Communication Skills I

Extended Abstract for the Presentation of

Drinking water treatment with ceramic filters in Africa

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Introduction

1.8 million people die annually because of diarrhea, of which 88% can be traced back to unsafe water and poor hygiene. [1] According to estimations of the World Health Organization (WHO), 94% of these diarrheal diseases can be avoided by improved water supply and sanitation. [1] 1.1 billion people worldwide do not have access to "improved" drinking water supply and especially in large parts of Africa the supply of good drinking water is inadequate. [1] African countries where more than 75% of the population have access to clean drinking water constitute an exception (in 2002). [2] Altogether in 2010 about 344 million people living in Africa did not have access to improved drinking water sources. [3]

Too often there is no safe central waste-water treatment plant and method. In order to improve the quality of the drinking water, the water can be cleaned directly at the point of use. This can significantly reduce the risk of dying from waterborne illnesses. In most cases these "point-of-use" treatment facilities are easy to manufacture and improve water quality enormously. [4] The diarrheal diseases are reduced by this considerable increase in the microbial water quality. It is also a very cheap version of water purification. [1] One of the most common "point-of-use" technologies is the ceramic water filter. [5] In developing countries (such as the African countries) it can be produced locally because only a few raw materials are needed and the traditional craft methods of the individual countries can be applied. According to that the required know-how for the production is already available and only little costs are incurred. In comparison to other filter method productions a lower effort is required. Due to the porosity of the filters, suspended solids, filiform bacteria and protozoa can be retained from the water by means of physical removal. [6] A similar and alternative "point-of-use" technology in developing countries are sand filtration processes, which can also be produced directly on site and therefore are a cost-effective way of water treatment. [7]

Manufacture of ceramic filters

The ceramic filters can be produced on site, with the individual production steps differing little for different filter types. First, the materials are selected, with the main components of the filter being clay, water and combustible materials. The added water is responsible for the processability of the clay, but it also affects the shrinkage during the further processing. The combustible material (e.g., sawdust, flour, rice husk ash) burns during the firing process and produces the desired pores. Due to the different diameters of the materials, pores of different sizes are formed. If only a small fraction of combustible material is added, only a few cavities are produced. Moreover, fire-resistant stones (chamotte) may be added (eg, pre-fired and ground clays, abrasive bricks) to minimize shrinkage during the firing process. The selection of the grain size depends on the desired properties of the filter (flow rate, cleaning performance, etc.) and the available possibilities (e.g the resources and the tools). Subsequently, the materials are mixed so that a relatively dry but still coherent mass is produced. A precise formulation can not be specified as this is strongly dependent on the materials, the tools and the ambient temperature. Subsequently, the filter is formed. For this purpose, a corresponding shape is required in which the later filter can be pressed by hand (or in better developed countries with a filter press). After the filter element has the desired shape, it is dried for two to three days, which prevents the formation of cracks during the subsequent firing of the filter. Most kilns in developing countries reach temperatures of approx. 700°C.

Higher temperatures increase the density of the filters and thus reduce the porosity. In order to achieve the optimum firing temperature for the production of ceramic water filters of 900-1000°C, heat-resistant kiln stones are required which can withstand repeated firing. Such bricks can be conveniently made with earth, sand and sawdust. [8] At firing temperatures >900°C the ceramic filters are vitrified and hard and permanent filters are formed. [9] The water filters are ready burnt in the ovens. After firing, it must be determined that the filters do not show cracks. The filter could then additionally be coated with colloidal silver in order to achieve further elimination of germs. [8]

In general, the structure of the filters is always the same. In this case, the filter system and the filter element (or also filter media) are distinguished. The filter element consists of the actual filter through which the water flows. The filter system accommodates this element more specifically the raw water and the purified water. Different filter elements differ in terms of some parameters, including their shape: so-called pot filters, disk filters and candle filters (see Figure 1). They also differ in the various materials used, for example how sandy is a clay or which combustible materials are used [8].

