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PRODUCTION MODELS FOR BONE CHAR DEFLUORIDATION, NAIVSHA, KENYA

SCHOOL OF APPLIED SCIENCES

WATER MANAGEMENT (COMMUNITY WATER SUPPLY AND SANITATION) MSC

2010, 8TH SEPTEMBER

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THIS THESIS IS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF WATER MANAGEMENT (COMMUNITY WATER SUPPLY AND SANITATION) MSC

ABSTRACT

The presence of fluoride in drinking water at levels higher than 1.5mg/l can be harmful to human health, causing dental fluorosis and crippling skeletal deformities. High levels of fluoride are often found in groundwater, therefore populations relying on groundwater sources are particularly vulnerable. Bone char, made from heated animal carcass is effective at removing fluoride from water sources, and this filtration technology is in use all over the world for making water safe for drinking and cooking.

The Catholic Diocese of Nakuru (CDN) is the sole producer and supplier of bone char to household and community de-fluoridation units in Naivasha, and elsewhere throughout the Rift Valley. Using results from stakeholder interviews and observations, this paper presents an analysis of the existing system of bone char production, and four alternative management models: community, private small scale enterprise, franchised small scale enterprise and sub-contraction. A cost evaluation of the existing system is measured against the estimated cost of the alternative models, using a system of profit and loss accounting, and an initial analysis of the sustainability of each is presented.

It is concluded that while the existing system preserves quality and cost, its current revenue will not allow for future expansion of operations. Additionally, the characteristics of its centralised system make monitoring of filters a significant problem. The recommended model is one of sub-contracting where the CDN concentrates on production and out-sources all of its other operations, allowing them to expand their production activities and preserve quality, whilst solving issues of monitoring with a more decentralised system.

ACKNOWLEDGEMENTS

Thank you to Richard Franceys, Alison Parker, Richard Wilson, Gertrude Salano and Kariuki Mugo for their support.

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This thesis has been prepared in the format used for scientific papers appearing in the Journal WaterLines. Additional information is available in the Appendix and the paper includes an extended literature review.

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The Catholic Diocese of Nakuru (CDN) is the sole producer and supplier of bone char to household and community de-fluoridation units in Naivasha, and elsewhere throughout the Rift Valley. Using results from stakeholder interviews and observations, this paper presents an analysis of the existing system of bone char production, and four alternative management models: community, private small scale enterprise, franchised small scale enterprise and sub-contraction. A cost evaluation of the existing system is measured against the estimated cost of the alternative models, using a system of profit and loss accounting, and an initial analysis of the sustainability of each is presented.

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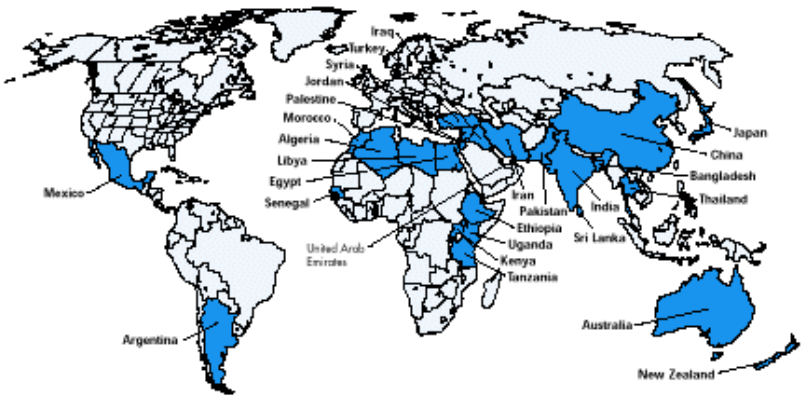
1. INTRODUCTION

The presence of fluoride in drinking water has both beneficial and detrimental impacts on human health depending on its concentration. At levels below 1mg/l, fluoride can prevent tooth decay, but as concentrations exceed 1.5mg/l the impacts on human health range from mild dental discolouration to crippling skeletal deformities (Fawell et al, 2006). The World Health Organisation (WHO) has set a guideline or permissible upper limit of fluoride at 1.5mg/l (ref) and public health programmes worldwide reflect the challenges of maintaining this balance. Indeed, Belyakova and Zhavoronkov (1978) suggest that fluorosis could be one of the most widespread of endemic health problems associated with natural geochemistry.

Fluoride occurs in all natural waters at some concentration, however groundwater generally holds the highest fluoride levels, where concentrations are determined by the aquifer type, the characteristics of the surrounding soil and rocks, and the action of other chemical elements in that area. Unicef indicates that fluorosis is endemic in at least 25 countries globally (see figure 1), and that conservatively, tens of millions of people are affected. In India, it is not uncommon for fluoride levels to exceed 35mg/l.

Figure 1. Location of countries with endemic flurosis



Countries with endemic fluorosis due to excess fluoride in drinking water

In Kenya, a study conducted by Nair et al (1984), discovered that the volcanic areas of the Rift Valley and Central Provinces had the highest groundwater concentrations, some reaching as high as 30-50mg/l. These areas contain approximately 59.5% of Kenya's population, many of which rely on boreholes and wells to provide for their water needs. This project focuses on the fluoride treatment system for an informal, peri-urban settlement named Karagita, on the outskirts of Naivasha. In Karagita, Water and Sanitation for the Urban Poor (WSUP), in conjunction with the Catholic Diocese of Nakuru (CDN) have installed community fluoride treatment plants, that treat borehole water using the bone

char method, and sell it to the communities through water kiosks. At present, the CDN is the sole producer of bone char and supplies an increasingly diverse range of communities and individuals in Kenya, and elsewhere throughout the Rift Valley. This project aims to assess the cost and sustainability of the existing, centralised production system, and assess the effectiveness of several alternative models

2. LITERATURE REVIEW

2.1 FLUORIDE REMOVAL TECHNIQUES (BONE CHAR AND ITS ALTERNATIVES)

There is a significant range of literature that examines and compares different techniques for the removal of fluoride from water. A number of techniques exist, and their use depends on the appropriate level of technology required, cost, and availability of materials. Indeed, WaterAid (199-) states that 'local circumstances dictate which methods, if any, are the most appropriate'. There are four main forms of removal method; precipitation, membrane filtration processes, distillation, and adsorption and ion-exchange processes. Feenstra et al. (2007) state that most of these techniques are 'complex and/or expensive…. Moreover they often require technical skills.' Activated alumina is the most widely used method for fluoride removal, and is most commonly found in large municipal treatment systems (Tripathy et al. 2006 and WQA, 2005). Other advanced and large scale treatment methods are reverse osmosis, electrodialysis and distillation. These methods however, are costly and technologically demanding, making them generally inappropriate for small, lower income community water treatment (WQA, 2005 and Feenstra et al. 2007).

Most lower technology methods of fluoride removal appear to rely on precipitation or adsorption and ion exchange processes, with the Nalgonda method being the most well known of these (Feenstra et al. 2007 and WaterAid, 199-). This method originated in India and is generally used on the household scale (Banuchandra and Selvapathy, 2005), using aluminum sulphate and lime in a process of ion exchange.

The use of bone char for fluoride removal is purported by most to be a very effective low technology solution. Feenstra et al (2007) describes it as 'the oldest known water defluoridation agent', and they and Milo et al (2010) state that the performance of properly prepared bone char is comparable to that of activated alumnia. The positive aspects of bone char use in comparison to the alternatives are that it requires no daily dosage of chemicals, has a high removal efficiency, the technology is easy to construct and manage and the materials are cheap and widely available (Feenstra et al, 2007 and Milo et al, 2010) There are issues, however, surrounding the social acceptability of the use of animal carcass to filter drinking water. This is particularly the case in some Hindu and Muslim societies.

The literature demonstrates that while there is a range of fluoride removal methods, there is no universal solution to the issue. When selecting an appropriate fluoride treatment method, economic, social and environmental factors must be taken into consideration.

2.2 BONE CHAR TECHNOLOGY

2.2.1 CHEMISTRY

Bone char defluoridation works on the principle of adsorption. Medellin-Castillo et al (2007) however, state that 'the mechanism of fluoride adsorption on to bone char has not been completely elucidated.' Albertus et al (2000) go on to say that 'processes of uptake of fluoride on bone char are complicated to describe, consisting of more than one process.

They describe the processes of bone char defluoridation as:

1. Direct adsorption into the empty sites on the bone char surface

and,

2. Re-crystalisation, where Hydroxyapatite is dissolved and fluroapatite is precipitated.

The following model describes the kinetics of fluoride uptake:

$$S = \frac{X_{BC} \cdot f_{m,b} \cdot S_0}{\frac{X_{BC} \cdot f_{m,b}}{S_0} \cdot e^{2(X_{BC} \cdot f_{m,b} - S_0)} - 1}$$

Where fluoride concentration is characterised by a given concentration of bone char *(XBC)* and a given initial fluoride concentration *(So)* by the means of the parameters: dynamic capacity *(fm,b)* and reaction rate *(k)*. (Albertus et al, 2000)

2.2.2 PRODUCING BONE CHAR

There is a range of bone char producing techniques, each varying in complexity. They range from large scale production of bone char in the developed world for paints and artificial leathers to individual home based systems. One of the best documented examples of bone char production is that of the CDN, that holds a monopoly over bone char supply in Kenya. Their bone char furnace has recently increased in size, produces approximately 5 tonnes of bone char a time, and is constructed out of two layers of bricks with a layer of sand sandwiched between. Oxygen content and temperature are important determinants of the quality of the bone char product so this is controlled through a chimney and a gate at the back of the kiln to allow an inflow of air. The air released through the chimney is recycled back through the gate to regulate the levels of oxygen within the system, preventing foul smells also. Once burned (approximately 10 days later) the bones are then mechanically crushed and sieved, then washed, dried and packed. (CDN et al, 2007). This process produces good quality bone char that is distributed to

communities and individuals across Kenya.

An alternative to the large centralised production is community based production, as discussed by Mjengera and Mkongo (2003). They argue that community production is appropriate due to its 'simplicity and local availability of materials'. They suggest that local people can process the material and then sell it to other locals, using the profits obtained to buy more input materials. They then go on to criticize the centralized system as being too capital intensive, requiring a large investment to set up the furnace, procure large quantities of bones, powered crushing devices, and transport to and from the production site. CSDWAND (2007) compounds this view by describing how communities in Andrha Pradesh, India, produce their own bone char, although in this instance the Sri Sai Foundation makes an initial investment in supplying the production systems free of charge.

Jacobsen and Dahi, (1997) describes a community- sized bone char production method, known as a 'charcoal packed furnace', first trialed in Tanzania, and concludes that this method is 'by far the cheapest and most user friendly technique.' The authors state that the furnace can be assembled from a standard oil drum fitted with materials that should be available in 'every market in small towns in developing countries.' The oxygen supply is controlled in a similar way to the larger furnace and the temperature is monitored using a 'Testo' temperature gauge (this being the only 'high-tech' piece of equipment required. Charcoal packed furnaces are particularly appropriate as they are scalable, depending on the quantity of bone char required.

A more crude method of bone char production is described by Rajchagool (1995), where communities simply burn bone char in the open, until it turns black. This is not advisable however, as there are no controls on quality, and the unregulated odor produced can put people off continuing the production.

This literature therefore, indicates that bone char can be produced on both a centralized and community scale, and the method selected depends largely on economic, social and environmental issues specific to that community or region.

2.2.4 QUALITY CONTROL

Temperature is considered one of the most important determinants of bone char quality in all literature on this subject. As mentioned above, crude systems potentially produce much lower quality bone char as there are fewer or no controls on oxygen inlets, and therefore temperature. Dahi (1995) states: 'defluoridation ability deceases with increasing charring temperatures and duration time even when treated at 550°C for 30 minutes compared with 400°C for 1 hour'. The CDN control their quality through the use of oxygen inlets and regular temperature monitoring (CDN et al 2007). This can be replicated on a smaller scale, as described by Jacobsen and Dahi (1997), but when technologies become

too crude, as is the case described by Rajchagool (1995), temperature and therefore quality control becomes impossible.

The CDN also maintain quality by washing their char with NaOH before using CO2 to neutralise the PH. This removes any remaining organic material and impurities from the char (CDN et al, 2007). The more crude production techniques described by by Jacobsen and Dahi (1997) and Rajchagool (1995) however, do not use a process of washing at all.

