant water quality improvements.

Moderate faecal contamination of drinking water is common in the Kenyan households surveyed, but gross contamination is commonplace in the Ethiopian households visited. In both countries, water quality deteriorates significantly between the point of collection and household storage containers. Unclean drinking vessels further add to pathogen intake.

Widespread fluoride exposure is causing a significant public health threat in East African countries. However, the disease burden posed by faecal contamination is likely even larger. This does not mean that fluoride mitigation efforts should be shelved, but rather that they should be implemented as part of integrated efforts to improve sanitation and hygiene as well as water quality.

References

[1] Künzle, R. (2011). "Household drinking-water quality in the Kenyan Rift Valley." MS Thesis, ETH Zürich.

[2] Küng, N. (2011). "Household drinking water in rural areas - impact of defluoridation filters on microbial drinking water quality in the Ethiopian Rift Valley." MS Thesis, ETH Zürich.