CDN'S DEFLUORIDATION EXPERIENCES ON A COMMUNITY SCALE

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The following summary is based on the defluoridation experiences of the Catholic Diocese of Nakuru, Water Quality (CDN WQ).
This document has been prepared jointly by CDN WQ and the Swiss Federal Institute of Aquatic Science (Eawag) and aims at giving a summary of the current development stage. Further research and development of the described techniques and processes are still ongoing.

1 Introduction

CDN WQ has implemented different types of community filters in the past. Some community-based filters are connected to the water supply system, others operate discontinuously. The scale of implementation ranges from 650 L tanks to large water work plants with a capacity of treating 200 m^3 of water per day. CDN WQ distinguishes three different community-based filters:

- Institutional filters: Institutional filters are designed for larger kitchens and/or institutions where the filters are connected to the water supply systems.
- Community filters: These filters are designed to supply 1'000 to 5'000 people with water for drinking and cooking. They are suitable for places, where the users collect their water at a central water point. There are two different designs of community filters. One is connected to the water supply system and one is specially designed for remote areas without a water supply system. The main activities on community-based defluoridation are currently on the training and the implementation of such remote community filters.
- Filters for water works: The filters for water works are similar to the institutional or community filters but consist of two or more of the larger units that are coupled in series. The working principles are the same but the filters are modified for a higher loading.

So far around 25 institutional filters, 45 community filters and 2 filters for water works have been constructed and taken into operation.

2 Institutional filters

The institutional filters are recommended where the water consumption for drinking and cooking is between 50 to 500 L per day.
The inflow to the institutional filter is connected to the water supply system and controlled by a ball valve. A flow meter shows the exact amount of water that has passed through the filter. The filter consists of a standard PVC tank (650 L), containing ~ 450 L of bone char of different sizes: Middle size bone char (0.63 - 2 mm) at the top (330 L) and coarse bone char (2 - 4 mm) at the bottom (120 L). Ballast at the bottom of the filter enables the drainage of the treated water, which is then collected in PVC pipes. These pipes contain cuttings, turned towards the bottom of the filter, where the water can enter. A nylon mosquito prevents the wash-out of the bone char into the drainage layer and hence prevents clogging of the system (see Figure 2-1). Due to the raised outlet, the filter medium is always saturated with water and hence never dries up. Depending on the wishes of the customer, the filter outlet can either be connected to a supply system, which for instance serves a kitchen with defluoridated water or it is connected to a tap where the people can withdraw defluoridated water.

The institutional filter costs KES 39'000 (550 USD) excluding the installations to the water supply system and/or a desired connection to the household.