2.2.3. FILTER MAINTENANCE

Bone char will periodically become saturated and need either replenishing or replacing. Regular monitoring is required to establish when the medium is saturated, although the fluoride content of the water can allow an estimation of the lifetime of the bone char. Regeneration of the filter material can be performed by back-washing it with NaOH. This is used particularly at centralized production centres such as the CDN's in Kenya, where the CDN collects filter material and recycles it before re-distribution. (CDN, 2007). Dahi (2000) however, states that regeneration is only cost effective at a large scale, as often NaOH will not be readily available on the local market. They go on to discuss how, at the community level it is easier, cheaper and often environmentally acceptable to discard saturated bone char. Some communities even recycle it as fertilizer and soil conditioner.

The literature therefore describes a range of production techniques, ranging from large scale municipal production to community based production. Cost, quality and maintenance are key variables in these different models.

3. METHODOLOGY

3.1. RESEARCH QUESTIONS

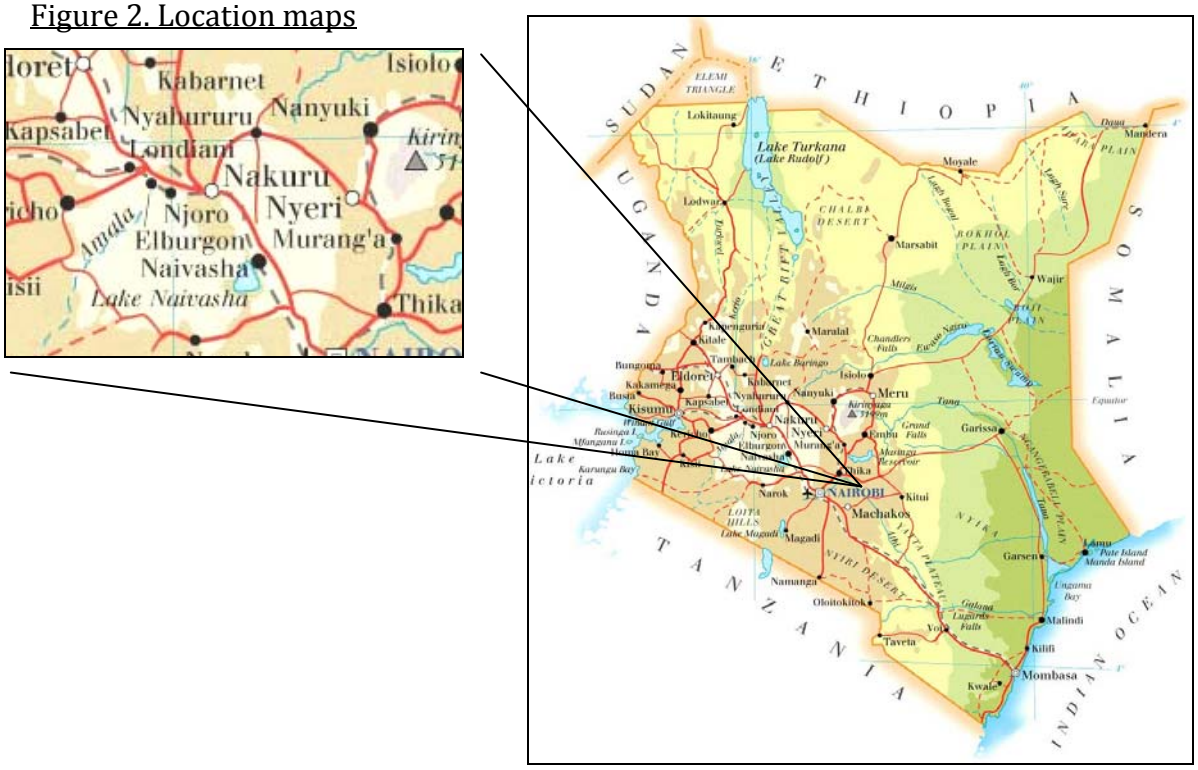
The primary questions addressed by this research are:

- *What is the sustainability of the existing production model?*
- *How feasible are the following alternative models?:*
    - *community production*
    - *small scale private enterprise production*
    - *franchised small scale enterprise production*
    - *sub-contracting*

3.2. RESEARCH ARENA

Karagita, is an informal settlement situated approximately 6km from the town of Naivasha, Kenya. Water kiosks in this settlement sell de-fluoridated water that has been treated by bone char, supplied by the CDN, based in Nakuru. The project's focus is on the sustainability of the CDN's current centralised production system.

Figure 2. Location maps



3.3. OVERVIEW OF APPROACH

The research methodology is based on two approaches, a case study approach, and a quantitative financial analysis. (Please see appendix A, for more detailed

technical notes)

3.3.1. CASE STUDY APPROACH

The case study approach is described as 'an empirical investigation of a contemporary phenomenon within its real-life context'. The case study methodology was considered the most appropriate means by which to gain an understanding of both the existing and alternative production systems. Facts are gathered from various sources and conclusions are drawn from these. External validity is ensured through the production of an 'audit trail', whereby the reader can access the data collected and understand the author's conclusions. Indeed, Yin (2009) argues that it is essential to take the reader's perspective to ensure validity.

Many key informants were recruited through snowballing and as such Rubin and Rubin's three principles of qualitative data were followed (2005).

3.3.2 QUANTITATIVE FINANCIAL ANALYSIS

A quantitative financial analysis of the costs and revenues of production for each of the models was conducted. Where possible, cost information was gathered through interviews and observation, however where unavailable, cost estimations have been based on average market costs.

3.4. DESCRIPTION OF METHODS

3.4.1. SEMI-STRUCTURED INTERVIEWS

Semi structured interviews are often regarded as one of the most important qualitative research tools and this is the primary method used in the research project. Key informants were selected independently and through the snowballing technique, where the interviewer was referred to other relevant informants.

Alternatives such as questionnaires, structured interviews and surveys were not used as a relatively small number of very detailed responses were required, some of which relied on allowing the interviewee to freely voice their views and opinions. If the questions had been too structured, there was a danger that the interview could have been leading or prevented gathering of important information that fell outside the question boundaries.

See the appendix for technical notes and interview transcripts.

3.4.2. OBSERVATION

Observation involves the submersion of the researcher into the 'lived reality' of the participants, and the recording of details of observations made in the form of notes or a checklist. In this instance, field notes were made, which were expanded upon

as soon as possible after the observation session. Observation was used as a means of supporting information provided through semi-structured interviews.

1.4.3. INFORMAL CONVERSATIONAL INTERVIEWS

Informal conversational interviews were undertaken during observation, as is typical for this type of interview, according to Cohen and Crabtree (2006). The interviews were essentially informal discussions about a particular topic, and were not controlled by a set of specific questions. One of the benefits of this technique is that it 'fosters low pressure interactions' encouraging participants to be more open and honest Cohen and Crabtree (2006). Crawford (1997) states that informal interviews must be recorded with the use of field notes.

3.7. DATA ANALYSIS

These three data collection techniques are used to present a rich account of the operational sustainability of the existing supply chain and its alternatives. Each management model has been presented and a range of cost calculations are also presented, including the estimated cost of production of bone char at present, compared with the cost of community or small scale enterprise production. There is also an estimation of the capital costs required to establish some of the alternative systems. The data is presented through 'the use of voice in the text', i.e. the use of quotes that illustrate the point being made (Hoepfl, 1997), and through reference to field notes.

4. RESULTS

This section presents the results of the interviews and observations, by painting a picture of the sustainability of the existing system and its alternatives. Quotations taken from semi structured interviews can be found in Appendix B, and summaries of observation field notes, and informal conversational interviews can be found in Appendix C and D.

4.1. EXISTING SYSTEM

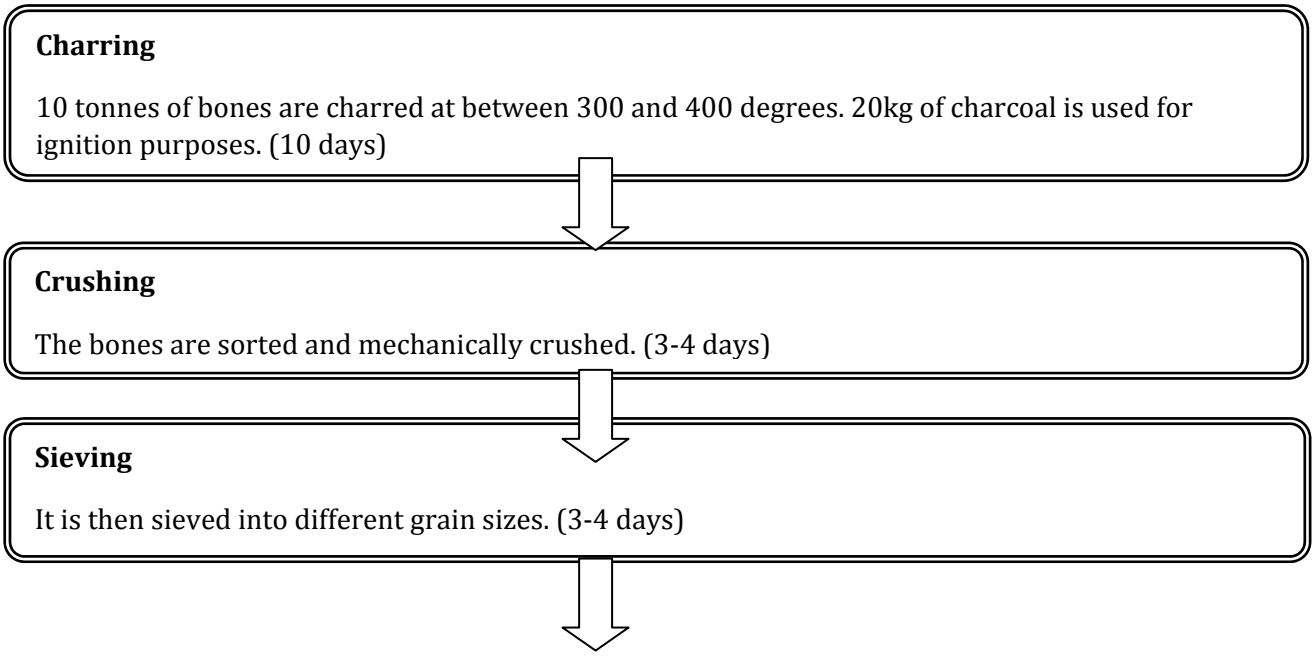
4.1.1. PRODUCTION

- SUPPLY

The CDN is supplied with bones by butchers and game keepers. Observations were made of bones being delivered to the production centre by people on bicycles. The suppliers were paid according to weight. Interviewee 4 states; *'We get them from butcheries mostly. People collect them and bring them here and we buy them for 7 shillings per kilo. Mostly people bring bicycles, lorries, pickups'.*

- PRODUCTION PROCESS

Below is the CDN's bone char production process, based on observations and the semi structured interview with the CDN representative responsible for production.



Washing

The bone char is washed with sodium hydroxide to clean it, rinsed, and then flushed with CO2 to restore the pH. (14 days)

Drying

The bone char is dried under the sun on trays and then packaged. Around 5 tonnes is produced. (1-2 days)

Based on these observations and interview, a cost analysis has been completed of the cost of production of 1 kiln's worth of bone char, using a profit and loss accounting method.

Table 1. Cost analysis of existing production system

	KES	USD	Based on:
Revenue (turnover)	**555533**	6866.75	5 tonnes produced, (8333 litres, at density of 0.6kg/l REF). 60 litres sold for 4000KES
Operating costs	**130042**	1607.40	
Wages and salaries	31669	391.45	5 workers employed at $2.6/day (guideline minimum wage for general labour REF), working for 30 days (time to make 1 kiln's worth).
Materials and supplies	72943	901.62	70000 KES for 10 tonnes of bones (sold at 7KES/kg), 1500 KES for 20kg of charcoal, 389 KES for 24 kg of NaOH (16230KES/tonne), 1054KES for 6kg CO2 (18KES/lb)
Electricity	25630	316.80	$1.88kwh. (article- production factor costs in Kenya) 168 hours (crushing, sieving and washing)
Overheads/Misc Expenses			
Operating profit	**425491**	5259.5	

(1 USD = 80.9019 KES 9/7/2010)

This of course, does not take into account the costs of the other aspects of CDN's operations, that include distribution, awareness raising, research and laboratory work.

