Comparison of household water treatment methods in low-and-middle-income countries under the perspective of a human rights based approach and their applicability in camps for displaced populations

Sonja Nientiet
Germany

Master in International Health

Royal Tropical Institute
Development, Policy and Practice
In cooperation with
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

2013

Comparison of household water treatment methods in low-and-middle-income countries under the perspective of a human rights based approach and their applicability in camps for displaced populations

A thesis submitted as partial fulfilment of the requirement for the degree of

Master in International Health

by

Sonja Nientiet

Germany

Declaration:

Where other peoples work has been used (either from printed sources, online publications or any other source) this has been fully acknowledged and referenced in accordance with the departmental requirements.

This thesis "Comparison of household water treatment methods in low-and-middle-income countries under the perspective of a Human Rights based approach and their applicability in camps for displaced populations"

is my own work

This thesis contains 10,459 words

Signature and date

29.05.2013
……………………………………………
Sonja Nientiet

Master in International Health (MIH)
September 2009 to August 2013
Royal Tropical Institute (KIT)
In cooperation with the Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

Going a day without safe water means being at risk

(Sobsey *at al*, 2008)

Table of contents

Figures, tables and textboxes

Tables

Figures

Textboxes

List of abbreviations

AAAQ	Availability, Accessibility, Acceptance, Quality
E. coli	Escherichia coli
CFU	Coliforming unit
CMR	Crude mortality rate
CRED	Centre for Research on the Epidemiology of Disasters
DALY	Disability adjusted life year
DBPs	Disinfection by-products
GA	General assembly
ICRC	International Committee of the Red Cross
IDP	Internally displaced people/populations
HWT	Household water treatment
HRBA	Human rights based approach
LMIC	Low- and middle-income countries
NGO	Non- governmental organization(s)
NTU	nephelometric turbidity unit
PET	Polyethylene terephthalate
TTC	Thermo- tolerant coliforms
UN	United Nations
UNHRC	United Nations Human Rights Council
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children´s Fund
WHO	World Health Organization
QMRA	Quantitative microbial risk assessment

Abstract

There never have been so many displaced people as today with 42.5 million worldwide. The United Nation high commissioner for refugees (UNHCR) has 25.9 million refugees, and internally displaced people under its mandate, living in more than 120 UNHCR- camps around the world. Diarrhoeal diseases are one of the three most common causes of morbidities in refugee camp settings. Poor water quality is one of the main transmission routes for diarrhoeal disease. Thus, providing the camp population with safe drinking water is an important factor to influence health. There are a variety of methods to improve water quality at the point of consumption. Access to safe potable water is a human right and the aim of this thesis is to evaluate whether the different forms of household water treatment (HWT) can ensure this right within a refugee population.
This thesis presents a review of recent implementations/evaluations of household water treatment. An adaptation of the “right to health” framework is applied to research to what extend the different point-of-use treatments fulfil a human rights based approach. The aspects of availability, accessibility, acceptance and quality with further detailed characteristics are used to extract relevant data from the selected publications. For this thesis biosand and ceramic filtration, chlorination, flocculation/disinfection and solar disinfection (SODIS) as methods for household water treatment were examined.
None of the 23 examined publications with 36 study arms had data covering all four aspects of the human rights based approach. Data on willingness/affordability to spend money for household water treatment and on costs of the different treatment options was only available in 13% and 26% of the publications respectively. Data on the availability of the HWT on the local market was published in 35% of the studies. Acceptance showed big heterogeneity in definition across the different publications: 35% of the studies reported data on non-health benefits, which was linked to acceptance, and 69% of the studies reported other data to argue for acceptance. Four indicators were used to look for quality aspects studies reported on: *E. coli* reduction (56%), adequate chlorine level (82%), turbidity reduction (28%), and impact on diarrhoea (87%).

In order to recommend a form of household water treatment to be used in refugee camps, more studies are needed that have evaluated interventions using the human rights based approach, as for too many studies relevant data is missing. More point-of-use treatment research needs to be conducted in emergency settings, and should have an implementation and follow-up period of more than six months. Local availability of products to treat water at point of use needs to be researched to make a long-term uptake feasible. Data on the different water quality and disease aspects should be measured to monitor the implementation and impact. A discussion, what acceptance means, how to define and to look for it, seems to be imperative. The heterogeneity of the definition of this term or using adherence, or compliance as analogy to acceptance does not seem to be helpful since accepting a new water treatment at home is related with a behaviour change. Such empirical data needs to be carefully included when examining household water treatment.

Keywords: household water treatment, refugee camps, human rights

1. Introduction

The human rights, which were declared in 1948 in the universal declaration of the human rights, are inherent to all human beings and they are inalienable. This means that this set of rights, which has further expanded and found entry in international treaties, is meant for every human being. They have to be safeguarded especially for vulnerable population groups. Refugees and internally displaced populations (IDPs) are such vulnerable groups who are in danger of being disqualified to exercise many of the human rights.

There never have been so many displaced people as today with 42.5 million worldwide, and 25.9 million refugees and IDP under the protection of the United Nation high commissioner for refugees (UNHCR, 2011). The population in camps is scattered over more than 120 UNHCR- camps around the world. Refugees and IDP are at greater risk to suffer from several diseases but the diseases with highest morbidity are: respiratory tract infection, malaria and, diarrhoeal diseases.

The right to the highest attainable standard of health is often at stake within camp settings. Both water availability and water quality are of concern in emergency settings. Even though the responsible organisations for water usually ensure good water quality at the source camp populations experience repeating high case loads and loss of life due to diarrhoeal diseases, especially in children.

Major outbreaks of diarrhoeal disease like in 1991 in a Turkish refugee camp, where 70% of deaths were related to diarrhoea, or 1994 in a refugee camp in Goma, Zaire, where more than 48.000 people died within four weeks of cholera, highlight the particularly fragile situation for refugees (Toole & Waldmann, 1997; Goma Epidemiology Group, 1995).
But apart from such epidemics, the constant or endemic diarrhoea is a constant threat: children below the age of five years bear a disease burden from 6.9 cases per 1,000 consultations in the camps of the Middle east and North Africa region to 20.1 cases in the West African camps (UNHCR, 2008).
While water quality might be good at source it is declining until it reaches the point of consumption. The water collectors contaminate the water with their hands as Roberts *et al.* (2001) found in a Malawi refugee camp. Wright *et al*. (2004) concluded the same in a review: they found water-quality declining considerably on the way from source to the point-of-use.
There are many options of household water treatment and it is difficult to choose the best for each situation. In this thesis household water treatment will be evaluated using a human rights based approach to find answers which treatment might best to apply in refugee camps. While applying this approach the aspects of availability, accessibility, acceptance and quality are researched using detailed characteristics for each aspect.

1.1 Background

1.1.1 Human right to health and to water

The universal declaration of human rights states that “everyone has the right to a standard of living adequate for health and well-being”. In its preamble the General Assembly of the United Nations (UN) proclaims that the human rights should be a “common standard”, be “constantly kept in mind…to secure universal and effective recognition…”(UN, 1948, Art. 25).
Other UN agencies used, and developed this declaration in their special foci and the importance of access to safe and potable water gained more importance. The World Health Organization (WHO) is the guiding and monitoring authority for global health matters on drinking water and is used as reference for water quality standards and treatment methods in this thesis. Attention to water as a determinant of health was raised at the International Conference of Primary Health Care in Alma Ata (1978), where the participants finally declared that the supply with adequate water is essential to promote better health for all (WHO, 1978). The latest development was the adoption of a resolution by the General Assembly (GA) of the UN and the UN Human Rights Council (UNHRC) in 2010, affirming “the right to safe and clean drinking water as a human right that is essential for the full enjoyment of life and all human rights” (UNHRC, 2010).