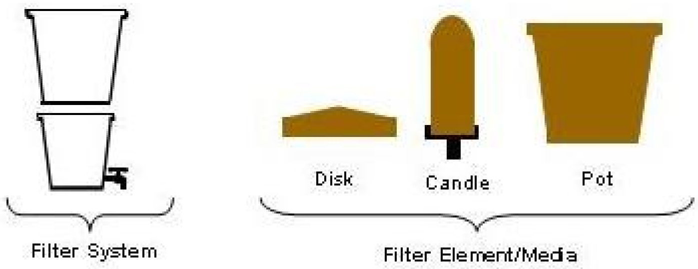

Figure 1: The filter system and the different forms of filter elements [8]

The Disk filter is a simple filter in a container (filter system) on which the water can be removed in the lower part (e.g. by a tap). The Pot filter is pot-shaped. There is usually another container that collects the purified water. The pot filter is placed on top of the other container and then filled with the raw water. The Candle filter also consists of two containers and additionally one or more candle-shaped ceramic filters, which are fastened to the bottom of the first container. There is a hole underneath the filters. In order to get into the extraction container, the raw water flows through the candle filters. [8]

Advantages and disadvantages of ceramic filters

The most important advantages and disadvantages are presented in Table 1

Table 1: Most important Advantages and Disadvantages of ceramic filters (as per [8]; [6]; [10]

Advantages	Disadvantages
• Economical and cheap in manufacturing and producing • Materials are readily available (sand, clay, saw-dust, rice husks...) • In most countries ceramic trade is established • Necessary know-how for the production is available • High cleaning performance (with regard to microbial contamination and turbidity)	• Partially slow flow rates (Ø 1 - 3 l/h) • Very fragile • Service life and reliability are user-dependent → difficult to ensure the durability • In poor countries there is often no high production rate

Guidelines and cleaning performance

Escherichia coli (E. coli) serves as an indicator of fecal contaminated water and should not be in drinking water. [11] A study in Cambodia with ceramic filters shows a removal rate of *E. coli* up to 99.99% (mean value 98%) and a reduction of diarrheal diseases by 46%. The water turbidity is reduced by 70%. [12] The removal rate of *E. coli* bacteria with biosand filters was carried out in a comparable series of experiments, also in Cambodia, and is 95%. The water turbidity is reduced by 82%. Compared to families who have not used this filtration method, the reduction in cases of diarrheal diseases is 47%. [7] The removal rate of *E. coli* is therefore better with ceramic filters, the turbidity is rather reduced by sand filters. The reduction of diarrheal diseases is comparable. However, according to Brown et al.[13] the risk of diarrheal diseases does not increase in the way as an increase in the *E. coli* concentration in the drinking water.

The WHO principle is that "*E. coli [...] should not be present in drinking-water.*" [11] In order to assess sanitary situations, the WHO [14] sets guidelines for risk groups (Table 2). They are determined by *E. coli* bacteria, which the population in developing countries is exposed due to the water supply.

Table 2: Classification *E. coli* bacteria in water treatment (as per WHO, [14])

Amount of bacertia per 100ml	Risk
0	WHO guideline
1-10	Low risk
11-100	Middle risk
101-1000	High risk
>1000	Very high risk

According to a study by Murphy et al.[5], ceramic filters compared to biosand filters have a higher probability to keep these guidelines of the WHO [14], especially for a low risk of infection by *E. coli* bacteria (Table 3).

Table 3: : Exceedance propability of the WHO guidelines [14] (as per Murphy et al.[5])

Guidelines WHO (1997) *E. coli* in drinking water	Exceedance propability (%)	
	Sand filters	Ceramic filters
>0CFU*/100ml	56–67	30–40
>10CFU*/100ml	37	15
>100CFU*/100ml	14	6

*CFU = colony-forming unit

The WHO [11] summarized the average reduction values of sand and ceramic filters (Table 4). However, these values vary depending on the manufacturing and operating conditions. They are divided into normal (expected usage values) and maximum (under optimal conditions). Ceramic filters therefore have a better reduction capacity of all pathogens.