4.1.2. QUALITY CONTROL

The CDN uses a range of measures to guarantee the quality of the bone char*: 'The packaging of the bones has to be done just right, and then the placement of the hot spots, or rather the burning points has to be done just properly.'* White bones are over-burnt and grey bones are not charred enough, brown bones are the optimum quality, and these are used to create the bone char. Quality is also controlled *'during the washing process. To make sure to remove any organic matter that might have remained in the water'*. The CDN then uses a range of measures to ensure the bone char is of the correct quality before it is sold: *'For pH we have a meter, connected to an electrode. For EC we have a conductivity meter. And for colour we use a spectrophotometer.'* Quality control is essential as *'a badly produced bone char for one can have a bad capacity and also if it is not charred properly it will give maybe colour to the treated water'.*

4.1.3. MONITORING

The removal capacity of the bone char must be tested once every 6 months: *'We have one arrangement where we do the monitoring every 6 months, another arrangement is where we train a community to bring a sample of water to us, to Nakuru.'* Where CDN takes samples themselves, this is generally for research purposes.

There are some problems with the monitoring system. Interviewee 2 states; *'our wish was that after we implemented, our work was complete',* but interviewee 1 states; *'In cases where maybe the cultural barriers play a huge part, then you have to go there yourself and do the actual monitoring… in some cases it just might be not possible because of logistics like money or other plans.'* Interviewee 3 expands on this, stating: *'They are not able even to afford a meal, so you can imagine for them, they are not able to afford a meal and a test here for fluoride is 100 shillings'.* It appears, therefore that distance from Nakuru and economics are important determinants in how often the filters are monitored.

This is compounded by the opinion of interviewee 5, an affluent household filter owner, who states: *'Nakuru is quite a long way to go just to get a test done. There should be a lab or something in Naivasha where you can take it to.'*

4.2. ALTERNATIVE 1: COMMUNITY PRODUCTION

This alternative system is based on the community supplying, producing and consuming their own bone char, rather than purchasing it from an outside agent. An analysis is conducted of the feasibility and sustainability of this.

4.2.1. PRODUCTION

- SUPPLY

For this model to work the community will require a reliable supply of free bones. Several informal conversational interviews were conducted with butchers in Naivasha town, in reference to their bone surplus. The consensus from these was that butchers never have bones left over. Customers take them home to feed to dogs or livestock, or they are used to make stocks. Therefore, without a monetary incentive, it is unlikely that a supply of bones could be guaranteed from local butcheries.

Similarly, observations of the diets of people in Karagita, and the goods sold in shops there indicate that meat is unlikely to feature prominently in their diet and as such, a reliable source of bones could not be guaranteed here either.

- INFRASTRUCTURE

Through observations of the CDN's production plant and interviews with those responsible for bone char production, an impression of the infrastructure required for production was generated. The first piece of infrastructure would be the kiln: *'One that is going to char the bones to the desired specifications.'* The kiln however, would not need to be the size of the CDN's, in fact it can *'be any size depending on the output required'*.

The next stage of production is the crushing, and members of the CDN appeared to be in disagreement about the importance of a mechanized crusher. Interviewee 1, argued that an electrical crusher is vital to *'control the crushing'*, i.e. ensuring it is crushed to the correct specifications. 4 however states: *'you can crush by hand'.*

The washing appears to be the stage that is viewed by the CDN as most problematic when it comes to community production. 2 states that the community would require: *'the washing tanks, the chemicals used for washing, and plenty of water'*. 1 continues; *'you also have to have some bit of chemistry as far as the cleaning process is. Somebody has to know the right proportions of mixing'*.

A costing exercise has been performed estimating the amount of money a community would need to set up a bone char production plant. The design of the kiln is based on Mjengera (2003), who discuss the use of low tech kilns in Tanzania. Note, there is no reference to washing after the crushing, despite claims by interviewee 1 that *'whatever method you use there should be a cleaning process afterwards'.*

Table 2. Initial investment required for community production

Item	Cost (KES)	Cost (USD)	Based on
TESTO thermometer	25206	311.56	TESTO 550
Manually driven iron roller	60000	741.64	
Tray sieve system	60000	741.64	
Oil drum 68 x 86cm	1000	12.36	
Cement	1000	12.36	
10 x corrugated iron sheets	1000	12.36	
5m x 3mm galvanized wire	500	6.17	
Gravel	0		Locally available
5m x ¾" galvanized iron pipe	1000	12.36	
Monitoring equipment	56967	702.99	HACH pocket II colorimeter
Labour	1687	20.82	2 labourers, 4 days work ($2.6 daily rate for general labour. Guideline minimum amount REF)
Total	208360	2571.22	

(1 USD = 80.9019 KES 9/7/2010)

(Estimations have been based on observations of the market in Naivasha, and quotes from internet sources.)

When discussing the funding of community production, interviewee 4 states: *'Setting up a defluoridation unit, has a cost implication. Somehow you need an investment. So I am not sure how a community can do that, unless maybe they have a donor, who can assist them'.*

Interviewee 1 agrees, saying: *'does it make sense, is it a good investment? Because it requires money, maybe it might be a loan that you have to repay. Sustainability in other words.'*

4.2.2. QUALITY CONTROL

Quality control is an essential and challenging element of the production process. Interviewee 2 states: *'producing quality bone char is a problem…. It took them around three good years to produce quality bone char'.* 1 describes the consequences for a community if they do not produce good quality bone char: *'(they) could be economic, they could be medical, they could be even legal... But again the end point is, maintain the good name that you have. Make sure that your clients or your customers are properly given the best quality there is.'* 2 goes on to describe the equipment used for controlling the quality of their bone char, post washing: *'for pH we have a meter, connected to an electrode. For EC we have a conductivity meter. And for colour we use a spectrophotometer'.*

4.2.3 MONITORING

Monitoring is regarded as another challenge by CDN. Interviewee 2 describes how they use a range of laboratory based techniques to measure the fluoride levels in the water. They state that a 'spectrophotometer' can be used, although *'you will get some positive error in the final measurement.'* For a community, without laboratory facilities therefore, the most appropriate form of monitoring is the use of a portable colorimeter that works on the same basis as a spectrophotometer. This can provide a fairly accurate reading, but will not be as accurate as CDN's techniques. Having easy access to a monitoring system however will reduce the burden on the community to travel long distances to have the water monitored.

4.2.4. SKILLS

Certain aspects of the production and monitoring process require specific skills. 1 states: *'someone needs to be trained on how to monitor the charring process. Then you also have to have some bit of chemistry as far as the cleaning process is. Somebody has to know the right proportions of mixing and then the overall, the basic training there would be managerial or other operational management kind of training. But safety is the underlying part so there needs to be somebody trained in rudimentary chemistry'*

4.3. ALTERNATIVE 2 & 3: SMALL SCALE PRIVATE ENTERPRISE (SSPE) AND FRANCHISED SMALL SCAL PRIVATE ENTERPRISE (FSSPE)

The SSPE system is based on small scale private company duplicating the role of the CDN, but creating a business of the sale of bone char. The FSSPE model is a

similar principle, but the CDN (the franchisor) gives authorization to a small scale private enterprise (the franchisee) to produce and sell their bone char. A contract is developed where the franchisee receives guidance from the CDN, and manages bone char production and distribution under their name, in exchange for a fee.

4.3.1 PRODUCTION

- INFRASTRUCTURE

The (F)SSPE will require very similar infrastructure to the CDN, depending on the size of their operations. Certainly they will require a kiln and crushing and sieving machinery. The FSSPE will also definitely require washing tanks in order to comply with CDN's quality standards.

The initial investment required for an SSPE is estimated below. This is based on the capital required to obtain the necessary infrastructure and facilities, at half the capacity of CDN.

Table 3: Initial investment required for (F)SSPE production

Item	Cost (KES)	Cost (USD)	
Kiln	500000	6170.13	Estimated, based on half the cost of CDN's kiln
Mechanised crush	120000	1480.83	Market price
Mechanised sieve	120000	1480.83	Market price
Lab facilities	371836	4588.55	4762KES for Jenco Vision Plus pH630F electro pH tester 9890KES Jenco conductivity meter 357184KES for 361 MC CRT- type atomic spectrophotometer
Vehicle	627350	7741.66	Pick up truck on kenyamotors.com
Total	1739186	21462.01	

(1 USD = 80.9019 KES 9/7/2010)

- PRODUCTION COSTS

Providing they are using similar processes, the costs of the (F)SSPEs operations will be proportional to those of the CDN. The re-sale of the bone char however, will need to make a significant return on capital employed in order to make a viable business. The FSSPE especially will need to ensure a good revenue, as they will be committed to pay a fee for the CDN's guidance and trade-name. The sale price of

the bone char therefore, will be increased, depending on the amount of profit the company wishes to make.

4.3.2. QUALITY CONTROL

Quality control, as stated earlier is a vital element of bone char production, and something that requires specific skills. The FSSPE will have guidance from the CDN on how to achieve good quality bone char and will contractually obliged to ensure quality. The SSPE however would not be regulated, and therefore quality could be a concern: *'it took (CDN) around three good years to produce quality bone char. They used to struggle with it, the bone char coming out was a real problem, so producing quality bone char is a problem.'*

4.3.3. MONITORING

It is likely that the (F)SSPEs will be located in geographic areas, meaning they will be located in more convenient locations for monitoring purposes. Reducing the burden on the filter owners.

4.4. ALTERNATIVE 4: SUB CONTRACTING

This system is based on the CDN recruiting and employing subcontractors in geographically defined locations, to take on the responsibility of distribution, community training and monitoring, leaving the CDN to concentrate on production. CDN would bulk sell bone char to the subcontractor, who would then re-sell it, keeping the revenue. The end sale price would be set by the CDN.

4.4.1. PRODUCTION

As stated, CDN would continue producing the bone char. When discussing this model with the CDN members, they seemed to believe that concentrating on production would reduce the pressure on the limited staff, and allow them to expand their operations. Interviewee 4 summarises this opinion: *'You see as more people are getting aware of the fluoride issues more people will be coming and we wont be able so much maybe to take care of them. More clients will be coming, so if there can be someone in-between… CDN managing the production, and then another firm who can be buying materials and selling them to communities and doing maintenance, monitoring, awareness creation, I think that can be good. It's an opportunity'.*

Interviewee 2 agrees, stating: *'all the burden is for CDN to do the production, to go ahead and implement, and going further to monitor these filters and the operation and maintenance its really overburdening us, and we have so many clients… Like in*

the production there is only one guy who is in charge of monitoring and supervising the production'.

1 states: *'we think if we can concentrate on the production and leave some elements of marketing to other people in this as, the kind of model you are mentioning, it could move towards a kind of arrangement that is something that CDN would be very welcome to work with'.*

The cost of production would obviously remain the same, however the re-sale price would have to take into account a profit for the sub-contractor.

4.4.2. QUALITY CONTROL

With CDN continuing to produce the bone char, the quality will be preserved.