The UNHCR is the agency responsible for refugees. As part of the UN system the UNHCR is obliged to promote the human rights in the camps under their mandate, and should apply a set of minimum standards, of which the fulfilment is monitored through standard indicators.
The human rights as such do not have an enforcement-power behind them and they are non-actionable. Individuals have to exhaust national remedies before international courts could be engaged.
However, the GA of the Human Rights Council reaffirms that the human right to drinking water is part of existing international law. Signatory states are called upon by the UNHRC to “develop appropriate tools and mechanisms, which may encompass legislation to achieve progressively the full realization of human rights obligation”. Furthermore, it is stressed to put particular attention to vulnerable groups, to integrate human rights into impact assessments, and to urge organizations to apply a human rights based approach (HBRA) in their design and implementation of development programmes (UNHRC, 2010).
Special rapporteurs for the different human rights visit signatory countries and investigate the “human rights in practice” and publish annual reports. The reports have the aim to highlight situations of concern, and to bring attention to issues that are not getting enough awareness by the public (UNHRC, 2001). Even though these reports are not legally binding documents they have a widespread audience and may influence the change over time.

1.1.2 Refugees and IDP

Refugees are people, who cross an international border to look for protection. IDPs stay in their country, but flee from conflict, or persecution to another region (ICRC, 2009).
Well-known reasons of forced migration are conflicts, persecution, complex and disasters. The Centre for Research on the Epidemiology of Disasters (CRED) monitored for 2011 about 244.7 million people being victims of natural disasters, of those more than 30,700 were killed whereby the survivors were affected with e.g. being wounded, losing their homes and property. It is estimated that natural disaster effect up to 21 million people in Africa, with the majority of victims effected by droughts and famines in countries like: Burundi, Djibouti, Ethiopia, Kenya, Somalia and Uganda (14 million victims). In Asia floods affected 131,4 million people (CRED, 2012). A substantial part of those victims were made homeless as a consequence of the disaster, and were in need of assistance.

The variation in size of the refugee camps across the world is big. While the smallest camps may host few hundred people about 78% of the more than 120 UNHCR-assisted camps worldwide host a population over 10,000 (UNHCR, 2008). Exceptional is the Dadaab refugee camp in Kenya: it was planned two decades ago for 90,000 people but currently hosts 460,000 (UNHCR, 2012).
The majority of refugees are still camp-based (89%) but the non-camp-based situations are becoming more important than they used to be (UNHCR, 2008).
One of the indicators used to monitor the public health situation in a camp are diseases. The morbidity rate describes the disease burden of a certain medical condition, while the crude mortality rate (CMR) is measured to report the number of deaths over a certain time- period in the camp. A threshold definition as in Textbox 1 gives guidance if the situation in a camp can be described as normal or if a certain alert-level is already crossed. The CMR differs over the camps: in the Southern African region a CMR of 0.22 was measured, while in the camps of the Middle East and North African region the CMR was at 0.33 per 1000/month (UNHCR, 2008).

> Textbox 1: CMR Thresholds
>
> CMR of 0.3 – 1.0 normal
> CMR > 1.0 alert
> CMR > 2.0 severe
>
> Source: WHO, 2005

The more stabilized a camp situation is, the lower the crude mortality rate is. If mortality rises in a stable situation, investigations have to be undertaken to find the possible reasons.
Such thresholds can be applied for certain population sub-groups in a camp: for children as one vulnerable group the UNHCR has set the indicator for the under five years mortality at <1.5 per 1000/month. In the camps this indicator ranges from 0.40 in Asia to 1.02 in West Africa (UNHCR, 2008).

1.1.3 Diarrhoea

Diarrhoea is a symptom of a gastro- intestinal infection, and is defined as the excretion of three or more loose or liquid stools per day (WHO, 2013).
A more or less constant number of diarrhoea cases in a certain region or population is called "endemic". In contrast, the epidemic situation is characterized by an exponential rise of diarrhoeal cases in a certain time- frame, which is exceeding normal variability.
Diarrhoea can be caused by a variety of pathogens, which include bacteria (e.g. *Escherichia coli* (*E. coli)*, Salmonella, *Vibrio cholerae*, *Shigella*), viruses (e.g. Enteroviruses, Noroviruses, Rotaviruses), protozoa (Cryptosporidiae, Entamoeba histolytica, *Giardia intestinalis*) and helminth infections (*Trichinella spiralis*, Schistosoma, *Trichuris trichiura*). These pathogens are transmitted from anus to mouth through several different pathways, which include contaminated water or food (Figure 1).

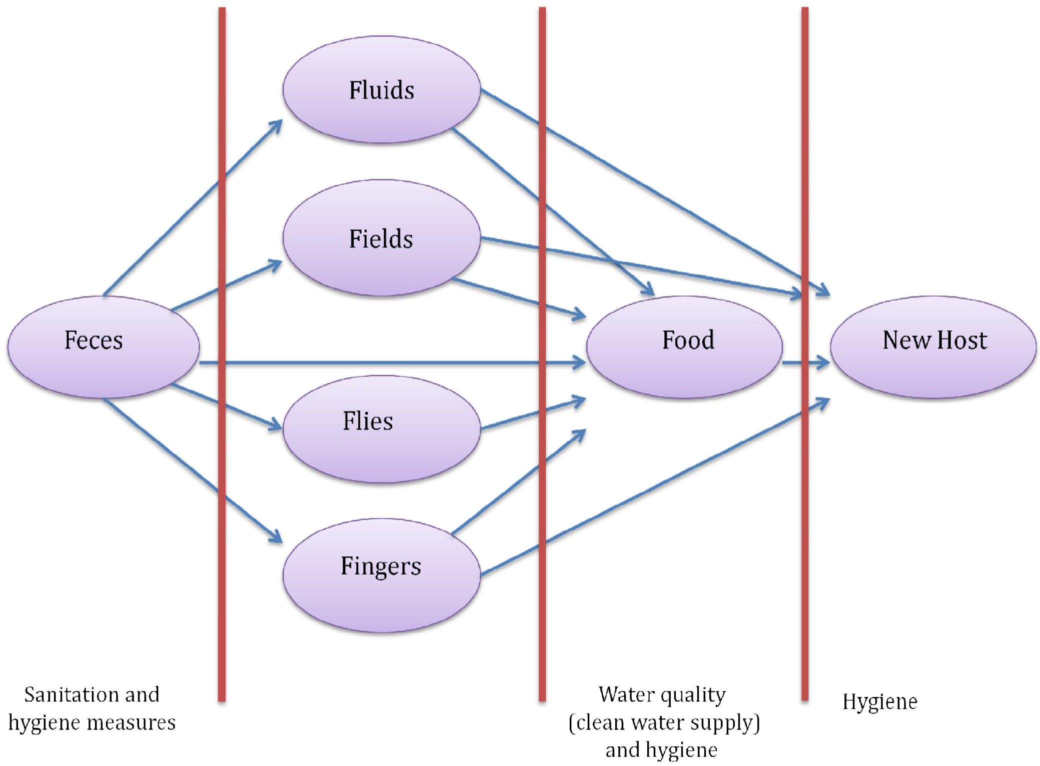


Fig. 1: Transmission pathways of faecal-oral disease and possible cutting points
Source: Wagner and Lanois, 1958 (adapted)

Pathogens, which cause diarrhoea, may come through several pathways at the same time. As a consequence cutting one infection route does not exclude the other transmission options. If, however a main infection route is opted out by adequate measures, transmission may reduce. Water borne transmission plays a major role in epidemics, especially during cholera outbreaks. Sanitation and hygiene measures would prevent (in optimal case) water from being contaminated.