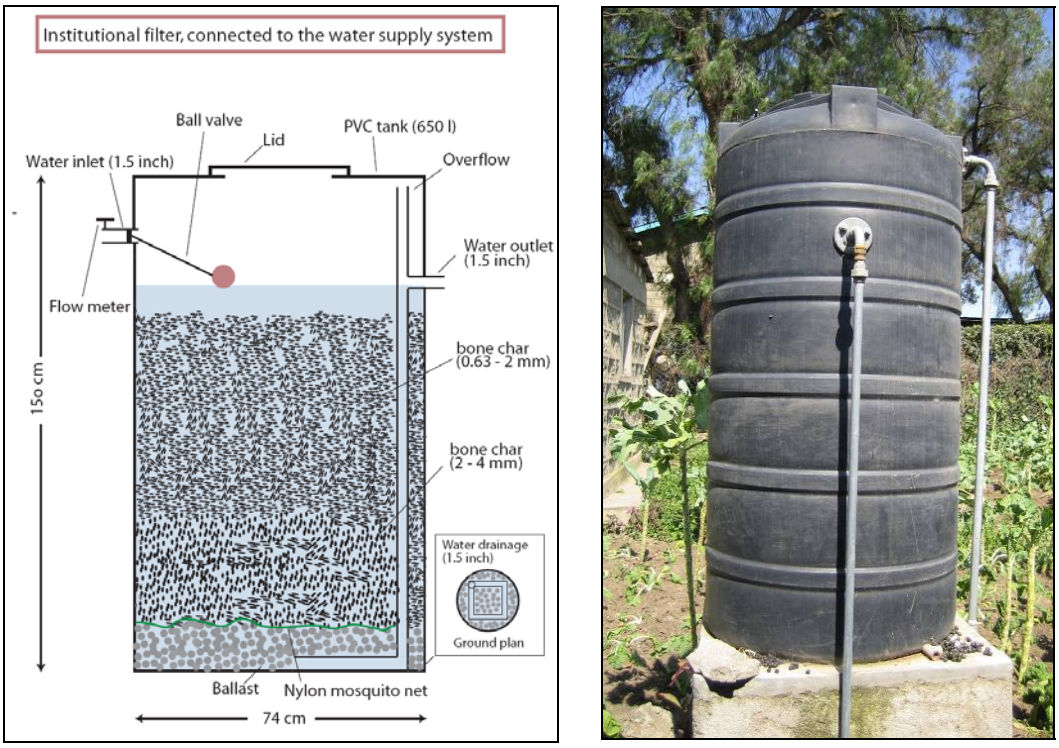


Figure 2-1: Sketch and picture of an institutional filter.

No daily maintenance is required as the operation does not differ from using a standard water storage tank. After a certain time, the bone char is saturated and has to be regenerated (see "Draft on CDN's experiences in producing bone char"). Based on the fluoride concentration in the raw water, estimations on the amount of treatable water can be given. The flow meter then indicates the time when the filter material has to be regenerated.

3 Community filters

Community filters are designed to supply 1'000 to 5'000 people with water for drinking and cooking. They are suitable for communities where the users collect their water at a central water point.
A community plant is basically a 4 to 12 m^3 standard PVC tank that is filled with bone char of different sizes. A concrete walling protects the PVC tank from damage, whereas the PVC tank prevents the filter from leaking. All the community filters are equipped with screen and connections for regenerating the filter medium. Draw point for treated water is integrated in the construction.
CDN WQ installs two different types of community filters:

- The inlet of one type of community filters is connected to the water supply system. In most cases the users collect the treated water at a central water point, either directly from the filter or at a sales point, called water kiosk. Some of the community filters are connected to a supply system for treated water that provides defluoridated water to the different households.
- The other type of community filter is called remote filter due to its implementation in areas without a water supply system. Raw water source is either surface water, which the users bring and pour into the filter, or groundwater that is pumped with hand pumps and treated in the defluoridation filter. Current implementation of community filters mainly focuses on installation of remote filters.

3.1 Community filters connected to the water supply system

The community filters are implemented in 3 different sizes as summarized in Table 3-1. The appropriate size depends on the water consumption and the fluoride concentration in the raw water.
The running costs of maintaining the filter are normally less than 50 KES (0.7 USD) per 1'000 L of treated water.

Table 3-1: Community filters that are connected to the water supply system.

Filter size	Amount of bone char	Filter capacity	Cost
3 - 5 m^3	2'500 L	~ 8 m^3/day	280'000 KES (3'950 USD)
6 - 8 m^3	5'000 L	~ 18 m^3/day	450'000 KES (6'250 USD)
12 - 15 m^3	10'000 L	~ 28 m^3/day	750'000 KES (10'420 USD)

The PVC tank is filled with 3 different sizes of bone char: Fine bone char (0.4 - 0.63 mm) in the top layer followed by middle (0.63 - 2 mm) and coarse bone char (2 - 4 mm) at the bottom of the filter bed. There is a layer of ballast for draining the defluoridated water at the bottom of the tank. The community filters are run down-flow with the advantage of facilitating the control of the inflow by a ball valve. One of the disadvantages is a bigger risk of clogging. The treated water passes through a pipe to the outlet. The outlet can either be:

- Fixed to a tap where the treated water can be withdrawn
- Connected to a water supply system that provides treated water
- Connected to a water kiosk that sells the treated water to the customers. There are currently 4 water kiosks in operation that sell fluoride-low drinking water. Two are placed in Naivasha, one in Njoro and one at the manufacturing site of CDN WQ (picture see Appendix). The prizes for 20 L of water vary between 2 to 5 KES (0.03 - 0.07 USD). The water kiosk is not only a sales point but also creates awareness on the detrimental health effects of excess fluoride and informs on the defluoridation process

in general. A water board, set up by the community runs the water kiosks. The construction of a water kiosk costs ~ 150'000 KES (2'120 USD).