4.4.3. MONITORING

Members of the CDN believe that by concentrating on production, and tasking the sub-contractor to perform the monitoring and awareness raising, this element of the operations will be more successful. 4: *'they can put more emphasis on the monitoring and the awareness creating to the community, empowering the community, all these things.'*

1 states: *'it will be plants or fluoridation units that belong to the subcontractor in this case. So the monitoring, the sustainability aspect, the overall sustainability, operation an maintenance kind of issues will be part of the subcontrator's kind of role.'*

With the sub-contractor being located closer to the filters, it will also allow more regular monitoring and reduce the burden on the community to do this themselves, as this would become the sub-contractor's responsibility. The interview with the household filter owner, suggests that this would be beneficial to them: *'Nakuru is quite a long way to go just to get a test done…. That's probably why I haven't bothered getting it tested again.'*

4.4.4. CONTRACT

The sub-contractor would be regulated by the CDN, who would ensure that the business is run ethically and effectively. 2 states: *'If you can co-ordinate and do the work together, it could be perfect.'*1 also says*: 'It's a matter of talking with an organisation, having an agreement that favours both organisations, then we can sub-contract, definitely'.*

<table>
<tr><th colspan="4"><u>SWOT ANALYSIS</u>
Existing system</th></tr>
<tr><th colspan="2">Strengths</th><th colspan="2">Weaknesses</th></tr>
<tr><td colspan="2">- Guaranteed quality.
- Dedication.
- Knowledge.
- Not profit-motivated.</td><td colspan="2">- Not making enough money for future investment.
- Monitoring- customers have to come to Nakuru.
- Limited staff and facility capacity- difficulty with expansion.</td></tr>
<tr><th colspan="2">Opportunities</th><th colspan="2">Threats</th></tr>
<tr><td colspan="2">- Increasing demand</td><td colspan="2">- Increasing demand
- Likelihood that filters will go un-monitored</td></tr>
<tr><th colspan="2">Alternative 1: community production</th><th colspan="2">Alternative 2: SSPE</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>- Do not need to pay CDN for bone char.
- Do not need to travel to Nakuru for monitoring.
- Sense of ownership.
- Local availability of bone char will increase filter use and awareness.</td><td>- Quality control.
- Requires initial investment.
- Requires specific skills.
- Monitoring equipment not as accurate as CDN’s</td><td>- Good business opportunity.
- Local supply and monitoring for communities.
- Awareness raising and regular monitoring is in SSPE’s interest.</td><td>- Potential lack of market.
- SSPE non-existence implies lack of awareness/demand.
- No quality control/regulation
- Out-priced by existing system, as motivated by profit.
- No guidance from CDN (experts).</td></tr>
<tr><th>Opportunities</th><th>Threats</th><th>Opportunities</th><th>Threats</th></tr>
<tr><td>- Possibility to develop into a business.
- Long term sustainable supply of bone char.</td><td>-Threat to health due to poor quality.
- Threat to reputation of technology due to poor quality.
- Loss of capital employed if unsuccessful.</td><td>- Development of a strong market for bone char.
- Good business opportunity.
- Increased awareness in regions surrounding SSPE.</td><td>- Risk of poor quality bone char.
- Risk of exploitation of communities.
- Risk of unnecessary replacement.</td></tr>
<tr><th colspan="2">Alternative 3: FSSPE</th><th colspan="2">Alternative 4: sub-contraction</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>- Guidance and regulation by CDN, ensures quality.
- Local supply and monitoring for communities.
- Awareness raising and regular monitoring is in SSPE’s interest.
- Use of CDN’s name gives credibility.</td><td>- Out-priced by existing system as motivated by profit, especially as have to pay CDN a fee.</td><td>- Allows CDN to concentrate on production. Ensures quality.
- Local supply and monitoring for communities.
- Awareness raising and monitoring is in sub-contractor’s interest.
- Use of CDN’s name</td><td>- Out-priced by existing system, as motivated by product and have to buy bulk bone char from CDN.</td></tr>
</table>

		gives credibility. -CDN regulates end sale price and uses community consultation to prevent exploitation.	
Opportunities	**Threats**	**Opportunities**	**Threats**
- Good business opportunity. - Increased awareness in regions surrounding FSSPE.	- Risk of exploitation of communities. - Risk of unnecessary replacement. - More expensive than existing production	- Good business opportunity. - Allows CDN to expand operations. - Increased awareness in regions surrounding sub-contractor.	- Possibly unsustainable if there is no market. - More expensive than existing production

5. DISCUSSION

Having presented the results of the research, this section aims to discuss the long term sustainability of the existing system and its alternatives, and form recommendations of further research.

The existing system of production has strengths in two areas: quality control and cost. The CDN has honed an inexpensive, almost waste- free method of producing bone char that guarantees good quality. They keep production costs to a minimum through employing few staff and using the most cost effective technologies. Since the CDN are not motivated by profit, this allows them to sell the bone char at a very reasonable price, which makes the technology affordable to even the poorest communities.

One downside of their lack of revenue however is the inability to expand their operations to meet demand. There is a consensus among the staff that the capacity of the CDN is already stretched, and that with increasing demand, the situation will worsen. Without increased funds, however, the capacity cannot be increased.

Another problem with the centralised production system that is discussed in all interviews is that of monitoring. Bone char filter users are expected to travel to Nakuru to monitor the removal capacity of the filter every six months. As is indicated by the interviews and the field notes however, this is inconvenient at best, and for informal communities similar to Karagita, an expensive and time consuming task.

A potential solution to the problems of increasing demand and monitoring is the decentralisation of production systems. The first of the decentralised models considered is community production. Community production has, in recent years been promoted as being one of the most sustainable forms of production. It decreases a community's reliance on outside sources, provides them with a sense of ownership of projects, is usually affordable, and can be a good money making initiative REF CASE STUDY. The model analysed here is community production, initially for their own purposes, but with the potential to expand to a commercial operation later. This model has the potential to provide all the benefits of community based production outlined above, but also has some significant challenges:

1. Supply

The community will require a reliable and free source of bones in order to produce the bone char without any expenditure. The diets of many communities are low protein however, butcheries rarely have bones remaining, and The CDN find it necessary to purchases animal carcass. The quantity required however for

community production would be significantly smaller, so it may be possible to source enough.

2. Initial investment

Table?? outlines the cost of building the simplest kiln, purchasing the hand operated, rather than mechanized crushing and sieving machines, and the most basic monitoring equipment. Despite the simplicity, this is not an insignificant sum, and for many communities, without donor support, this would be an impossible amount to raise.

3. Quality control

The case study this model is based on does not use any form of washing at the end of the process to ensure impurities are removed. This is despite CDN stating that this is an essential part of the process. Including the washing however, would increase the overall cost of the system significantly, and rely on a reliable, clean source of water, that can be a scarcity in many environments. Similarly, the equipment used for monitoring the effectiveness of fluoride removal is the most basic available, and therefore, least reliable.

4. Skills

A certain skill set will be required for constructing and managing the system, including financial management skills, an understanding of temperature control using oxygen inlets in the kiln, and an ability to use instruments such as the spectrophotometer and thermometer. Interventions by an organization similar to the CDN would be required to provide the necessary training.

As such, although community production is theoretically sound, in practice, financial donor support is essential, as is training and support. Then there is the serious consideration of quality, as this cannot be guaranteed, or monitored as effectively as it should be. Finally, this model assumes a level of awareness of issues of fluoride that is uncommon in most parts of Kenya. Without a sustained awareness campaign, it is unlikely that this initiative would ever be taken by community groups.

Next is both the small scale private enterprise (SSPE) model, where private businesses take on the role of the CDN, in producing bone char for smaller, geographical areas, and the franchised SSPE model, where the CDN provides their name and expertise, in exchange for a fee. These models are flawed simply because of the fact that none of them currently exist. If bone char production was considered a viable business, then it is likely that the market would likely be saturated with businesses of this nature. The reason that bone char production is not seen to be a viable business seems to be due to one key factor.

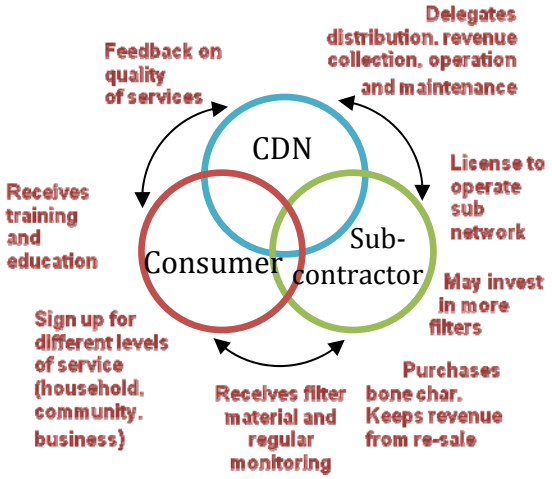
Currently, the CDN produces bone char at the lowest possible price, and sells it at just enough to make enough to cover their other operations. They are motivated altruistically, rather than by profit. For a business model to work, and be attractive to potential entrepreneurs, the sale price of the bone char would have to comfortably make a return on capital employed, with a good overall profit margin, which means they would have to charge more for bone char, meaning that the CDN would out-price them anyway. In the case of an FSSPE, this is a particular problem, as they will also be required to pay CDN a fee for the use of their name and their expertise. Whether the convenience of local supply and monitoring facilities is worth the increased price of bone char, is debatable, but clearly for some communities, cost is a real issue.

Another problem with the development of (F)SSPEs, is the potential for exploitation of communities, and a lack of regulation. The more customers the business has, and the more times the bone char is replaced, the more money they will earn, therefore, there is certainly the potential for communities being convinced they need to replace their bone char more often than they do, or in fact, have a filter at all. There is therefore a positive and negative side of being motivated by profit: Although it is in the (F)SSPE's financial interest to generate awareness of the issues of fluoride, a lack of regulation means there is the potential to exploit or mislead communities.

Similarly, with a lack of regulation, comes a quality control issue. With the FSSPE, this is less of a problem as the CDN will provide training on producing a good quality bone char, and they will be expected to uphold their name. The SSPE, however will not be regulated, and as such, could potentially supply poor quality bone char, particularly if this means the filters require replacing more often.

Finally, there is the sub-contracting option, where CDN concentrates solely on production and out-sources the other parts of their operations. The benefit of CDN putting all their resources into production is that it will allow them to expand their operations and continue to ensure quality, whilst producing the bone char for a minimal cost. This means they can then sell to the sub-contractor at a price that lets them add a margin onto the re-sale price, and yet still provide affordable bone char to communities, particularly as the CDN will set the end sale price. Sub-contractors located in geographical areas will reduce the monitoring burden on communities, and make awareness and training activities much easier and more consistent. Additionally, the location of a regional supplier, will increase the uptake of the technology considerably. Finally, the sub-contractor will be regulated by the CDN, through community consultation and the use of a competitive and renewable 5 year contract, reducing the risk of exploitation and ensuring quality control.

Figure 3. Diagram depicting sub contraction model (adapted from Castro, 2009):



6. CONCLUSION

In conclusion, the existing system of production, whilst ensuring quality and keeping costs low, is unsustainable as it cannot meet increasing demand whilst making such low revenues. The monitoring system of this centralised production model is also inappropriate in expecting users to travel so far to monitor the filters.

The alternative model of community production is unlikely to be successful due to a lack of money for initial investment in infrastructure and poor quality control. Similarly, (F)SSPEs would probably not succeed due to the CDN undercutting their prices.

Finally, it is recommended that sub-contraction is the most effective method of ensuring a sustainable and expanding provision of bone char to those affected by fluoride. This method retains the expertise of the CDN, ensures communities get a fair deal, and addresses the existing problems surrounding distribution and monitoring. Although the other systems have their merits, in most cases quality and price is compromised, potentially making the use of bone char a health risk, or simply out of the reach of the poorest communities.

Further work should involve the investigation of the potential market for bone char, and focus on increasing awareness of the issues and the solutions, because, as awareness increases, models such as SSPEs become inevitable in such an entrepreneurial society as Kenya's.

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APPENDIX A

METHODOLOGY TECHNICAL NOTES

Yin's three principles of case study research were employed throughout the project:

2. Triangulation
3. Maintenance of a case study database (1 database containing data, and the other containing the reports of the researcher).
4. Maintenance of a chain of evidence (all data collected will be listed in the appendix and cited within the report).

Rubin and Rubin's three principles of qualitative data collection have been followed:

1. Flexibility
2. Iterative design
3. Continuous design

Semi structured interviews

The questions in a semi structured interview are broad and open ended, allowing an interviewee to expand on certain points. The questions were carefully designed to encourage the interviewee to speak freely about the topic, as opposed to being leading (Robson, 2002). Questions were omitted or added where appropriate and the interviewer changed the order of the questions depending on their perceived importance in that particular interview. As English is commonly spoken throughout Kenya, and most of those interviewed had obtained a higher level of education, translation was not required. This avoided risks of translator bias or misinterpretation.

Each interview began with 'warm up' questions , where the interviewer attempted to build a rapport by asking background questions such as the interviewee's job title, and the time they had spent with the organisation. The interviews were concluded with the question; 'Is there anything else you would like to discuss?' This ensured all important issues had been covered.

Once the interview was completed, the tape recorder was checked to ensure it had recorded the interview correctly, and impressions were noted down immediately. Later the recordings were transferred into transcript form.

Ethical considerations

All participants in the data collection were provided with an outline of the purpose and intended use of the research. All were informed of their rights to anonymity, and their consent was obtained before any recording took place.

Reliability and validity

The use of multiple sources of information, in the form of observation and semi structured interviews allow triangulation, as interview topics and observation themes overlap. Reliability has been ensured by allowing time for a summary and the end of an interview, this ensures that the interviewee's views and opinions have been correctly interpreted.

The interviewer was aware at all times of potential bias in data collection and has made every effort to ensure no leading questions were used.

APPENDIX B

INTERVIEW 1

I: So if could ask a few questions mainly about the monitoring and the distribution and the replacement and then maybe discuss some alternative systems. But first of all could you just explain who you are, your position in the company and things like that.

R: My name is _____ I'm the manager of the water quality programme at the CDN. What we do here is dealing with defluoridation issues at community and household levels.