People with a probably weak immune system, forced to live in a camp after the fleeing phase, are prone to infections. The reason of displacement correlates to a certain degree with the actual health situation: people fleeing from drought/famine are more likely to be physically exhausted and undernourished, which makes them vulnerable to infections (Guha-Sapir, 1991). Children are especially vulnerable to experience life-threatening dehydration from diarrhoea- causing infections. Their body encloses proportionally more water than adolescents or adults and their metabolism uses more water. This is resulting in more serious outcomes of diarrhoeal diseases and in the end death through dehydration (UNICEF, 2009).
The dense living conditions in a camp, together with a compromised hygiene situation provide ideal conditions for the outbreak of waterborne epidemics as the examples of Goma and the Kurdish refugee crisis have shown (Goma Epidemiology Group, 1995; Toole & Waldmann, 1997). Water sources in the camp may already be contaminated, or are at high risk due to unhygienic behaviour and dense, poor living conditions. Roberts *et al.* (2001) found the collectors of water contaminating the treated water with their hands in a Malawi refugee camp. Wright *et al*. (2004) concluded the same in a review: they found water-quality declining considerably on the way from source to the point-of-use. The UNHCR discusses the task of providing refugees with an adequate water quantity and quality as an "enormous logistical and technical challenge" and reveals that targets have consistently not been reached. These conditions contribute to the fact that diarrhoea is the third most predominant pathology for children below the age of five with 26 new cases per 1000 consultations/month in Central Africa up to 82 new cases in Asia (UNHCR, 2008).
Not all camps report on childhood diarrhoea and water quantity. Water quality is currently not stated as an indicator in the UNHCR reports, so water quality problems may only be detected once a situation is already out of the norm. Situations in camps vary regarding many factors such as water quality, water amount, density, influx of people and their physical status. To judge the pubic health situation in a camp the standard indicators for those factors have to be taken into consideration as well as the crude mortality rate. The comparison with the host country health statistics (where available) is used as well to put the public health in the camp into perspective. Usually the morbidity rates should be the same as outside the camp. But sometimes the morbidity rate in the country is higher which should of course not lead to lessen the driving force of reaching better health in the camp. And country statistics refer to a large territory while a camp is an enclosed setting. Camps in Ethiopia have a diarrhoea morbidity rate of 1.4 to 7.5% (UNHCR, 2007) while the overall Ethiopian morbidity is as high as 14% (WHO, 2011d). Of course the camp management should strive for the best and not use a reference of lower quality to guide decisions for the camp population.

1.1.4 Water in camps

The importance of water quality as main point of amendment regarding the transmission of endemic diarrhoea has been questioned in the past (Esrey *et al.,* 1991; Gorter *et al*., 1991).

Moe *et al*. (1991) investigated the correlation between the concentration of *E. coli* in drinking water stored in the household and diarrhoeal disease. The study showed that no significant difference in diarrhoea was observed until drinking water was grossly contaminated (> 1000 *E.coli*/ml). This would suggest that other transmission routes play a more dominant role than drinking slightly contaminated water.
However, the above results are related to research in poor but nevertheless stable settings and focussed on endemic diarrhoea. It seems that focussing on source treatment and provision from a bulk, where people can fetch treated water does not assure that the camp population in fact consumes clean water: Atuyambe (2011) found people in Uganda preferring to drink the contaminated river water instead of the treated water in the camp and the quality of source treated water declines to the point of consumption (Roberts *et al*, 2001; Wright *et al*., 2004)

Household water treatment is an intervention that can deal with contamination between source and point of consumption, and by practicing HWT the responsibility for good quality drinking water is shifted from an organization-controlled source treatment to a family. If people cannot keep the water clean from the point where they fetch it, the chance is probably higher if water is treated at the point of consumption. Safe drinking water could be achieved by practicing HWT. This treatment consists of low-cost techniques, designed for non-experts, which should remove contaminants present in the water and make it safe to drink.
For a camp situation in low- and middle- income countries (LMIC) it is imperative to look for technical solutions, which do not rely on power supply or combustible material. Power supply cannot be guaranteed for obvious reasons. Burning material is often a problem in scarce environmental situations, and large refugee populations are a pressing issue on the environmental costs of the hosting countries. Deforestation is a problem in high influx camps (UNHCR, 2011) and therefore alternative options have to be researched.

Summery
It is known that living conditions in a refugee camp are harsh, posing a threat to health, especially for children. Water quality, sanitation and hygiene are major factors influencing the living conditions and health. Even though water treatment is practiced at source, camp population experiences outbreaks of waterborne diarrhoeal diseases. The question remains if other interventions like personal and environmental hygiene measures and water treatment at point of consumption could possibly have an impact on diarrhoeal diseases in refugee camps. The type of intervention should be of low cost, easy to use, acceptable by the camp population as well as accessible and with a proven impact on diarrhoeal diseases. It seems that source treatment is not the only answer to this set of preconditions and that there is a need to look for other options. In this thesis, household water treatment will be examined as an alternative to source treatment. There may be situations where HWT is probably more appropriate than source treatment. Finding such situations with the most appropriate HWT would be an asset. Keeping in mind that human rights apply worldwide to all people and acknowledging that this set of rights has to be safeguarded for vulnerable population groups, a human rights based approach will be applied to examine if point-of-use treatment could be an alternative to source treatment.

1.2 Statement of the problem

Diarrhoea is one of the main causes of morbidity and mortality among refugee populations. Children are especially in danger of infection and more vulnerable of experiencing more severe consequences due to their natural condition. It is imperative to look at low-cost solutions to improve water quality and have an impact on diarrhoeal diseases in camp settings. Different forms of household water treatment will be evaluated and assessed for their suitability under camp conditions; the evaluation will be conducted within a human rights based approach. As there are wide variety of point-of-use treatments available, and not all could be evaluated a selection had to be made. Within this thesis methods that require electricity, wood or other combustible materials, which are often scarce within refugee settings, will not be evaluated.

Overall objective

To describe a selection of household water treatment methods, which are used in developmental context and that can be implemented in refugee and IDP camps in low and middle-income countries. To investigate the chosen household water treatment for their ability to adhere to a human rights based approach and to research if point-of-use treatment within a HRBA could be included in guiding policies of organizations responsible for drinking water in camps. To provide recommendations for the appropriate selection and use of household water treatment in refugee camps in low-and-middle- income countries.

Specific objectives

- To synthesize the impact of HWT on water quality and diarrhoeal diseases
- To assess the performance of different HWT methods in their ability to meet “The right to health” standards concept.
- To use a human rights based approach to evaluate the performance of HWT

2. Quality guidelines for drinking water and technologies for household water treatment

The correlation between drinking water and diarrhoea and the specific situation of refugees has been demonstrated: drinking water is one option of transmitting pathogens, which cause diarrhoea as a symptom of an infection. The importance of water as an infection route varies and is dependent on other possible transmission options. If, however, water is polluted it is likely that pathogens, which cause diarrhoea are in the polluted water.

2.1 Water quality

To define "good quality" of drinking water, the WHO has set quality guidelines. It is suggested that water, which is directed for consumption, should be free of *E. coli* (WHO, 2011a).
Other reference pathogens are used under laboratory conditions to assess the quality of water. Those reference pathogens are: *Campylobacter jejuni* for bacteria, rotavirus for viruses, *Cryptosporidium* for protozoan parasites. They have a public health importance and it is likely that, if those pathogens are absent, more agents of those classes are controlled as well (WHO, 2011c). To test for those pathogens, rather sophisticated devices and procedures are necessary. Besides a clean environment, skilled technicians have to be in place to perform microscopy, staining and to use incubators and immunological test kits. It is rather unlikely that this could be provided in a refugee camp setting. On the other hand *E. coli* is an indicator organism: if *E. coli* is absent, it is likely that other pathogens are absent as well and vice versa. Controlling the contamination load of *E. coli* is therefore a correlated with controlling other pathogens as well. Turbidity, another water quality parameter, representing the amount of dissolved particles in the water, should be below 5 NTU. To measure turbidity it is not necessary to use expensive equipment or sophisticated methods WHO, 2011a).
From a purely on quality focused point of view the WHO, as the worldwide reference organization for health and its determinants, should aim for noting less than the optimum for health. On the other hand, if "optimum" is defined with absence of all pathogens that might be an aim, which is not feasible to reach and which might even not necessary to make a healthy live possible. Guidelines with limits for different pathogens should be provided and followed in setting where it is feasible to control these pathogens, and react on contamination. On the other hand the WHO acknowledges difficult country situations and notes that quality standards have to be flexible, especially in emergencies (WHO, 2011a).
The WHO guidelines are a tool help people and institutions in charge to strive for the optimum. *E. coli* is likely to be present in generally polluted water and since the detection of *E. coli* is feasible under field conditions, it is a useful indicator to assess the quality of water.