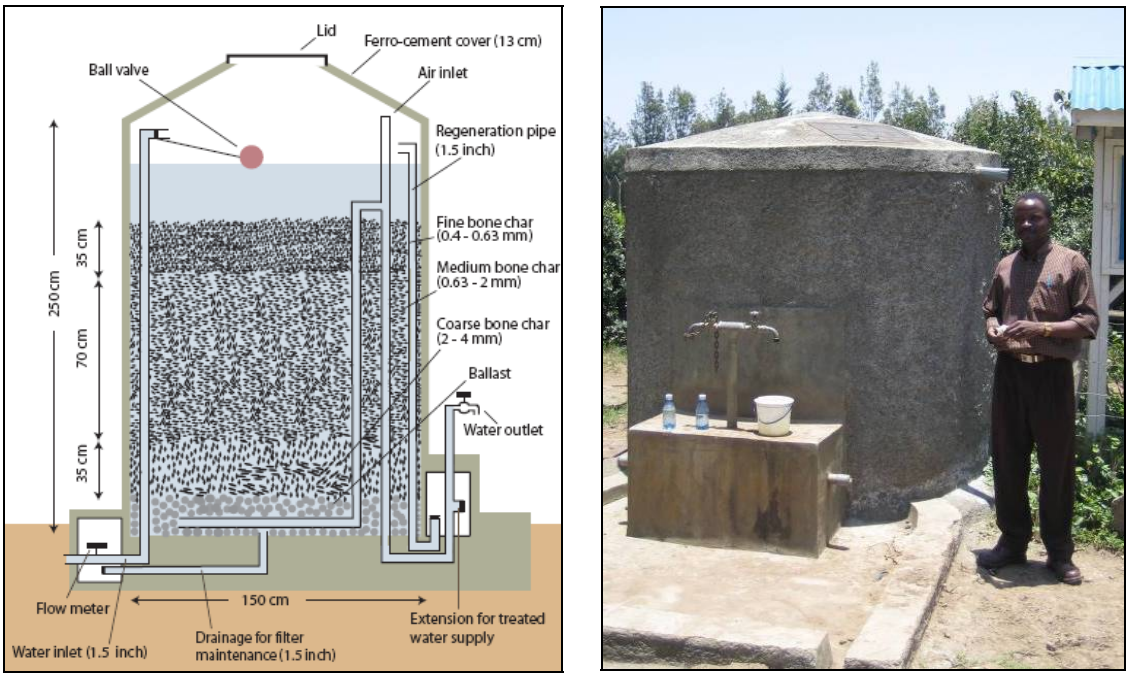


Figure 3-1: Sketch and picture of a community filter where the inlet is connected to a water supply system.

No daily maintenance is required. Regeneration of the saturated bone char is explained in "CDN's experiences in producing bone char".

3.2 Remote community filters

CDN WQ has implemented most of the remote filters in Baringo district in areas without communal water supply system. A baseline study in 2005 on the severity of dental fluorosis concluded that between 52% and 93% of the pupils of 11 different schools were affected by dental fluorosis. CDN WQ therefore currently focuses on implementing remote community filters in that specific area.
The inhabitants source their drinking water either from Lake Baringo or from groundwater that is pumped with a hand pump. The lake water is highly contaminated with fluoride, microorganisms and has elevated turbidity.
CDN WQ developed a special filter design that:

- enables the treatment of such highly turbid water without clogging
- reduces not only fluoride but also microbiological contaminants and problems related to elevated turbidity
- can be used discontinuously. Whenever raw water is added to the filter, treated water can be withdrawn instantaneously.

Table 3-2 shows the removal efficiency of two such remote community filters.

Table 3-2: Efficiency of removing fluoride, microorganisms and turbidity for 2 different remote community filters. The analysis were carried out in February 2006 at Kampi ya Samaki and in September 2006 at Kokwa.

	Fluoride removal (mg/L)	**Fecal coliform removal** (#/100 mL)	**Turbidity removal** (NTU)
Kampi ya Samaki	99% (8 to 0.05)	>95% (>200 to 9)	70% (175 to 53)
Kokwa	99% (7.6 to 0.05)	>88% (>200 to 24)	70% (183 to 55)

To date, CDN WQ has implemented 22 of such remote community filters. 12 are connected to hand pumps and 10 are used for surface water treatment. Two of the remote community filters for surface water treatment were implemented in Southern Sudan. Although these areas do not face any problems with elevated fluoride concentration in the water, implementation of this special filter design was favored for reducing turbidity and microbiological contamination.