I: Thank you. First of all I'd like to ask a few questions about the distribution of the bone char. So could you roughly tell me some ideas of where you supply to?

R: Ok, we have several end point, supply points. In this case we have either domestic users, as in the filters themselves. We also sell bone char it'self to southern Sudan. We also sell it to Ethiopia, to Southern Sudan we sell through World Vision Sudan, Food for the Hungry Sudan, we also do some sales to Ethiopia. We also sell in Kenya, we sell bone dust to producers or manufacturers of food for animals. Basically livestock type of feed. Also we sell bone char, well in this case we don't necessarily sell but we share some of the smaller quantities for research with other organisations. But mostly the majority of the users of the bone char is going to be the community filters and the small household filters, all the modern type of filters.

I: Ok great. And so in terms of distribution, how does that work? To the community filters and household filters? Do you distribute to them?

R: We distribute in two formats. If it's a new filter for example, obviously it will come with it's share of bone char. If it's an old filter it will require replenishing so we have to arrange, sometimes we have an arrangement where the community will either come to Nakuru to buy the bone char from us or alternatively we can go and take it to them if we are the ones in charge of that particular plant. Or if we have an agreement with them for us to resupply the bone char. So if it exhausted or replenishing, refurbishing of an old filter we normally do that. That is the arrangement. It is a mutually agreeable arrangement.

I: Ok so you have different contracts?

R: Yes we do

I: Ok and if you were to distribute it, how would you do that? Via lorry or would you, say for example have an area with several community filters in and take it all there at one time or....

R: Ok depending on the scattering, the location of the filters, it could be arranged so that we have one trip but unfortunately we have very, it's very difficult for us to place so many filters in one place. Other than in Naivasha, all our other filters are fairly scattered, so what

we do is that we try as much as possible to have a geographical supply so that we target one area and say that we are going to take maybe a lorry or a pick up, but this can be impossible. Most of the time it will be a pick up because it could be just two filters but if it more than 2 filters then we are likely to use a lorry. For the local supplies here, we are talking about small quantities, so you see a smaller vehicle like a pick up or in some cases just a smaller vehicle will do. But again it will depend very much on the arrangement and the location. Geographical location and the arrangement, the type of agreement we have with the clients.

I: So moving on to monitoring, how often should you really monitor the removal capacity of the bone char from the filters?

R: The monitoring aspect depends really on the lifespan of the filter. So if we have a filter that is situated in an area of low fluoride concentrations, we typically should give it as much as, really in some cases 5 years. So we are talking about 6 month intervals, monitoring. So we have one arrangement where we do the monitoring every 6 months, another arrangement is where we train a community to bring a sample of water to us, to Nakuru. And a third arrangement is where they do it monthly, so they keep on taking a sample of water every month. Especially the first year, just to make sure the filter is behaving as per design. However the recommended would be 6 months intervals. Monitoring and as far as taking samples, there are other types of monitoring like financial monitoring that we don't necessarily do but the community is encouraged to do.

I: And how easy is it to encourage the community to bring samples to CDN for testing?

R: That is very important. Each community has it's own priorities, so it is easy if you have already trained the community and made them have a sense of ownership of the plant. If they believe the plant is beneficial to them it is very easy. But in some cases where there are issues of opposition, whether it is cultural or just a simple misunderstanding, it can be difficult. So in cases where maybe the cultural barriers play a huge part, then you have to go there yourself and do the actual monitoring but I would say that 70% of all the communities we deal with are easy to convince to either bring a sample or to do monitoring ourselves.

I: And they would be willing to bring it from over the other side of the country, for example?

R: The willingness could be there, in some cases, sometimes it just might be not possible because of logistics like money or other plans. It is a complicated issue that one, because it is a sense of ownership, they own that project. If it is the community that came to you in the first place or if you are very successful in making them have a sense of ownership then you are likely to have a very high rate of monitoring.

I: Ok. So once you've got a sample for monitoring, how long does it take to turn it around. To get the results and let the community know what the results are?

R: We have two ways of feedback. The first is SMS. We just SMS the results, the data the figures. Because we normally have contacts with community. The second one is the actual data, the print out. You have to give them the print out for record purposes. But the most important is to make sure they get the immediate feedback so that they can make

necessary arrangements wherever possible. So ordinarily that should between 2 days to 3 days at most. At least for the SMS anyway.

I: Are there any other types of monitoring or maintenance done on the filters or on the operation of the filters?

R: Well our filters are designed to be rugged to be able to withstand. And I'm talking about the community filters. As a matter of fact all our filters including the household filters, so that the only monitoring or maintenance that you have to do is simply to make sure there is water, as long as there is water the filters are designed to last long. So very minimal operation and maintenance kind of aspects. Very minimal. They are designed to be low maintenance in terms or human resources.

I: Ok great so now talking a bit about replacement or replenishment of the bone char. So how often would you say a community filter needs replacing? I know it obviously depends on the amount of fluoride in the water, but roughly.

R: Average would be three years in Nakuru area, but the further you go North you go to about 1, 1 and a half years average.

And who's responsibility is it to co-ordinate this, so once you've got the results saying it's not working as it should be, who's responsibility is it then?

R: There are three people here. The manager, myself and then there is also the defluoridation technicians or rather the head of that, and then the community. So those are the three main persons. But the overall co-ordination is the manager who makes sure all the parameters of that aspect are followed through.

I: And generally would you replace it completely, or would you bring it back here and replenish it and take it back to the community?

R: As of now the science is such that it makes economic sense to replace it completely rather than to clean it . Because cleaning is possible, recycling is possible but the cost will go high. And in some cases we have question marks in as far as how long will it last beyond the recycling. So it is recommended that we have clean bone char every time we replenish. But research is on going now and we think that we could be able to have complete replacement using recycled material.

I: So while it's being replaced, what happens to the water. Does it just go untreated.

R: There is a pocket of maybe like two or three days, where people will have to take untreated water. That is one of the weaknesses of our system. In other words you'd have to have a secondary plant treating water in the meantime an inmost ass that does not happen so that means there will be a gap of 2-3 days which we think should be ok. I mean there's not so much being drunk… and also we try to tie in whenever possible with, we try to time our replenishing to coincide with the rainy season, so that people have alternatives to that.

I: Now I'd like to talk about an alternative system, so perhaps the possibility of producing it completely locally, using the community, them being responsible for the supply to the filters, and then the operation and maintenance, and just talk a bit about the feasibility of

that. So what essential infrastructure would be required for a community to be able to produce and monitor bone char themselves?

R: You mean bone char? Or the?

I: Actually produce the bone char

R: You would need to have supply chain for the purchase of the bones, the source of raw material in this case. Then you would definitely need to have a working kiln. One that is going to char the bones to the desired specifications. So the kiln could be any size depending on the output required, however it must be standard kiln that is meeting all the local government or whatever, environmental issues. Now the third portion of that would be a crushing machine, that one must be there because again you want to control the crushing. And then you ahve a tertiary or the next point would be the cleaning tank, or a cleaning process. Whatever method you use there should be a cleaning process afterwards. And then very minimal chemicals. In this case we're talking about monosodium hydroxide an in some cases carbon ioxide or pH calibration. So those are the basics.

I: Of course, the community would need money, obviously. Do you think in your opinion the communities you are serving at the moment would have to capability to produce bone char themselves?

R: They might have the capability. They might even get the funds, but the justification would be the issue. Do you need a bone char producing plant? That is the question because what would you use the, after you have done all that, does it make sense, is it a good investment? Because it requires money, maybe it might be a loan that you have to repay. Sustainability in other words. So those are some of the decisions the community has to do. But if they do have a long term effort or a desire to have a long term bone char production unit then it is worth it because the market is there.

I: In terms of the skills that the community would need to be able to effectively produce the bone char and then monitor it to make sure it was replaced at the right time, would the community need training?

R: There are some basic training, for example the operation of the kiln requires the capacity to be able to read data from a thermometer, I mean that kind of basic reading capacity. So someone needs to be trained on how to monitor the charring process. Then you also have to have some bit of chemistry as far as the cleaning process is. Somebody has to know the right proportions of mixing and then the overall, the basic training there would be managerial or other operational management kind of training. But safety is the underlying part so there needs to be somebody trained in rudimentary chemistry.

I: Do you think without someone like CDN promoting the importance of removing fluoride from water, do you think the community would be willing to invest in this and then pay for the water to be treated?

R: I cannot speak for many communities because priorities are the issues her. Do the community see fluoride as a social problem? Without our intervention I think It would be very difficult because if we do this because it is our job. It is what we do. So we have the time and the resources to go out there year in year out. But it might get tiring for a community that does not have a lot of support. So a few communities might want to go

that way but we think that the role of CDN and hopefully in future the role of the government in promoting defluoridation could help. But for now it would be very difficult. That is why you see, we are the only ones doing this. Even other organisations that know there is a problem do not necessarily invest in this kind of information. So it's tough, it's tough for communities to have that.

I: In terms of quality assurance, How easy is it to make sure you have good quality bone char? And what are the problems if you don't have good quality bone char?

R: Quality assurance, we are talking about now what i mentioned earlier, about the control of the charring. The packaging of the bones has to be done just right, and then the placement of the hot spots, or rather the burning points has to be done just properly. And then the kiln it'self must b signed in such a way that it is not going to either overburn or not cook properly and finally you're talking about the human element here. Making sure that there isn't over-burning then that person has to have the discipline to make sure they are there so it can be controlled. And make sure you give it the number of days that are required and make sure that all the parameters, all the operational guidelines are followed to the letter. But it is not diffiult. I just mentioned those issues to show that it is supposed to be followed, but it is not difficult.

I: So if you didn't produce bon char of the same quality that CDN produces, what would be the consequences?

R: There could be huge consequences. Basically, you're talking about health. Because you are talking about a bone that is coming from either an animal that died from maybe anthrax or something like that so it's very important that the bone char is charred to perfection, or rather to completion. So for example if you are finding undercooked or under charred bones, then you know your kiln has got a problem and you are likely to pass those problems to the community. Plus the water is going to taste. You'll find the water that is going to taste bitter, just like almost taking water with, like taking charred food. You know how bad it can taste. Again on the other hand if you overcook then you're not removing fluoride, you're removing very little amounts of fluoride so you'll be incurring huge costs in terms of producing very low grade bone char. So it is important that it is done properly, otherwise the consequences could be economic, they could be medical, they could be even legal, if you are supplying people who want to sue you. But again the end point is maintain the good name that you have. Make sure that your clients or your customers are properly given the best quality there is.

I: Finally, I would like to discuss an alternative business model, where a subcontractor is used in a more decentralised system so for example, DN would continue producing, but would then actually bulk sell it to a sub contractor who is then responsible for distributing it in a small area and then the monitoring and maintenance of the filters. What are your opinions of this kind of model?

R: It's a very welcome kind of model. We are trying to encourage people to do that as a matter of fact. Because we think if we can concentrate on the production and leave some elements of marketing to other people in this as, the kind of model you are mentioning, it could move towards a kind of arrangement that is something that CDN would be very welcome to work with. It's a matter of talking with an organisation, having an agreement that favours both organisations then we can sub contract, definitely. We are already doing that. Especially thd world vision kind of job that is exactly that. Because we do everything

here but they are the ones who take the bulk supply to southern sudan. We dont even go there ourselves so that is an exact example of that kind of arrangement that can be done even in Kenya.

I: What do you think would be important to make sure that that kind of business model would actually work? What would be essential, in terms of infrastruture, for the subcontractors, and then agreements between you and the subcontractors, and then the skills that people would need for the monitoring and the distribution?

R: I think the subcontractor should be equipped properly to be able to sustain that kind of business model. Because you are talking about having a supply that has a market. If the market is there and it is sustainable then the subcontractor will be able to break even, otherwise it will be very difficult for the subcontractor to keep on selling bones and we can produce the bones, and we can sell to the subcontractor, but what does the subcontractor do? So the subcontractor should have a good market survey properly done and then the right people to make sure that they sustain the programme. So I think the huge part has to be the human element. So also, the subcontractor will also take over what CDN normally does in as far as the training of the communities. The monitoring aspect that we normally do. Because also it will be plants or fluoridation unit's that belong to the subcontractor in this case. So the monitoring, the sustainability aspect, the overall sustainability, operation and maintenance kind of issues will be part of the subcontractor's kind of role

I: So in a way it would be in their interest to raise awareness of issues of fluoride?

R: Absolutely. Always, always, whether it is electronic media or it is just word of mouth, community property, it leads to the subcontractor's advantage, and in a big way. Whether in Kenya, or East Africa or whatever region the subcontractor is willing to work in.