To influence water quality, and thus indirectly health, a variety of HWT recommended by the WHO are at hand (Textbox 2). In principal, three approaches are used: chemical, physical and the combination of those two.

Textbox 2: WHO list of recommended HWT

Chemical:

- Chemical disinfection includes any chlorine-based, ozone and other treatment with oxidants, acids and bases.
- Multiple-barrier treatment is combining e.g. coagulation with disinfection, filtration with disinfection
- Coagulation, precipitation and/or sedimentation removes through any device or coagulant/precipitant particles and microbes: after coagulation/ precipitation the sediments settle on the ground of the bucket

Physical:

- Granular media filters use sand and earth to hold back microbes through physical and chemical processes.
- Membrane, porous ceramic or composite filters use different pore sizes for physical removal of pathogens.
- Solar disinfection uses the radiation of the sun for pathogen- inactivation.
- UV light technologies with lamps use artificial UV radiation with electricity- based lamps producing a wavelength of 254 nm.
- Heat with either pasteurization temperatures (> 63°C for 30 min) or boiling by using combustible material

Source WHO, (2011a)

The WHO has defined performance-levels of "highly protective", "protective" and "interim" for point-of-use treatment for water. These levels are indicating the reduction of contamination, and the correspondence to a calculated burden of disease in "disability-adjusted life year" (DALY).

Table 1 shows the performance targets, and how they fit in the three quality-levels for HWT. "Highly protective" means that waterborne diseases would be limited to 10^{-6} DALY per person if a technology would be used correctly and consistently over a year. This water treatment is recommended for use.

"Protective" stands for a less stringent target regarding disease burden of 10^{-4} DALY per person. In a setting with suspected high burden of waterborne disease this would still result in a significant health gain.

The "Interim" target has been set because it is not always possible, and not cost-effective to achieve the higher performance targets. The "interim" target applies to technologies, which achieve the "protective" level in two of the three pathogen classes, and is seen as a way forward to the improvement of water quality and in the end, in health (WHO, 2011c).

Table 1: HWT performance targets

Target	Log10 reduction required: **Bacteria**	Log10 reduction required: **Viruses**	Log10 reduction required **Protozoa**
Highly Protective	**≥ 4**	**≥ 5**	**≥ 4**
Protective	**≥ 2**	**≥ 3**	**≥ 2**
Interim:	Achieves "protective" target for two classes of pathogens and results in health gains; should be recommended if there is evidence of reduction in waterborne disease		

Source: extracted from WHO (2011c, p. 4)

In the end it is not the technical possible performance of a point-of –use method to influence water quality but the impact on health defining the performance.
The WHO has translated this statement into "health-based performance targets". The goal of reducing microbes at the recommended level of 10^{-6} DALY would be the upmost performance. However, a significant reduction of diarrhoeal diseases may be achieved below this quality-target for drinking water especially, if the disease burden is high.
HWT that are effective against two of the three pathogen classes could be recommended if positive health impact is supported by epidemiological evidence (WHO, 2011b).

2.2 Household water treatment methods

After having looked at different quality aspects for drinking water, the challenges of testing the quality and the resulting practical implications, point-of-use options will now be presented. The mode of operation of slow sand filtration, ceramic filtration, chlorination, flocculation/disinfection and the treatment with solar disinfection (SODIS) are briefly described. Further information is presented under the AAAQ-aspect of the "right to health" framework.
To show the quality- aspect, the performance targets of each method is presented in a table format, which provides information on the performance under laboratory conditions and under field conditions where non-experts are handling the water treatment. The laboratory results are displayed as maximum $\log_{10}$ reduction value (max LRV) and the field results are presented as baseline $\log_{10}$ reduction value (base LRV). The values for the pathogen reduction lead to the three different levels of performance as discussed (table 1) and are indicating the achievable health benefit.

2.2.1 Slow sand filtration

Filtration as point-of-use method means that water is passing through a filtering device, which is excluding particles by size. Here the methods of slow sand filtration "biosand" and the filtration through a ceramic device will be presented.

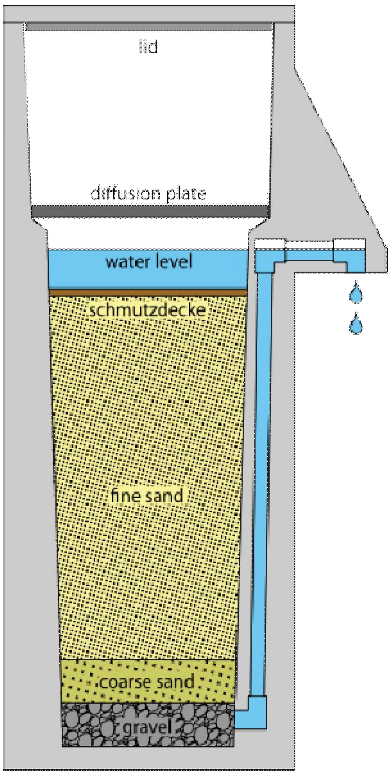


Figure 2: Example of a concrete Sand filtration device
Source: Wikimedia Commons,
Author: Alexis Doucet, 2010

Mode of operation

The filters are made of concrete or plastic. The filtering elements are different layers of sand and gravel inside the device. Near the bottom filtered water can leave the container through a collection pipe. A diffusion plate on the top layer assures that the sand layer remains stable under the flow of water. The collection pipe exits at a level, which allows a level of untreated water to remain above the sand. The water on top of the sand is building a complex biological layer, called `Schmutzdecke`. This layer is metabolically active and contributes to the filtration process.

During the filtration, organisms get absorbed to the sand by static charge. The sand deep in the filter acquires a coating and is getting more effective for absorption. During the filtration process the lack of light and nutrients hinder pathogens survival (Samaritans Purse, 2010). The device, depending on the size has a capacity to filter 3-60l per day. The top layer (5-10cm) has to be removed and replaced periodically. The sand can be washed and later be reused. The reduction of pathogens is influenced by filter maturity; operating conditions, flow rate, grain size and filter bed contact time.

Pathogen and turbidity removal

The results of tests under laboratory and real-life conditions show, that neither the WHO-level of "highly protective", nor "protective" is achieved.

Table 2: Reduction of pathogens with sand filtration

Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)
Bacteria	1	3
Viruses	0.5	2
Protozoa	2	4

Source: WHO, 2011a, p. 145

Costs

The relatively high investment of 12-100 US$ leads to monthly costs of 0.50-4.16 US$ for a household, assuming a life of 24 months and a production of 20 litres a day (Lantagne & Clasen, 2009).

2.2.2 Ceramic filtration

Mode of operation
Ceramic filters exist in a vessel or candle- shaped form. Generally the water passes the medium from outside to inside. Some filters are coated with a bacteriostatic layer to prevent the development of a biofilm on the surface. Pore size differs from one model to the other and therefore the removal capacity varies. Pores may clog as a result of high turbidity, or high microbial load. As a result the filters have to be cleaned to keep their normal flow rate performance (Sobsey, 2002).