For a sustainable implementation of such remote community filters, awareness creation and active participation of the community is as important as training on technical/operational issues. Community members participate in constructing (i.e. excavation of the site, transport of hardcore and other locally available material) and in the fundraising for the defluoridation plant (the community contributes with at least 10% to the initial cost). The community is trained on the health effects of excess fluoride and operation/maintenance of the community filters. A curriculum prepared by CDN WQ facilitates these training activities.

Construction of the remote community filter

The implementation of a remote community filter takes ~10 days. A basic implementation timetable is given in Table 3-3. The initial cost for constructing a remote community filter ranges from 450'000 - 500'000 KES (6'250 - 6'944 USD), depending on the location of the defluoridation unit.

Table 3-3: Timetable for the implementation of a remote community filter.

Days	**Activity**
1-2	Transport to the site, preparation of construction materials and foundation
3	Setup of the plastic tank and pipe work
4	Packing of the filter materials in the filter tanks and internal pipe work
5 - 6	Filling the tanks with water, preparing the formwork for walling, lid setup and concrete walling
7	Finishing of the walling, filling of water for flushing and curing of the bone char
8	Construction of the staircase and final touches
9	Wall curing and assessment of the general functioning of the plant
10	General site clean up and preparation for return

Filter design and operation

Filter design and its operation depend on type of remote filter:

- Treatment of surface water:
  The users carry buckets filled with lake water to the filter. The water is poured into a galvanized metal lid with a screen at the bottom. First attempts setting up the filter without lid failed as the community members mistrusted the quality of the treated water and feared someone might poison the water. Another problem were children who urinated into the filter. Therefore all remote community filters now contain a lid with a padlock.
  The raw water flows in a first chamber (1350 L PVC tank) that serves as a sedimentation tank to remove bigger particles. The raw water passes up-flow through a filter bed containing bone char where the particles are separated from the water through filtration and fluoride is already partially adsorbed. The sedimentation/filtration chamber is fitted with a pipe that collects the water at its surface. The water then passes through the bone char filter, placed in a second tank (4000 L PVC tank). As the whole system is saturated with water, treated water can be withdrawn instantly after pouring in raw water. The whole filter unit is placed about one meter below ground level to facilitate the access to its top with a full bucket of water (see Figure 3-2).
- Treatment of groundwater:
  The design for treating groundwater is very similar to the design for treating surface water. Major difference is the raw water inlet that is connected to the hand pump unit. To facilitate withdrawal of treated water, a pipe reconnects the defluoridation unit with the hand pump unit. Hence the user can check the amount of collected, treated water while pumping and thus avoid spillage.

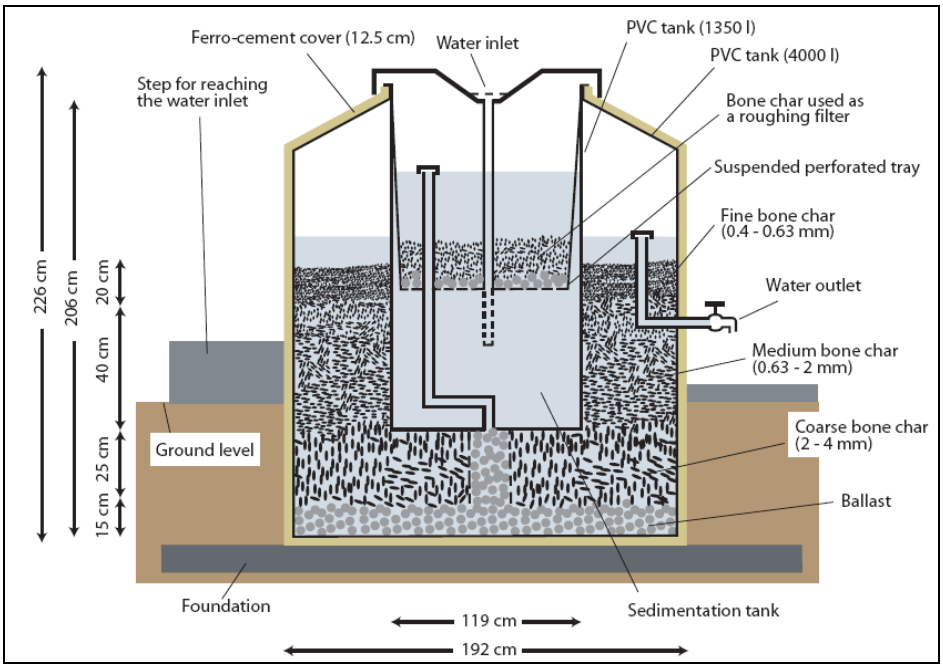


Figure 3-2: Sketch of a remote community filter for treating surface water.