I: Of course there will b an issue of regulation there aswell. Because obviously you would want to ensure the subcontractor was working in the interests of the community. How do you think regulation would work?

R: With the agreement, we would have to set out what we expect as the end user kind of agreement, so that the subcontractor is not misusing the purpose of defluoridation. Thats the overall theme here, defluoridation. So the contract, the agreement it'self will address legal issues, will address ethical issues that a subcontractor is bound to follow. But overall we also will assist the subcontractor in as far as every now and again, paying a visit because we are not likely to surrender everything to the subcontractor, we will assist, because it is to our advantage if the subcontractor is successful. It is to our advantage, so it is a matter of going there every now and again, maybe every so many months we visit, the subcontractor's zone of operation, maybe ask questions and see what else can we do? And we will get the subcontractor to keep that conversation open. It's a partnership, it's not really a business, It's not a profit, it is a partnership. It's also, one of the key things that you have to remember that the impact of defluoridation is not less than 5 years, therefore you cannot know if you are making an impact, so it is a long term commitment so subcontractors will be ready to put a lot of effort on the ground for years to come.

I: And in terms of where you would find subcontractors, what kind of organisations do you think would be wanting to be involved in this? Or do you think it would be entrepreneurs and do you have any ideas of how you would recruit subcontractors.

R: We would be looking at the entrepreneurial aspect obviously because remember they have to make money. They cannot go there and just give away things. They have to break even. We would be looking for the entrepreneur to have very sound financial management aspects in place. But it is not the only thing. We are looking heavily at the ethical aspect. Remember this person must be good to have a good name with the community. But the entrepreneurial aspect is huge. At the end of the day no matter what you do, no matter the source of money, you will have to show justification for that money so the entrepreneurial aspect is what is going to drive either the success or the failure. Unless you have someone who is willing to give you money for free, and that is not likely to happen!

I: Ok great, did you have any more questions or comments before I finish the recording?

R: Not right now but It would be useful to have anybody willing to go that way should be willing to look at that aspect of the human being. That you are helping a human being to have a better life, so that is the overriding point here. We should not forget that no matter the technology, no matter the finances, at the end of the day we are talking about human beings, so that is the most important thing, and mostly children, so a generation will benefit either from the research, or not, depending on how we implement all this.

INTERVIEW 2

I: Would you be able to just introduce yourself and tell me about your role within CDN.

R: Ok my name is _____ I'm working with the CDN Quality control person, in charge of quality checking our products which we produce here locally and going further, doing research into new technology, contact precipitation fro fluoride removal. That is generally about me and what I'm doing.

I: If we start off on production. So you're quite involved with the quality control of the bone char thats produced. So could you tell me a bit about how you make sure that the quality of the bone char is good for giving the communities.

R: Ok the first quality control we control during the production is during the charring process in the furnace or the kiln. You have to control the temperature. The moisture content of the air inlet, so as to maintain the temperature between 400 to 500 degrees. When you go beyond 500 hundred degrees, the bone char will be white and the absorption capacity will be limited. When you go below 400, there will be black and some organic matter will remain in the bone char. Finally the end product will have some taste, some colour that will affect the water. So we have to quality control there. From there we go to crushing process. I'm sure peter has taken you through that process. The crushing, we have to increase the surface area for absorption. After there is washing process where we

do quality control also, during the washing process. To make sure to remove any organic matter that might have remained in the water. And finally the effluent water, we have to control 3 parameters, we have pH, EC, and the colour, they have to be within a certain standard. The effluent part of the water that is sused for washing. So washing we use sodium hydroxide, which is caustic soda, which removes any organic matter which might have remained in the water to do away with the colour and the taste in the water. So after the washing is completed with sodium hydroxide, the pH tends to go even up to 10 so we use co2 as a pH adjuster to bring down the pH to an acceptable limit. That is of the effluent water, the water that is used for sprinkling and washing. Then we have to check the EC test will be below 60. EC tells you about the ions present in the water, so it has to be below 60. And also the colour of the water. So normally we wash using sodium hydroxide and after we do sprinkling. We sprinkle with just plain water and flush it off, sprinkle, up to twelve times, as we monitor that water that is flushed out of the watering tanks.

I: The facilities that you use for the monitoring. You have laboratory here?

R: We have a laboratory here

I: And what kind of equipment do you use?

R: For pH we have a meter, connected to an electrode. For EC we have a conductivity meter. And for colour we use a spectrophotometer.

I: Moving on to monitoring of the community filters and the household filters when they're actually in place and they're up and running. How does the monitoring process work?

R: Monitoring is part of my duty. Once we implement a filter in a community, we go there, we do creation awareness, so the filter has to belong to the community, they have to take it as their own. Thats what we really wish. But now it depends on the community. The community they work very well, they bring a sample after 6 months, yeah they do the monitoring themselves, but they bring a sample to us for anlaysis. But some communities we have to go there in person and pick some samples and come analyse, we give them the data, so it varies, but our wish was that after we implemented, our work was complete. The community has to go further and do the monitoring for themselves. But yeah some communities they work very well, but others we have to push them, make some calls, do some follow up.

I: So the kind of agreement depends on how well the community adopt the idea of the filter?

R: Exactly. It all depends with the community. Some communities they adopt very well, they do everything. If we have some time I could take you to a very nice community around here. They're very organised, depends on the community. They have a committee with a chairman and a secretary.

I: So do you set up a water committee when you go there and put in a filter?

R: Yeah we go there initially before we implement a project, we go there we do creation awareness, we tell them, you have to organise yourselves, make a committee. Yeah so each community has committee members and a chairperson and a treasurer. But some of them with the changes, some of them change every year so it varies for community. But some they say there's no need of doing an election every year, you can do it throughout. So it all

depends on the community. But we do some follow up actually. Sometimes we go visit them, see how they are doing, we go pick a sample and go analyse to see how saturated are the material or how far the filters are, how efficient they are.

I: So you say you monitor every 6 months?

R: Yeah, ok, it was supposed to be quarterly. Yeah but the first year, at least we are sure, that is guaranteed that the filter is still working. But every year you have to do test at least 4 times per filter. We have some database in Access, where we feed in the details of monitoring, the results all that, so we know that this filter, we have to do something about it, we go there and do. Like now we did one in January, and then this is July, another one is going on. Another one will be done in September and another one towards the end of the year. Around four times, three to four times per year.

I: And does the community pay to have the water tested?

R: Yes they pay for fluoride it's highly subsidised, about 100KSh for a sample. For fluoride it's highly subsidised so at least they can afford.

I: And they also have to pay for the travel to CDN if they're bring the sample?

R: Ok there are different kinds of monitoring. There is research monitoring which we as CDN have some interest, so with that one with have to pay the mileage and everything else. But when a community they come, they bring a sample it's like they have the interest, they come, and analyse and then they just pay for their own means and the analysis cost. But the filter that we have some interest at least, we have some interest ourselves, we take all the burden of paying the mileage and analysis costs.

I: And do you think economics could be a reason for people not bringing samples to CDN to be tested?

R: Yeah somehow it's a contributing factor, especially the distance, yeah especially like, lets say Naivasha, you'll find some people they opt to go to other labs which is nearer, but at least they're doing some form of monitoring, they don't have to bring to CDN. But some community like in Baringo, they are very poor, so we just take the initiative and do the monitoring for them. I think poverty and the economy, economics is a challenge to them.

I: Is there any other monitoring or maintenance done on the filters themselves, or the operation of the filters?

R: When we go for monitoring that is picking a sample and coming to analyse, we also ask the committee, what is the problem, why is the filter not operating? So they tell you this is not happening, the tap has broken down, so some issues, they come up, it's part of our duty to maintain them. But some communities like that one im telling you, they do it for themselves, everything, if a pump breaks down they just repair it, out of the savings from the sales of the water. But others we have to take the responsibility and repair and do some maintenance.

I: Why do you think there's such a difference between communities? Is it something to do with the awareness raising or, the community structure, or the money?

R: I think it is the community structure , because ok some communities they were really effected by the post-election violence, the people who were there, they went away, so there are new people, who are there. There are new people on the committee as the chairman and the treasurer. It's a problem. But some you get they're very perfect. So it's al dependent with the community. Once they're organised, everything will run smoothly, but some you have to go an do some follow up. The performance, the operation, we have to train them before implementation, training, operation and maintenance, some form of training, we have to train the community on how to operate and maintain the filter. But in case of anything like I said, the pump breaks down, yeah we have to go and assist them. But some they do it perfectly. They told me, in fact last time, the pump was broken and we repaired, the bill was this much and we managed to pay.

I: Out of the revenue they make from the water sales?

R: Yeah. So it's all dependent with the management.

I: Moving onto this model of localised production. So imagine the community is producing the bone char themselves. In terms of quality control how easy would it be for a community to produce their own bone char?

R: That one is almost impossible! With the design of the kiln, in fact, some people are trying to duplicate it, but in Ethiopia, they are trying to duplicate the production system here. I don't know how far they are but like this kiln for it to char the quality bone char it took CDN from history, around 2 years here, it took them around three good years to produce quality bone char. They used to struggle with it, the bone char coming out was a real problem, so producing quality bone char is a problem.

I: And what infrastructure would they actually need, what would be essential to producing the bone char?

R: Producing it the kiln, yeah and some monitoring gadgets like the temperature control, yeah, the thermostat for monitoring the temperature, the crusher, the washing tanks, the chemicals used for washing, and plenty of water.

I: And what would be the consequences if the produced poor quality bone char?

R: The consequences, if the crucial factor is temperature. If they produce at let me say maybe 300, below 400 degrees Celsius, the bone char will not be of good quality in terms of some organic matter will remain, the water will have some taste and odour. And then if they go beyond, maybe the inlet air is so high then maybe the temperature may go high, maybe up to 600 then the final product will be white in colour and the adsorption properties of the white bone char is limited. So you can just tell the quality of the bone char by looking at it, so the best one should be grey-ish, brown-ish in colour, but if it's black it means some organic matter is remaining and then if it's white in colour the temperature was exceeded up to maybe 600 and the the adsorption capacity is limited.

I: Also in terms of skills that the community would need. Would the community just be able to produce it themselves or would they need specific skills and training?

R: Yeah they need specific skills and training

I: What kind of things would they need to know?

R: Ok like the temperature control, I keep insisting the temperature because it is the most crucial. They have to keep monitoring the temperature and also the air inlet, you know the air inlet will control the temperature inside the kiln. So they have to regulate, if the temperature inlet is so high then they have to cover, just behind the kiln there. They have to cover to regulate the air in

I: So they'd need training

R: Yeah they need training.

I: If the community was to monitor the levels of fluoride themselves, what facilities would they need to do that

R: For fluoride, since our system is phosphate based, we have to use the electrode method, the electrode method for analysis. So they need a fluoride electrode connected to a meter, some buffer solution for fluoride specifically and some reference electrode. Maybe I can take you through the lab? Just show you the equipment. You can use other methods like by using the spectrophotometer where there is some colour development, but that one, with a phosphate based system, you will get some positive error in the final measurement. So the best method which we adopted is the electrode ion selective method.

I: So they'd really need a laboratory for that?

R: They don't really need a laboratory, for just fluoride tests, not really. Just a bench with that meter, and the electrodes and the solutions, buffer solutions for fluoride.

I: Finally, talking about the alternative system. Where CDN was to concentrate on production, and quality control and then hire a subcontractor, in geographical areas, to then be responsible for distribution and monitoring and maintenance, awareness raising, so working with the communities. What do you think about that model? Whats your first impressions about how that would work?

R: It will make things easier because us at CDN we are really strained. Like in the production there is only one guy who is in charge of monitoring and supervising the production, but I support him sometimes, but he does also the implementation work. Yeah so somehow we are strained. In fact we are trying to get some people, someone who will be responsible for implementing and doing the technical implementation work in the field, out there. Yeah I think that could be a good thing to try out.

I: You said earlier that there was a problem with people coming from a long distance to bring samples to CDN to be monitored. If there was somewhere more locally that hey could go and do it, do you think that monitoring would be done more often by the community.

R: Yeah I think it can improve because this is also a challenge. Going up to 200km away for just analysis. But if they could get a lab within say a town like Naivasha, but going to Baringo there, getting to a laboratory is a problem so they have to come all the way to Nakuru, to access a lab. Yeah that could be a way of improving the monitoring systems that we have now. But it all depends with the community. Like Baringo. It's really a problem, coming all the way. You know to them, it's a very poor community.