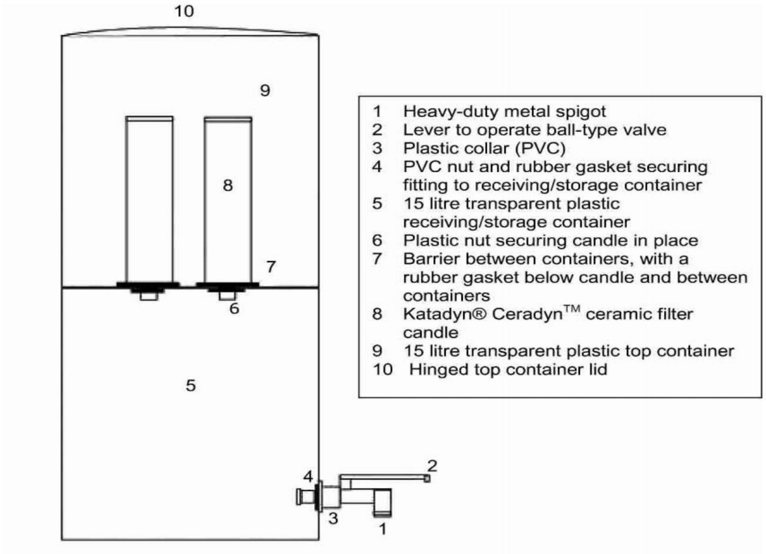


Figure 3: Ceramic water filter (Katadyn® Ceradyn™ ceramic filter)
Source: Clasen et al., 2004

Figure 3 shows an example of a ceramic filter with ceramic candles inside the device. The collected water has to be added in the top bucket where the ceramic candles have been placed in. Through passing the porous ceramic, microbes are filtered by size exclusion (porous size in the above example 0.2 µ). The filtered water is safely stored in the lower bucket. The candles can be cleaned with the filtered water and a sponge (Clasen, 2004).
A different approach with the same principle is the low-cost flower- pot shaped ceramic filter made of burned material with a fine porosity. The water passes the filter with 1-3 litres per hour into a storage container where it can be dispensed with a tap. The filters can be treated with a silver compound or other agents to prevent microbial growth in the filter.

Pathogen and turbidity removal
Because this method is reaching good reduction values for bacteria and protozoa as displayed in the below table, it classifies for the “protective” level of WHO performance for pathogen reduction in drinking water.

Table 3: Reduction of pathogens with ceramic filtration

Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)
Bacteria	2	6
Viruses	1	4
Protozoa	4	6

Source: WHO, 2011a, p. 145

Costs

Lantagne & Clasen (2009) calculated with a 24 months life span, and a daily production of 10 litres water that monthly costs would range from 0.31-1.25 US$ for a household, depending on the initial investment.

2.2.3 Chlorination

Mode of operation

Chlorine has to be stirred in the drinking water and after a contact time of 30 minutes, free chlorine inactivates >99.99% of enteric bacteria and viruses. The chlorine remains for days if there is no chlorine demanding processes. One has to be aware that chlorination becomes less effective in highly turbid water because pathogens are “protected” by particles and dissolved constituents (Sobsey, 2002).

Untreated water, which is below 10 NTU, can be treated with free chlorine about 2mg/l, while water with a turbidity of above 10 NTU will require the double dosage in order to assure in the end a free residual chlorine concentration of 0.2-0.5mg/l (WHO, 2011a).

Free residual chlorine should not exceed the concentration of 5mg/l (WHO, 2011a).

Pathogen and turbidity removal

Looking at the results of baseline removal of pathogens in table 4, the overall performance of chlorination at point of use is in the category “protective” according to WHO standards.

Table 4: Reduction of pathogens with chlorination

Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)
Bacteria	3	6
Viruses	3	6
Protozoa, non-*Cryptosporidium*	3	5
Cryptosporidium	0	1

Source: WHO, 2011a, p. 145

Costs

Lantagne & Clasen (2009) identified the cost per month at household level for sodium hypochlorite at 0.20 US$ and for NaDCC tablets at 0.30 US$. Imported tablets were found to have a higher price whereby local products are cheaper but need quality control to ensure proper dosage (Lantagne & Clasen, 2009; CDC, 2008).

2.2.4 Coagulation/flocculation in combination with disinfection

Especially surface water contains dissolved and suspended particles. Coagulation and flocculation processes are used to separate those particles from the water. A coagulant influences the charge of the particles. Once the charge is neutralized, the particles can collide and as a second step build larger particle sizes, the flock.
The chlorine inactivates pathogens in a second step, it causes cell wall damages, which in the end, interrupts the normal function and the reproduction of organisms.

Mode of operation

Commercially available sachets include a formula which coagulates/flocculates particles in the water and releases chlorine. The mixture (tablets or powder) has to be stirred for some minutes and then left alone to let the flock settle. As next step the water is strained through a cloth, leaving some water with the sediment in the first container. After another 30 minutes the water is ready for consumption as the chlorine by then inactivated the remaining pathogens (Sobsey, 2002).

Pathogen and turbidity removal

The results in table 5 display the "highly protective" performance of this point-of-use method

Table 5: Reduction of pathogens with combined flocculation /chlorination

Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)
Bacteria	7	9
Viruses	4.5	6
Protozoa	3	5

Source: WHO, 2011a, p. 146

Costs

The product is sold to non- governmental organizations (NGOs) at a price of 3.5 US$ cents per sachet, excluding shipping (CDC, 2008).
Lantagne & Clasen (2009) looked at the monthly costs for a household and determined them at 2.10 US$ per month.

2.3.5 Treatment with solar disinfection (SODIS)

Mode of operation

Solar disinfection is using sunlight to treat water: water is filled in polyethylene terephthalate (PET) bottles and exposed to sunlight. The UV radiation penetrates the plastic. During the exposure time of ≥ 6 h, cells are damaged and loose their infectivity (Berney *et al*., 2006).

Solar collection is enhanced if the bottles are placed on a dark or shiny surface. Both applications increase the cumulative effect of radiation and heat. The bottles are best placed in full sunlight. This method works sufficient if water is < 30 NTU. The bottles should be replaced when they show deformation signs and scratches. A temperature sensor may be used to be sure that a temperature of 50°C or higher has been reached. There are reusable paraffin sensors: if the paraffin melts, the target temperature was reached (Sobsey, 2002).

Pathogen and turbidity removal

The SODIS method qualifies for the “protective” level of performance as it reaches good removal values for viruses and protozoa, and a higher removal/ inactivation for bacteria as presented in table 6.

Table 6: Reduction of pathogens by solar disinfection

Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)
Bacteria	3	5+
Viruses	2	4+
Protozoa	2	4+

Source: WHO, 2011a, p. 146

Costs

Monthly costs for a household are estimated at 0.04 US$ by Lantagne & Clasen (2009).

3. Conceptual framework and methodology

3.1 Conceptual Framework

For the purpose of this thesis, the broad concept of human rights is downsized to the right to health. This right includes a wide range of elements, which are essential to have the opportunity to live a healthy live. Underlying determinants of health cover all aspects in life, which are related to health such as food, shelter and housing, sanitation, healthy working conditions and a healthy environment (WHO, 2011b).
Health inequities can only be prevented or be overcome if the underlying determinants of health are respected (WHO, 2011b). Access to safe and potable water is a human right and is one underlying determinant of health (UNHRC, 2010; WHO, 2009).
By respecting the underlying determinants of health, neither health as such is guaranteed, nor does it mean that diseases will remain absent. Many factors influence life and personal decisions as well are supporting or hindering health. But if preconditions are not met, there is even not the chance to live as healthy as possible and therefore the human right to the highest attainable standard of health is compromised from the start.