Figure 3-3: The picture on the left shows a remote community filter for treating surface water. The picture on the right shows a remote community filter that is attached to a hand pump unit for pumping groundwater.

No daily maintenance is required. Regeneration of the saturated bone char is explained in "Draft of CDN's experiences in producing bone char".

4 Filters for water works

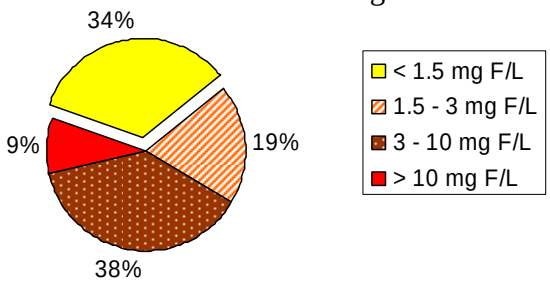
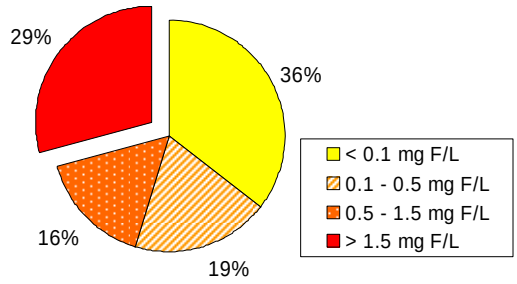
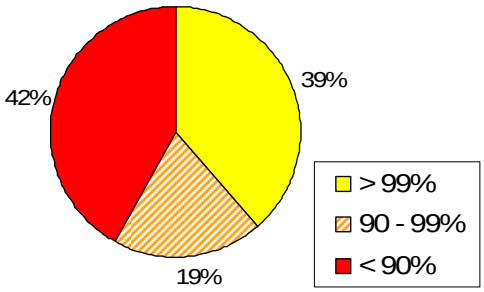
The filters for water works are similar to the institutional or community filters but consist of two or more of the larger units (see chapter 3.1) coupled in series. The working principles are the same but the design and equipment of the filters is slightly modified for the higher working load.
The filters are dimensioned to be regenerated more frequently than other units, every 2 to 8 weeks. The regeneration process does not interfere with the defluoridation process, as both are run in parallel. The treatment capacity ranges up to 200 m^3 per day.
The initial cost for construction and installation of the water work plant ranges from 1'200'000 KES (16'600 USD) to 3'000'000 KES (41'660 USD).

CDN WQ offers a warranty that guarantees adequate performance and running cost for maintenance below 35 KES per 1000 L of treated water (0.5 USD).

5 Monitoring results

Monitoring data are only available for the community filters. Data for the institutional filters are now being updated. Table 5-1 gives a summary of the fluoride analysis and the related removal efficiency of the defluoridation filters (related figure see Appendix).

Table 5-1: Summary of fluoride analysis and calculated efficiency of the community filters.

F in raw water	• CDN's boreholes with known F concentration (196) - Average: 4.3 mg F/L, ranging from 0.1 to 40 mg F/L - 66% (130) of the boreholes drilled by CDN have fluoride concentrations >1.5 mg/L  • Total monitoring of community filters (31) - Average: 7.4 mg F/L, ranging from 2.4 to 16.1 mg F/L
F in treated water	• Total monitoring of community filters (31) - Average: 1.4 mg F/L, ranging from 0.04 to 7.3 mg F/L • In 36% (11) of the community filters the fluoride concentration in the treated water was < 0.1 mg/L • In 71% (22) of the community filters the fluoride concentration in the treated water was < 1.5 mg/L • Filters with elevated fluoride concentrations in the treated water have been in use since several years without regeneration. 
Removal efficiency	• Total monitoring of community filters (32) - Average: 81%, ranging from 11% to 99% • 58% (18) of the community filters had a removal efficiency > 90% • 39% (12) of the community filters had a removal efficiency > 99% 

6 Appendix

Figure 6-1: Remote community filter under construction. The concrete walling will protect the PVC tank from damage.