I: If that kind of model was to be adopted, what do you think would be important to make sure that it was successful, so the agreement between CDN and the subcontractor, what would be important?

R: I think the most important thing is the co-ordintation between CDN and the subcontractor you are talking about. If you can co-ordinate and do the work together, it could be perfect. I think it's a good thing to try out, because now, all the burden is for CDN to do the production, to go ahead and implement, and going further to monitor these filters and the operation and maintenance it's really overburdening us, and we have so many clients, yeah i don't know if peter has told you, we have only 12 working here for the fluoride project, and we have to do all that work. So somehow we are strained.

I: Were there any more comments you wanted to make about anything or any questions?

R: No not really. Thank you.

INTERVIEW 3

I: If you could just introduce yourself please?

R: In the water quality section, you have three subsections, now where you are is referred to as relations. Because here is where we try to lobby for a fluoride free society and also we create awareness on fluorosis and water quality. We also train communities on monitoring and evaluation. So before they go and implement, the implementation section, we normally create awareness, and in creation of awareness we use an entertainment approach, where we have a theatre group, a group pf young people, they are using artistic performances, just poems, comedies, just so when they are acting they are entertaining but at the same time they are passing information on fluoride and water quality. So before we go to any community, we have to create awareness first, and when we go our link in the community, normally we approach the chiefs, the village elders, the head men. So we have to go and tell them what we want to do, then they're the people that mobilise the ground, we are coming. So they mobilise people and also through 'barases' barases are meetings where the chief calls everybody in the village and if he or she has any important information that he wants to pass across then he normally uses those forums. So after the creation of awareness, there is the implementation. Then immediately after the implementation, the construction of the filters, we normally undergo training. And in the training what we normally factor in is water and sanitation because we can give people water but eventually you think that maybe you've given them safe water but there are other diseases that may crop up. If they are told maybe that how they are storing their water, how they are using their water, if they are not using it to clean maybe, make sure they are ensuring that cleanliness. So we normally factor sanitation, and in sanitation it depends. Because we've got some areas, they are still using bushes, bush, they go to the bush. When they go to the bush, are they using water plants? Where they collect the water, so everything they have done in the bush is swept, and so they drink the same source, and some of them may suffer, from some disease like cholera. And in the training, normally what we do with the community, we don't train them as such, but we are using what we call 'thee point sorting' this is just a set of pictures. One is good behavior, showing good behaviors, the other one in-between behaviors, not good, not bad, in-between, and also we have bad behavior. So when we show them the pictures, then we ask them, what are you seeing? Are you seeing somebody defecate maybe in the bush. Is this good behavior or bad behavior, and then they tell us. So that is basically what we are doing. And also, in monitoring when we train them. We also tell them maybe for the filter that you are using, after maybe 6 months or 1 year, they need to bring a sample of the water from the filter to our laboratory here, so when there is somebody coming maybe to a place, they need to bring that water, then it is analysed. Then after that they are being told to continue, either continue using it for some time or they have to mobilise to buy the new material

I: So what challenges do you face with trying to persuade communities to bring the water to be monitored?

R: The challenges you know, some of the communities we are dealing with, they're degree of poverty is quite, very high. They are not able even to afford a meal, so you can imagine for them, they are not able to afford a meal and a test here for fluoride is 100 shillings. So you see because of poverty, in fact sometimes when you go there, when we go to train them, we are forced to carry food, because they are poverty stricken areas, but when you go with food they are able to sit there and listen to you all the time. But when you don't have food, people feel hungry and they start going away, but immediately they realise that you've come with food you get a good core of people until you finish everything that you've come to discuss. And also, you know, we are dealing with the issue of bones, there are some areas you know, if you are using bones, some of those cultural region's beliefs.

Like when you go to create awareness to Islams, they say 'are you using pig bone?' if you go to Hindus, 'are you using cow?' and because they think that they are sacred, so if you use them you are offending them. And also the other thing is that we realised, people are more to quantity, rather than quality. Provided I have the water, I don't bother about the quality. What I need is water, that was my problem. So when you start talking about the quality. They say 'me only need water first, before you start telling me about the quality.' So it is also a challenge.

I: And do you think the distance is a problem as well because some people have to travel a long way to get the testing done.

R: Yeah of course some people are walking. Some people come from far, 300km, 250km away, simply because the water testing laboratory, there are few. Like here in Nakuru, there are only 2. So you can imagine people from the other side, Baringo, the other side. So they have to raise first of all the transport, to reach here, to and fro. So it is a problem.

I: And an alternative system is the idea of CDN concentrating on production and then subcontracting to more local organisations to be responsible for the distribution and the maintenance, so that communities have less distance to travel for example, to test the quality of the water. So you think that that would encourage communities to monitor more effectively?

R: That would encourage, if we have mobile laboratory testing. Maybe we go to certain communities, tell them we are coming. Let's say for Naivahsa, so all the water projects we have in Naivasha, we collect their sample for them, then it is tested at one point. Or maybe we say later once a month we go there to different places where we have the community filters.

I: How often do you need to monitor?

R: Normally the community filter after 6 months. Because we need to keep on checking. After 6 months or even after one year. Just to be sure. But also we train the community themselves to take charge of the monitoring, because monitoring is a continuous process. You don't monitor today then it is finished. You need to keep on monitoring. Because for the material to get saturated it depends on two factors, the consumption. If they are using more water so we know it can get saturated earlier, so they keep on, they need to keep on monitoring.

I: And what sort of factors influence how easy it is to create awareness in a community, and train them to do these kind of things?

R: You find the communities that are maybe in the urban setting, the way they handle even the project is quite different from the other one, simply because they're management structures afre well defined. They have good officials, maybe the leaders the leaders that have been elected to manage the project, they are there, they are keeping records, and also if there is a crisis, a conflict, they are able to resolve it and you find that when you tell them you are coming, they are ready to welcome you, simply because they know the objectives, why we have done this project. If they hear there is something good coming up to help them, for them to benefit, they turn up in numbers. But in other areas they just say; 'there's no need in going there, are they going to give us food? they're going to tell us things we know, so there's no need'.

I: So you think perhaps how much money they have effects?

R: Yeah because the others you know they have the accounts whereby they save because they know this project, they need to maintain it, so they keep accounts, they keep money, they know, or they have ways of raising their funds because a tap breaks or anything, so they keep on making sure they have enough money.

I: If you don't involve the community, if they don't contribute something then they don't feel they own the project, but if they contribute to it, they will be able to own the project. So that's why we normally tend to, it's good, you also contribute on your side and you also contribute on our side so that you can be able to own the project. Because once the project is there, we are not the ones that will be using that filter. We are not the ones that will be using it, we will go away, so how about it. So they need to own it for the project to be part of them.

I: And when it comes to the replenishment and the replacement, and you say to the community, that their filter isn't working anymore and they need to replace the bone char. Are there any challenges with mobilising them to then come up with the funds?

R: Yeah there is a challenge, simply because some, we find that they are using it and there is no mechanism put in place to save. Even though we tell them this material will get saturated, what are you going to do when it gets saturated, because you need to be prepared all the time, because it can be saturated any time, so what do you do? So you find that some communities the material is saturated, they don't know what to do, they go maybe try to mobilise for funds, they are not able, so it takes some time before they get funds.

I: In the meantime, they are drinking water that is not being treated properly?

R: Yeah, well they continue using the water, but you know for this one, at least for the household, those are small unit's which they use at the household level because you know it is somebody monitoring individually. But you know for the community people say it's for the community, not for me, it's for all of us. But you know for this one you say, it's for me, but for the community sometimes it's a challenge, you are not able.

I: Do you encourage them to use the revenue from selling the water to replace the filter material?

R: Yeah yeah yeah, because we encourage them especially those who have community filters, they have these water kiosks, they normally sell water, and what we normally advise them, it's up to them, if they are told they are selling the same price their treated water and the raw water because they want to decide for themselves, we cannot tell them. Some communities they sell water, but for other communities like Baringo where they are using surface water from the lake, and they are forced to pour it to the filter. Like when you to Baringo we have the filter, they are not able to sell. But for these others that have water kiosks, they normally sell water. So yeah basically part of the money they are making they keep aside for the operation and maintenance of the filter.

I: So your involvement with the community. You say before you put the filter in you do awareness raising.

R: Yeah because you have to tell them before you put the filter in, what you are going to do, so awareness is very important, thats what we realise. For you to maybe go to the community and to have success, first of all you have to create awareness.. If you convince them that what you want to do is good, it's for their benefit, actually they will be able to embrace what you want to say of the project. But if you don't create awareness, just bring and put it there, you will see nobody using it because they don't have the knowledge, they don't know why you brought it, so unless you tell them how the water they are using is affecting their life, some of the diseases like dental fluorosis, skeletal, you need to explain to them. Give them time to ask questions, even if it is a silly question just to understand. So after the awareness creation, thats when we go in now and start mobilising.

I: And do you ever go back and do more awareness creation later on?

R: We don't really go back, but also during the training now we run awareness creation, takes like maybe 1 hour. But when we go now for training, it takes like 2-3 days. So now in the training now we are able to, what we didn't catch in the awareness now in the training we are able to...

I: And do you give anyone on the water committee responsibility for awareness?

R: It is we who create awareness because we know what we are talking about. Because if you give somebody in the community to create awareness maybe it can mislead people, unless we really really train that and convinced that this person is trained, when this person goes to the community there and be able to train exactly what we are doing. So when we defined someone in the community we would have to train him or her well, because it may mislead people there, the community. And you know if people get wrong information then they say ..... because if the awareness creation that you see, talking about this, some of this is talking about chemistry, you this is dental fluorosis, how you say that you know fluoride is being attracted to calcium, you know, somebody in the community may not understand that because it is more scientific and chemistry. So it needs somebody who knows well. But of course they have that general knowledge, that oh it is cause by water, oh it is caused by high levels of using water with high levels of fluoride, that's why the problem arises.

I: So you find that that one awareness raising stage and then the training after that is passed on to new generations i the community?

R: But of course when you train some communities, those who are knowledgeable, they end up going also and telling others so that is part also of sensitisation and awareness because also, I've got the information, I've got my friend who was in a certain meeting, who learnt about this., so people learn this way. And also we leave the materials like you have seen some information stands we have you here?

I: Yes I have.

R: So where we constructed these water filters, we usually leave information for them to read. Which is also part of awareness, because when people come to fetch water at the same time they ar reading and they are able to get information.

I: And with the CDN filters, do you sell non treated water alongside them, or do you only sell treated water?

R: Where we have constructed the community filters with a water kiosk, this kiosk will have, we have a water kiosk. This water kiosk will have a pipe that is bringing out water that is raw and the other one is treated. So when you come to buy water, you are being told, the water for cooking and drinking, buy the treated, water for other uses, you buy the raw water. So in the kiosk, there is a way we have managed the pipes.

I: Does the kiosk vendor tell people what they should be buying?

R: Yeah because the person, the caretakers, we normally call them for workshops during the training, we usually train them because they are the people meeting people, many people, because they also need to be knowledgeable because somebody may come and ask yu a question: which water am I supposed to fetch. If you do not know the water, they say, ah what is water. So when we meet them we just tell them to keep on telling people this is the treated water, for cooking and drinking, this is raw water for other uses.

I: Thank you, that's the end of my questions, was there anything else you wanted to say or any questions you wanted to ask?

R: What I just wanted to say, working in the community, is good, in fact community if you go there, they know you, you really be able what you want to, if it is a project, because what I feel is, community awareness is very important, community awareness, without the awareness you cant do anything so you need to go first of all, talk to people. Share in what they are saying everything, and when you come to learn they also know you, and if they have questions they can ask you and because you have created that rapport, good rapport. So if there is any project that you want to run there, it will be easier for you. But when you just go, or when you just go and meet the leaders, don't meet the leaders, meet everybody, if the project is supposed to benefit each and every person, call them, everybody, women, men, youth, everybody. But when you rely on leaders only it wouldn't be a success, but when you call a meeting for a community meeting, then each and every person airs his or her views, then you will have success.

INTERVIEW 4

I: Could you just explain who you are and what your position is within CDN?

R: Ok i am _____ and mostly I am concerned with the production of the filter materials. That is the bone char, the pellets, and also the side of implementation in the field. Implementation of the filters.

I: So if we could start off on the production side of things. Starting from the very beginning. Where the bones come from?

R: The majority of the bones that we us, they're mostly from animals especially cows and goats, animals that people use in eating. Then we get them from butcheries mostly. People collect them and bring them here and we buy them for 7 shillings per kilo. Mostly people bring bicycles, lorries, pickups.