The HRBA is a tool, which helps to detect disrespect of human rights and to understand causes for this discrimination (WHO, 2011b).
The original framework of the right to health (annex 1) is designed to investigate policy- making and health systems. In this thesis the right to health framework is adapted to research HWT as a possible intervention to get access to safe and potable water as one underlying determinant of heath. As such point-of-use water treatment could be one option to approach the right to health by influencing one of many preconditions necessary to live a healthy life.

The right to health framework uses four aspects to examine interventions or policies for their respect, or disrespect of the human rights. These aspects are: availability, accessibility, acceptance and quality. To examine point-of-use treatment for water, those four aspects are further specified for the objectives of this thesis. Eight characteristics, either technically measurable or detectable through empiric methods, were defined and then researched in the publications of implementation and evaluation studies of HWT. By this approach, it should be possible to get better insight if point-of-use treatment is a tool to support health by having access to safe water.

The eight characteristics to describe the aspects of availability, accessibility, acceptance and quality are:

1) local availability of a HWT device or the capacity for local production
2) economic capacity of the local residents to buy a HWT tool or product
3) local cultural acceptance of a HWT
4) benefits like better odour, appearance or better taste of treated water
5) contamination load/reduction with a reference pathogen
6) effective residual chlorine in treated water
7) turbidity of the water
8) reduction of diarrhoea

The characteristics in detail:

Availability:
1) To assess the availability of a HWT- device or product the studies were screened for any type of information if such devices or products could be locally purchased or manufactured.
Accessibility:
2) In this work accessibility is defined as the economic capacity for the local people to buy a HWT- device or product. Any given information on this outcome was used to assess accessibility.
Acceptance:
3) Since acceptance was not defined in the same way across the examined publications, any form of information was extracted, which could be linked to acceptance.
4) Other benefits like better taste, smell and appearance of treated water is defined as another outcome for the acceptance and was separately documented.
Quality:
5) The reduction of contamination with a reference pathogen (*E. coli,* thermo tolerant coliforms (TTC).
6) Where applicable, the effective residual chlorine level was extracted.
7) Impact on turbidity or the baseline turbidity measured in nephelometric turbidity unit (NTU).
8) The reduction in diarrhoea incidence, prevalence or days with disease, published in any form.

Adapted framework

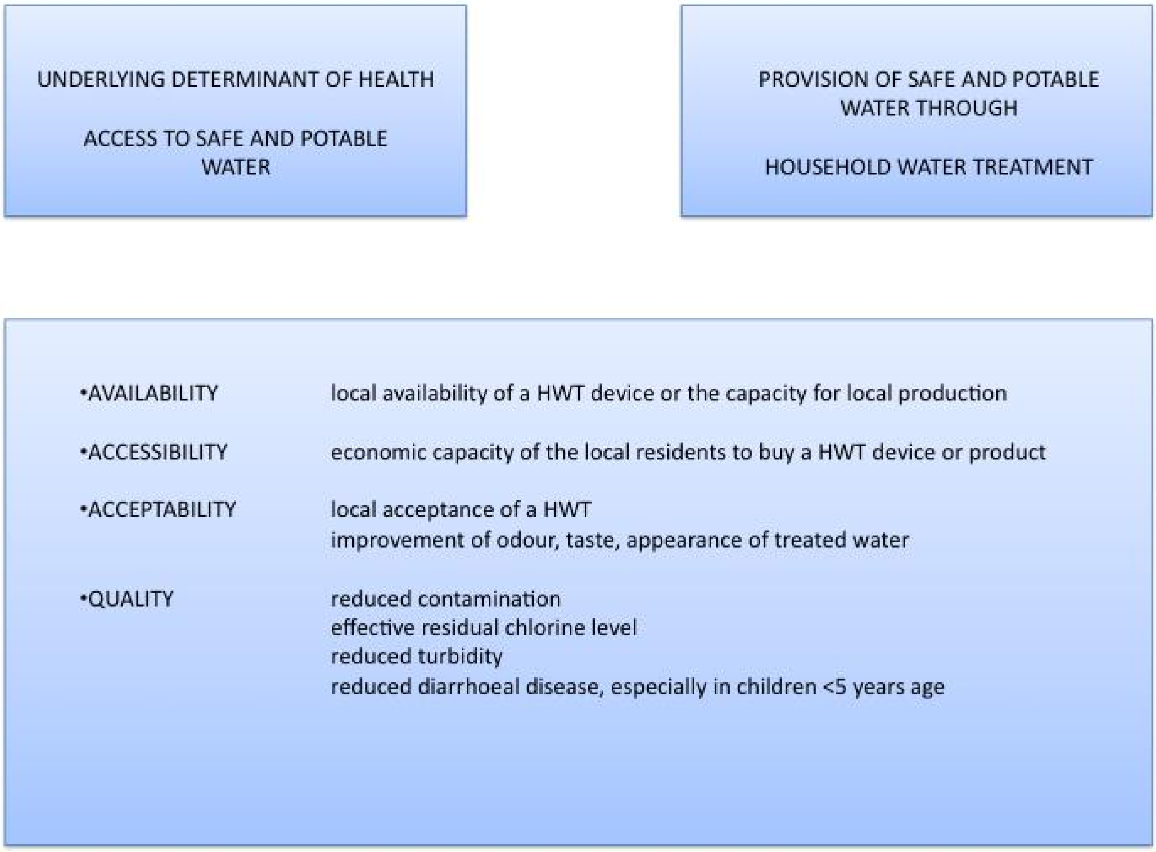


Figure 4: Adapted framework for comparison of 4 HWT methods using the aspects of availability, accessibility, acceptability, quality
Source: adapted from WHO, (2011b)

In the adapted framework (Fig. 4) the underlying determinants in the first pillar are replaced by the “access to safe and potable water”. The second pillar is representing the “provision of safe and potable water through HWT”.
The underlying determinants of health and the health care should be addressed by services, conditions and treatments, which are available, accessible, accepted and of proven quality. This principle has to apply as well to the HWT. The researched publications are reviewed with the focus on the fulfilment of the four aspects of availability, accessibility, acceptability and quality (AAAQ) with eight characteristics.

3.2 Literature review

This thesis is based on a desk study of reviewed literature.

The PubMed database was used to identify documents related to health and human rights relevant to water provision in camps. The following search terms were used in combination with the logic connector “AND”: “human rights based approach”, “refugee camps”, “potable water”, “camp management”, “refugees”, “refugee health”, “environmental health”, “diarrhoeal diseases”, “household water treatment”, “human rights”, “health”, “right to health”, “public health”, “water”.

The websites of the UN agencies WHO, UNHCR, UNCHR were searched for key documents related to human rights, public health, right to health and the foundation documents of the organizations.

For the objective of describing household water treatment methods, which are used in LMIC, literature was searched to gain general and technical information about the HWT methods of:

- filtration,
- chlorination,
- combined flocculation with chlorination,
- solar disinfection (SODIS).

This set of HWT represents the main techniques for water treatment in LMIC and in emergency settings. As a prerequisite, only techniques independent from power supply and combustible material were considered.
Then implementation and evaluation studies were searched, using one or more of the chosen HWT, measuring water quality improvement and reduction of diarrhoeal disease. The abstracts of the retrieved publications were screened to assure relevance regarding the research questions. Since only few studies published both, the water quality and reduction of diarrhoeal disease, this information prerequisite was withdrawn.
Literature was searched using the database of PubMed and Scopus and the search engine Google scholar. The following search terms were used in combination with logic connectors (“AND”; “OR”): “household water treatment”, “point of use treatment”, “refugee camp”, “refugee health”, “diarrhoea”, “diarrhoeal diseases”. Publications in English from 2000 to 2011 were included, presenting the implementation of a HWT or the evaluation of a point-of use treatment. All geographic areas were included.