Figure 6-2: Water kiosk in Naivasha that sells defluoridated water from a community filter installed by CDN WQ. The water kiosks are opened at fixed times that are set by the local water management.

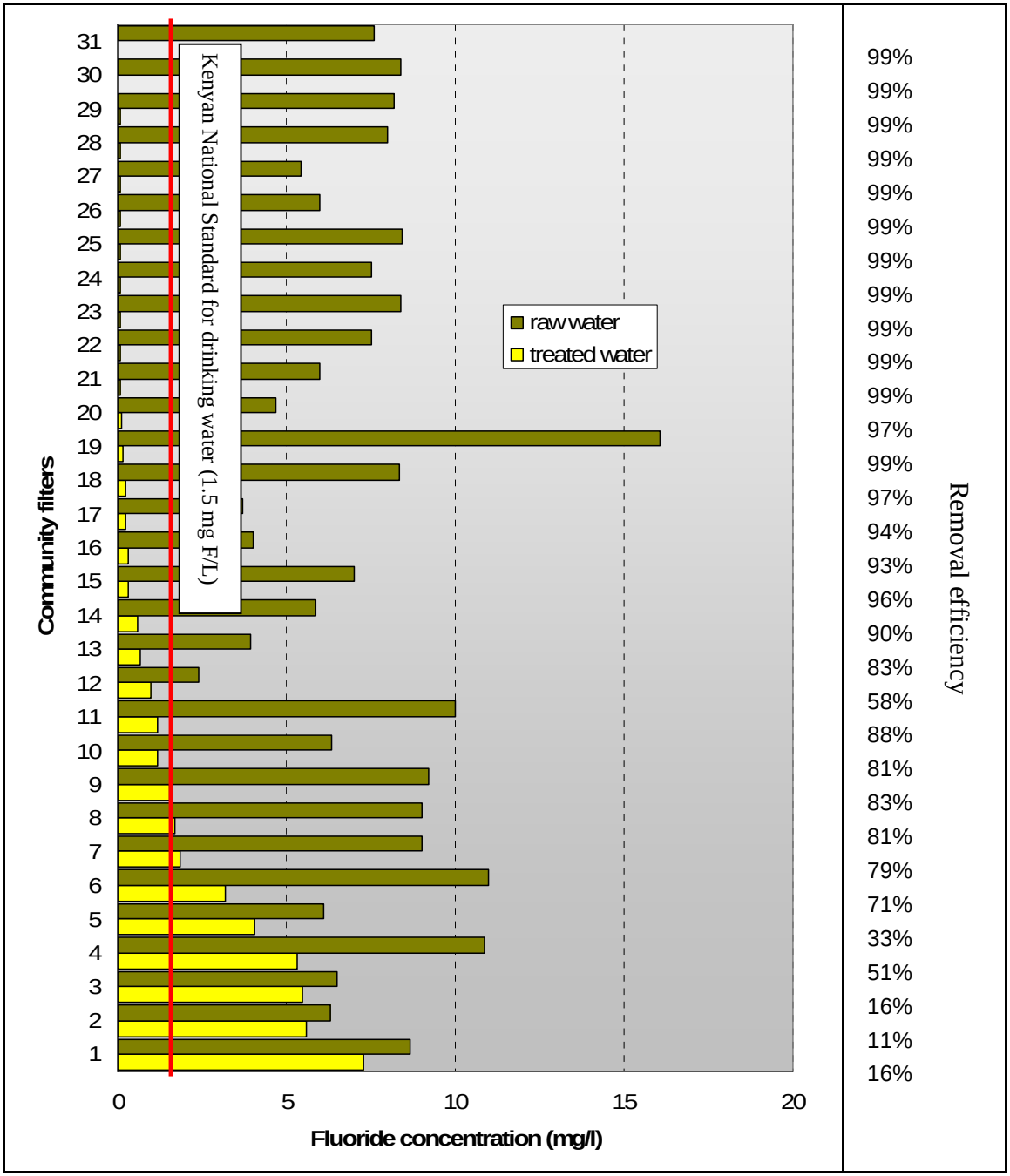


Figure 6-3: Fluoride concentration in the raw and treated water and the calculated efficiency for 31 of the community filters that have been monitored in the last two years.