Table 4: Reduction with household water treatment in LRV* (log_10 Reduction Value) (as per WHO [11])

	Reduction „point-of-use“-water treatment (LRV*)			
	Slow sand filters		Ceramic filters	
Pathogens	Normal	Maximum	Normal	Maximum
Bacteria	1	3	2	6
Viruses	0,5	2	1	4
Protozoa	2	4	4	6

* LRV = Log_{10} (Pathogenic concentration before treatment) - Log_{10} (Pathogenic concentration after treatment)
LRV = 1 = 10^1 = 90%, LRV = 2 = 10^2 = 99%, LRV = 3 = 10^3 = 99,9% reduced pathogens.

The reduction values required by the WHO [15] can be found in Table 5. It becomes clear that the LRV of the ceramic filters meet the required values under normal conditions more than the values of the sand filters.

Table 5: Required $Log_{10}-$ reduction values (as per WH0 [15])

	Required Log_{10} - reduction values*	
Patogens	Protective**	Highly Protective**
Bacteria	≥2	≥4
Viruses	≥3	≥5
Protozoa	≥2	≥4

* Log_{10} (Pathogenic concentration untreated water / pathogenic concentration treated water) ≙ LRV
**WHO aim: 10^{-4} (“Protective”) resp. 10^{-6} (“Highly Protective”) DALY per person per year (WHO, 2008)

Ensuring drinking water demand

According to WHO [16] 20 liters of safe water per day and per person are needed for a minimum of health and hygiene. Starting from these amounts, Sobsey et al. [17] investigate the effectiveness of different point-of-use-systems, including ceramic filters. With an average flow rate of 1-3 l/h, also determined by Brown [10], a ceramic filter takes aver-aged approximately 10 hours to provide the necessary 20 liters for one person (see better flow rate of the sand filters with 15-60 l/h). The flow rates of the ceramic filters depend very much on the thickness of the filter, the material used and the associated pore size of the filter. Sandy clays cause larger pores. [8] Brown [10] has not found any correlation between a change in the performance of the ceramic filters and the length of time they are in use. It is generally assumed that a span of probably 4 or more years is required in which this filtration process purifies the water without great problems. [12]; [10] Filter cleanings are mandatory to remove particular material and maintain the regular flow. [19] The possibility of use is limited by the filter characteristics and the transport. The fragility of the ceramic filters is the limiting factor. [18]. The dependency of filter production on local resources [19] is also a problem for the production or a low-cost acquisition.

Summary

In many parts of Africa less than 75% of the population have access to drinking water and even this is not free from bacteria. Many people die from diarrhea because of this deficit. As the existing central sewage treatment plants are insufficient in Africa, it is necessary to resort to the further cleaning of the water on the point-of-use. In this way, the individual households get cleaner water. Point-of-use ceramic filters can be produced in the developing countries themselves and with locally available resources (clay, water and combustible materials). It is a cost-effective technology that can be used to eliminate *E. coli* up to 99.99%. Thus, they have a better reduction performance than the comparable biosand filters (95% *E. coli*). Overall, the ceramic filters have a better cleaning performance with respect to all pathogens compared to the biosand filters. The reduction of turbidity is better achieved with sand filters (reduction by 82%, ceramic filters by 70%). The WHO states that no bacteria should be present in drinking water. Ceramic filters are more likely to keep the guidelines for the low risk of infection by *E. coli* than sand filters. Due to the low flow rate (1-3 l/h), however, ceramic filters only provide slowly enough clean water and must often be cleaned by the user himself. The filters are estimated to be operational for up to 4 years, with regular maintenance and no damage. Due to the possibility of on-site production, the low production costs and the reduction of diarrheal diseases, ceramic filters are an additional measure for drinking water purification in developing countries. However, further cleaning steps are necessary to remove viruses (regular reduction by ceramic filters by 1 LRV) and the non-retained bacteria from the drinking water.

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