For supportive information regarding the context of refugees, IDP and water quality standards, the websites of UNHCR, WHO, ICRC, UNICEF and UNHRC were searched and screened for relevant publications.

3.3 Limitations and data analysis

Literature, which encompassed health and human rights together with the aspect of water provision in camps was difficult to find. For the literature research many different search terms were used with many combinations. However, publications with free access and free of charge could hardly be retrieved, which resulted in a limited review.

From all the material retrieved, only one study was performed in a refugee camp. However, other studies were performed in settings, which, to a certain extent, resemble the characteristics of a camp situation. They have been either conducted in stable but dense living conditions like squatter camps/slums and dense urban quarters or in remote places where people do not have access to clean or treated water and have to rely on possibly contaminated water.

Of the chosen publications the retrieved information of the earlier discussed eight characteristics were transcribed in a data extraction sheet (annex 2). If the publication did provide unsupported statements or if information could not be retrieved it was marked as “no data” in the extraction sheet.

4. Results

A total of 23 studies were selected and reviewed for this thesis. The selected publications had a total of 36 study arms, with several studies (35%) including more that one intervention arm, and more than one form of household water treatment. Flocculation/disinfection was the most common form of HWT (26%), followed by chlorination (22%) and ceramic filtration (17%), biosand and SODIS (17% each)

Table 7 gives an overview of the selected studies. The reference number indicates where to find the publication details in the reference list. The data extraction can be found in annex 2 with the same order of studies as presented in table 7.

In table 8 are the findings for the parameters of accessibility, availability and acceptability presented. The results for parameters of quality are shown in table 9.

Table 7: The reviewed HWT publications

Ref.No *	First author	Year	Country	Intervention	Outcome	Study design
44	Stauber	2009	Dominican Republic	Biosand filtration	Water quality (*E. coli*), diarrhoea	Randomized controlled
1	Aiken	2011	Dominican republic	Biosand filtration	Water quality (*E. coli*, turbidity), diarrhoea, acceptance	Evaluation
19	Fiore	2010	Nicaragua	Biosand filtration	Water quality (CFU), diarrhoea, acceptance	Evaluation
45	Tiwari	2009	Kenya	Biosand filtration	Water quality (CFU, turbidity), diarrhoea	randomized controlled
10	Clasen	2004	Bolivia	Ceramic filtration	Water quality (TTC), diarrhoea	Randomized controlled
9	Clasen	2005	Colombia	Ceramic filtration	Water quality (TTC), diarrhoea	Randomized controlled
17	Du Preez	2008	Zimbabwe, Republic of South Africa	Ceramic filtration	Water quality (*E. coli*, turbidity), diarrhoea	Randomized controlled
4	Brown	2008	Cambodia	Ceramic filtration	Water quality (*E. coli*, turbidity), diarrhoea	Randomized controlled
26	Jain	2010	Ghana	Chlorination (NaDCC)	Water quality (*E. coli*, chlorine level), diarrhoea	Randomized controlled, placebo-controlled
11	Clasen	2007	Bangladesh	Chlorination (NaDCC)	Water quality (TTC, chlorine level, turbidity at baseline)	Randomized controlled, placebo-controlled
30	Luby	2004	Pakistan	Chlorination (bleach)	Diarrhoea	Randomized controlled
36	Quick	2002	Zambia	Chlorination (Sodium hypochlorite)	Water quality (E. coli, chlorine level), diarrhoea	Randomized controlled
34	Oprysko	2010	Afghanistan	Chlorination (Sodium hypochlorite)	Diarrhoea, acceptance	Randomized controlled, evaluation
15	Crump	2005	Kenya	Flocculation/disinfection vs. sodium hypochlorite	Water quality (CFU, turbidity, chlorine level)	Randomized controlled
38	Reller	2003	Guatemala	Flocculation/disinfection vs. bleach	Water quality (E. coli, turbidity, chlorine level), diarrhoea	Randomized controlled
8	Chiller	2006	Guatemala	Flocculation/disinfection	Water quality (chlorine level), diarrhoea	Randomized controlled
31	Luby	2008	Guatemala	Flocculation/disinfection	Water quality (chlorine level), acceptance	Evaluation
16	Doocy	2006	Liberia	Flocculation/disinfection vs. improved storage	Water quality (chlorine level), diarrhoea	Randomized controlled
13	Colindres	2007	Haiti	Flocculation/disinfection	Water quality (chlorine level)	Evaluation (KAP- study)
32	Mäuse-zahl	2009	Bolivia	SODIS	Diarrhoea,	Randomized controlled
20	Graf	2010	Cameron	SODIS	Diarrhoea	Evaluation
37	Rai	2010	India	SODIS	Diarrhoea	Randomized controlled, double blinded
14	Conroy	2001	Kenya	SODIS	Diarrhoea	Outbreak observation

Table 8: Results of the accessibility, availability and acceptance-aspect of a human rights based approach for implementing HWT

	Biosand	Ceramic Filtration	Chlorination	Flocculation/ Disinfection	SODIS	All
# Reporting on costs	50%	75%	-	17%	-	26%
Reference No.	19, 46	10, 17, 4	-	31	-	
# Reporting on willingness or affordability to buy	25%	-	-	30%	-	13%
Reference No.	46	-	-	31, 13	-	
# Reporting local availability/local manufacturability	50%	25%	60%	33%	-	35%
Reference No.	19, 46	4	37, 35, 30	15,31	-	
# Reporting any non-health benefits	50%	25%	20%	67%	-	35%
Reference No.	19, 46	4	26	15, 39, 31, 13	-	
# Reporting any data for acceptance	75%	50%	80%	83%	50%	69%
Reference No.	1,19,46	10,14	26,11,37,35	15, 39, 31,16,13	32,20	

This page is empty on purpose

Table 9: Results of the quality- aspect of a human rights based approach for implementing HWT

	Biosand	Ceramic Filtration	Chlorination	Flocculation/ Disinfection	SODIS	All
# Reporting *E coli* reduction	100%	100%	60%	33%	0%	56%
Reference No.	45, 1, 19, 43	10, 9, 17, 4	26, 11, 37	15, 39	-	
# Reporting on chlorine level	-	-	60%	100%	-	82%
Reference No.	-	-	26, 11, 37	15, 39, 8, 31, 16, 13	-	
# Reporting on turbidity reduction	25%	25%	-	33%	-	28%
Reference No.	1	4	-	15, 39	-	
# Reporting on impact on diarrhoea	100%	100%	80%	67%	100%	87%
Reference No.	45, 1, 19, 43	10, 9, 17, 4	26, 30, 37, 35	15, 39, 8, 16	32, 20, 38, 14	

Availability
In total 35% of the examined studies reported about the availability of the concerned household water treatment- device or product as presented in table 8. Chlorination products were found to be most widely available (60%), while ceramic filters were the least to find on local markets (25%).
Biosand filters were in 50% of the interventions available and chlorination/disinfection products could be purchased in 16% of the studies.
None of the studies researching solar disinfection were reporting about the availability of PET- bottles. Usually one can use empty soft drink bottles, which are widely available but none of the studies did look into that detail, or reported prices for soft drinks in PET- bottles.