I: Ok and you don't remove cow bones if muslims wouldn't want to use the filters?

R: Most people are not muslims. You find in the localities where fluoride is, there are not many muslims. So we have not found much resistance in the use of the filters due to the source of the bones.

I: And so when you put them in the kiln, how much bone o you use?

R: The kiln we are using currently takes around ten tonnes, and they stay in the kiln for about ten days. The precise temperature is around 250-400 degrees.

I: How much bone char does that produce?

R: With a ten tonne load, depending maybe on how the bones burned, we are able maybe to produce like half of that. Around 4-5 tonnes of filter material

I: How much charcoal do you use per load

R: We use like around 20kgs of charcoal. We out thm at th top of the bones at ifferent points, maybe 2, 3 points.

I: So that's 20kg over the whole ten days of burning?

R: Yeah, because the charcoal is just meant for igniting the bones. Once they get fire and the fire is well established, then it starts burning.

I: So the next stage is the crushing?

R: Yeah, so depending on how the bones have burnt, because in some channels maybe the temperature has gone too high, above 400, 500 degrees, you see around that temperature the bones get white. Some maybe are under burnt. Temperatures less than 200. They are black. Because the bone gets black and then grey-brown. That is around the precise temperature 300-400 degrees. Then after that when the temperatures are too high, they get white. So there is that activity of sorting. They sort the black ones to be bunged in with the next burning and the white ones, we still use them in the filters but we also crush them because they are also used for bone meal.

After the sorting, thats when we crush the bones. The grey brown ones we mostly use for the filter

I: So crushing, what machine do you use?

R: We use an electric machine which is using power and, there is one w use for crushing an also for sieving. Because after crushing now we need to sieve them to different grain sizes, to remove the dust and have the sizes you want.

I: So how long roughly per load would it take to crush and then sieve?

R: In one load it can take maybe like 1 week. That is the crushing and also the sieving. From there that is when we go to the washing tanks. The washing, that takes roughly 2-3 weeks.

I: And the washing runs on electricity as well?

R: Somehow because we use the caustic soda, to remove the colour and also in the process we are able to remove any trace of dust, and also they are also cleaned. So w use water pumps, we also use power and sprinkling.

I: Once the washing is one, what is the next stage?

R: Once the washing is completed that is when we monitor the pH it shoul be around 8.5. now we dry. We dry it in trays under the sun. After that we just pack them.

I: Throughout the whole process, is there any wastage?

R: Basically there is not much that we waste. In the part of making the filter material. You can say the dust is the by-product but normally it is not necessarily waste, because you see in this country we use it to make bone meal, that is for maybe poultry and also for livestock. So they come here and then we sell to them

I: Sell the bone dust?

R: Yes because we cant use the very fine material for the filter.

I: And what happens to the over-charred bones.

R: Those ones, we also use them. It's only that the uptake capacity is not as high as the nicely brown bones, but they still work.

I: But you use them in a smaller proportion?

R: A smaller proportion yeah, because mostly we monitor the furnace to burn at that temperature of 300-400 degrees. So we find even one burn it is not much white bones which we get, it is not much black that we get. So we get 80% brown at once, and then we get some 5% of the black and the rest is white, but we mix it with the brown.

I: Ok great. So moving on to where you have filters at the moment, where are your filters located?

R: Currently mostly we have filters around this Nakuru area these are the most places we have the filter. More concentration in Naivasha area, Nakuru and Baringo. Maybe in Nairobi some few filters here and there. It is only now that we are extending further to maybe central province, where there are traces of fluoride.

I: Can I ask how maintenance and monitoring of the filters works. So who's responsibility is it to do that?

R: Basically this can be a challenge sometimes, because it is meant to be the community's initiative to be monitoring the water. So they can know when they need to change the materials. But sometimes you see in these places, it is not normal for water laboratories, so you cant just take a sample and get it sampled. There are not quite a lot of water laboratories around. So, and also to us, we have taken it somehow, just to monitor ourselves, to see how our plants are operating in the fields. But you will find maybe that some places are far, so we do not monitor them as much.

I: So the distance is quite a big factor in how often they are monitored?

R: Yeah because you find that the distance, some are like 70, some are 100km away so you can fin in some places they have not been so effective in periodically monitoring. So if we pass by we take a sample.

I: But it should really be the community's responsibility to do that?

R: Yeah.

I: Ok so I would like to discuss the idea of local production of bone char with you. So communities producing it themselves and then monitoring an managing it themselves. What do you think about this?

R: The charring process is a bit too complicated, so maybe having th community to produce th bone char by themselves can have that challenge of maybe burning thm right and also th process of washing them an all this. It is a process which is taking time an also to mak some laboratory for the checking of the pH and the quality of the en product

I: So what infrastructure would they need?

R: A kiln, a crusher, washing tanks, and... Kilns, you can dimension them into whatever size you want. You can have them very small. The community could produce the char themselves but the process of washing and testing, that's the big. Because you think of crushing, you can crush by hand.

I: So what are the consequences of bad quality bone char?

R: A badly produced bone char for one can have a bad capacity and also if it is not charred properly it will give maybe colour to the treated water, you could also have some odour or something so.. that's the challenge.

I: Do you think that without CDN raising awareness, that a community would be willing to invest the money in producing their own bone char?

R: Setting up a defluoridation unit, has a cost implication. Somehow you need an investment. So i am not sure how a community can do that, unless maybe they have a donor, who can assist them. It's a bit challenging cost wise, and also the technology behind the bone char process.

I: Another model that I am considering is where CDN concentrates on production, and then bulk sell bone char to sub contractors in a geographical region who then sell the bone char to communities and are responsible for the monitoring. So they would have the lab facilities there. What is your opinion of that kind of model?

R: So CDN produces the bone char, and sell to businesses, who in turn sell to communities an also facilitate the monitoring process?

I: Yeah

R: I think that sounds like a good plan. It can work. Because they can put more emphasis on the monitoring and the awareness creating to the community, empowering the community, all these things. It's an opportunity.

I: What do you think would be necessary in terms of the agreement between CDN and the subcontractor for that model to be successful

R: You see now, we even have firms which we are working for. We train their people, the people who will be implementing it in the community. So they would have to be responsible for the monitoring and the training of the community, so more people will buy.

I: So you are saying that it is in their interest to raise awareness so that more people will buy more bone char?

R: Yeah if they can give it the initiative. It's also funny because you know like here we go for everything at once. The staff capacity needs to be higher. The amount of people you need to employ needs to be high because co=operation with the community, awareness creation, production, all these things, and the facilities. You see as more people are getting aware of the fluoride issues more people will be coming and we won't be able so much maybe to take care of them. More clients will be coming, so, if there can be someone in between. CDN managing the production, and then another firm who can be buying materials and selling them to communities and doing maintenance, monitoring, awareness

creation, I think that can be good. It's an opportunity. And for that now especially, our capacity has to be higher so we can really be able to upscale ourselves and really produce lots of bone char.

I: So more kilns?

R: More kilns, more washing tanks...

I: So you think awareness of issues of fluoride is increasing?

R: Yeah. Compared to when we started, now w find that people are getting more serious on the aspects of water. Water quality in general. So we find them taking fluoride more seriously. If you have someone who is fining their teeth brown, what is the solution, what is the problem? So people are getting aware of fluorosis issues as time is going on

Now you find that surface waters like rivers are drying up, people are tending to use groundwater. And groundwater mostly has these fluoride problems

I: Great thank you. That is the end of my questions. Was there anything else you wanted to discuss?

R: We have an issue where fluoride and fluorosis... you know for one, in Kenya, there are not a lot of people who have running water. And you find that because fluorosis is something that comes very gradually, the first priority is taking water, it's coming very gradual, people don't tend to take it so seriously. The problem is that once it's there, it's done, it's not reversible.

I: So do you think that effects people's willingness to invest in...

R: Yes, invest much in de-fluoridation. There are problems with fundraising because of this.

INTERVIEW 5

I: How long have you owned your filter for?

R: Just under a year

I: what made you get a filter?

R: Well my children's front teeth started going brown. I hadn't really thought about fluoride before but one of my friends got a filter from CDN...

I: So did you buy it from the CDN in Nakuru?

R: Yeah, I just drove over, and bought the filter and the filter stuff. They showed me how to put it all together.

I: and how many times has it been tested to see if it is still working?

R: only once actually. I keep meaning to do it again but I haven't got round to it.

I: how did you monitor it last time?

R: the CDN told me I needed to test it every six months, so I took a sample of water to them for them to monitor, and then they just sent me a text saying the water was alright.

I: So you had to take it to Nakuru?

R: Yes.

I: How did you get there?

R: I drove.

I: would you have considered public transport?

R: possibly, although I hate taking matatus and the CDN isn't actually in the centre of Nakuru, so it would have been awkward to get to

I: Did you pay to have the sample tested?

R: yes, 100 bob I think.

I: do you know what happens when the filter material needs replacing?

R: I don't know actually. I have to buy some new stuff to go in the filter, and then I think I give the old stuff back to the CDN. I'm guessing I have to go to Nakuru to do that.

I: is there an alternative to the existing system that you think would be better?

R: Um, im not really sure. I suppose Nakuru is quite a long way to go just to get a test done. There should be a lab or something in Naivasha where you can take it to. I dont know, thats probably why i haven't bothered getting it tested again.

I: how about producing the filter material? Do you think that it's best that CDN continues to produce it?

R: I don't really know. I mean, it would be handy if they made it in naivasha, then lots more people would probably have filters. I didn't even know about it until my friend told me. I don't know how you make it though and the CDN do seem really good.

I: great I think that's all of my questions. Do you have anything else you would like to discuss?

R: only that I wanted to say about ... that I didn't really know about fluoride or what it did and stuff until my friend told me. And that's quite worrying I suppose because it's quite easy to stop. I can't believe that this filter actually works! But you see people all over Naivasha with brown teeth and it's really sad because they probably don't know what caused it, or what to do about it. I think the government should be doing something, but they wont. I mean, people are still drinking out of the lake...

APPENDIX C

Informal interviews	Summary
Kiosk operators	
Nakuru 1	Kiosk operator very knowledgeable about issues of fluoride and importance of using revenue to pay for replacement of filter. Less well aware about monitoring as CDN does this for them.
Nakuru 2	As above.
Nakuru 3	Kiosk operator no longer selling treated water as believed that after 6 months it is no longer safe to drink. No monitoring.
Nakuru 4	Operator quite knowledgeable about fluoride problems. Dont sell water as this is a school. School pupils take water to CDN for monitoring as they pass this on their school bus
Karagita 1	Kiosk operator not very knowledgeable about fluoride. Know they need to save money from sale of water but unclear why. Dont seem to know how to get water monitored
Karagita 2	As above.
Karagita 3	Good knowledge of fluoride and know about importance of monitoring.
Karagita 4	Kiosk operator not very knowledgeable about fluoride. Know they need to save money from sale of water but unclear why. Dont seem to know how to get water monitored
Karagita 5	As above.
Karagita 6	As above.
Butchers	
Butcher 1	Very few bones left over, people take them for dogs. Use them for cooking
Butcher 2	As above.
Butcher 3	As above. Said they would be happy to sell them
Butcher 4	As above.
Butcher 5	As above. Also give bones to local restaurant.

APPENDIX D

Observations	Summary
Bone supply	People on bicycles bringing bags of bones. Weighed and deposited in store. Paid. 3 people arrived in 1 hour
Production	
Kiln	Large brick kiln with chimney and holes for monitoring temperature. Sectioned door
Crushing	Crushing machine. Run off electricity into wheelbarrows
Sieving	Sieving machine. Run off electricity into bags of different grades
Washing	Electrically monitored washing machine. 4 tanks. Sprinklers, CO2 tanks
Drying	bone char put on metal trays under sun.
Labour	Roughly one labourer per process
Kiosk organisation	
Nakuru 1	Very well organised. Office with complete paperwork.
Nakuru 2	As above
Nakuru 3	No office on site, paperwork complete. Visitor's book
Nakuru 4	No office on site, although have office in school.
Karagita 1	No office. Paperwork kept in kiosk. Up to date records of visitors and filter discharge
Karagita 2	No office. Paperwork kept in kiosk. Records of filter discharge
Karagita 3	As above
Karagita 4	As above
Karagita 5	As above
Karagita 6	As above
Meat consumption karagita	Very little meat sold in shops and no evidence of meat consumption at all in homes.