Accessibility
In 26% of the researched studies data was published for the costs of HWT, and 13% provided data on the willingness, or the affordability for people to buy such devices or products.
Referring to table 8, only one (25%) research group (Tiwari *et al*. 2009) reported about biosand filter purchase. The implemented filter, which had original costs of 22 US$ was sold to the study participants for 4.86 US$. 90% of the intervention group and 69% of the control group bought the filter.
Imported ceramic filters have prices of 25 US$ (Clasen *et al*. 2004) to 60 US$ (du Preez *et al*., 2004). Clasen *et al*. found out that people would be willing to pay 9.25US$ for those imported filters. The intervention by Brown *et al*. (2008) was done with locally produced filters for 8 to 10 US$. However, purchase-willingness was in this case not examined.
Even though chlorination products were found to be most widely available no information was provided on costs.
The costs for flocculation/disinfection were often linked to relief prices for NGOs. Only one publication (17%) (Luby *et al*., 2008) presented, that the product was available for 0.14US$, but people would only be willing to buy regularly if the price was half. In 2007 Colindres *et al.* did not mention the local market price but people were only willing to buy regularly at a price of 0.027 US$.
PET- bottles would be accessible through buying soft drinks. That means that one bottle has the price of the soft drink. The other options were leftover bottles, which were otherwise garbage, or to get them through a local recycler. There were no such investigations in any of the studies.

Acceptance
The publications reported in 69% about acceptance, however with heterogeneity regarding definition and method: from counting device- use in announced and/or unannounced visits during the trial, using post- trial purchase as indicator or more general statement without providing evidence.
In the discussion sections it was sometimes claimed that participants liked the HWT without being more specific (du Preez et al. 2008; Doocy & Burnham 2006). Of the examined publications 35% were looking for other benefits than health, which could then support acceptance.
The diversity in measuring acceptance may explain the high acceptance rates of 83% for flocculation/disinfection, 80% for chlorination and 75% for the biosand method. Ceramic filtration and SODIS were both presented to have 50% acceptance rates. Clasen *et al.* (2007) are discussing that 100% of water samples having detectable chlorine would indicate strong uptake and compliance.
All four examined evaluation studies (17%) (biosand: Aiken *et al*., 2011; Fiore *et al*., 2010; flocculation/disinfection: Luby *et al*., 2008; Colindrs *et al*., 2007) did look into uptake or acceptance.

Flocculation/disinfection and chlorination of drinking water influences taste. Despite possible impact on water quality users may not use this method consistently over a longer period of time. In this respect it is important to look for acceptance to get an idea if people would drink the water with a chlorine-taste continuously.
Looking more into detail to analyse acceptance, one finds in the study of Crump *et al.* (2005), that people preferred treated water in 99% to 100% in both study arms. However, adequate chlorine level in unannounced visits was between 44% to 61%. Colindres *et al.* (2007) found only 25% of the households using flocculation/disinfection more than 5 times over a period of 2-4 weeks and Luby *et al.* (2008) report only 5% of the households meeting the criteria of repeated use.
In the camp setting where Doocy & Burnham (2006) did an intervention 85% of the water samples were adequately chlorinated. If this adherence to a treatment protocol suggests acceptance of the water taste was not investigated.
Only Jain *et al.* (2010) did go into detail and found 84% of participants thinking that chlorinated water did not taste better and 79% disagreeing that chlorination was easy to use.

As table 8 shows that 75% of the biosand and 50% of the ceramic filtration studies published data for acceptance:
Aiken *et al*. (2011) and Fiore *et al*. (2010) each found one year after the implementations that 91% (77%) of the biosand filters were still in use. Post-trial purchase after the intervention of Tiwari *et al*. (2009) achieved 69% in the control and 90% in the intervention group.

Clasen *et al.* (2004) and Brown *et al.* (2008) measured acceptance for ceramic filters with counting the filters in use during field visits (72% and 98% respectively).

50% of the SODIS interventions provided information on acceptance. In comparison to the other methods the effort of visiting the households is prominent which, however, does not lead to outstanding acceptance results.
Mäusezahl *et al*. (2009) found a mean user rate of 32%, even though the households themselves reported 80% compliance; indicating clearly the problem of bias in self- reporting.
Graf *et al.* (2010) published a regular user rate of 46%. Despite the effort of biweekly and monthly household visits, 19% used SODIS only irregular and 35 % did not uptake this method.

Quality
Table 9 shows the cumulative results for the researched quality aspects.
56% of the interventions gave information about the impact of the intervention on *E. coli* concentrations in treated water.
All filter studies provided results for *E. coli* reduction, while 60% of the chlorination studies and 33% of the flocculation/disinfection trials report on this detail. SODIS interventions did not provide data regarding impact on *E. coli* contamination.

Reporting on turbidity reduction was low with 28% of all publications reporting on this parameter. Even though one would assume turbidity reduction with using filtration and flocculation/disinfection, only 25% of both filtering methods were reporting and 33% for the flocculation/disinfection interventions.
Chlorination does not reduce turbidity but its effectiveness is influenced by turbidity. Only Clasen *et al.* (2007) provide baseline turbidity.
SODIS works the better with lower turbidity levels, but none of those interventions did measure turbidity.

100% of the flocculation/disinfection studies did look into the aspect of chlorine levels after water treatment, while 60% of chlorination interventions report residual chlorine.
Looking at adequate chlorine levels of ≥ 0.1mg/l one finds that Jain *et al*. (2010) reached this in 74-89% of samples and Clasen *et al.* (2007) found in 74% of water samples adequate chlorination levels. It has to be mentioned that in the intervention of Clasen *et a*l. (2002) 11.7% of the water samples were even above the WHO recommended maximum of 5.0mg/l. In 2002 Quick et al. found 55 to 80.5% of treated water at chlorine levels ≥ 0.2mg/l.

Directly after the intervention of flocculation/disinfection Chiller *et al*. (2006) and Doocy & Burnham (2006) both report 85% of the samples being adequately chlorinated, while Reller *et al*. (2003) measured only 27% effective chlorine level. Crump *et al.* (2005) found 86% of the water samples with >0.1mg/lchlorine in announced visits, but this rate dropped down to 44% in unannounced visits.
Luby *et al*. (2008) studied the uptake of flocculation/disinfection six months after the intervention and found only 1.5% detectable chlorine.

Impact on diarrhoeal diseases was researched in all biosand, ceramic filtration and SODIS interventions, while 80% of the chlorination studies, and 67% of the flocculation/disinfection interventions presented data for this outcome.
When looking specifically at the reduction of diarrhoea in children below five years age an age group, which is more vulnerable to experience serious outcomes of diarrhoea episodes, less data was published. One (25%) of the biosand interventions (Tiwari *et al.* 2009) reports 51% reduction of diarrhoea in this age group while 75% of the ceramic filtration studies publish between 13% to 72% reduction of diarrhoea in this age cluster.
40% of the chlorination trials had data for below- fives but could not show any reduction of diarrhoeal disease.
17% of the flocculation/disinfection studies reported a reduction of 39% in the below-five age cluster. Half of the SODIS interventions measured 34% to 76% reduction of this symptom of gastro-intestinal infection in children below the age of five years.

Though it was not in focus, it needs to be highlighted, that 78% of the intervention studies had a study- duration of 6 months and less and only 22% were of 12 months and longer.

5 Discussion, conclusion and recommendations

5.1 Discussion

Point-of-use treatment is a technique to improve water quality at the point of consumption. Quality aspects of pathogen reduction, free chlorine levels and turbidity are used to prove the effectiveness of HWT. Even though all researched implementation studies intended to improve water quality, not all were looking at the complete set of quality aspects. The impact on health is observed by the reduction of diarrhoeal diseases. In 87% of the examined publications data on diarrhoea reduction was provided.
When looking at other aspects important to examine the HRBA, data was often not available and definitions were unclear. Especially when talking about acceptance the available data is often of poor quality with unsupported comments (Stauber *et al*., 2009; du Preez *et al*., 2008; Clasen *et al*., 2007; Luby *et al*., 2004; Rai *et al*., 2010) or not available at all. The evaluation studies, which represent 17% of the researched papers, did all look into the aspect of acceptance and uptake of HWT.

The human rights based approach
The perspective of a HRBA was applied while examining HWT since human rights are inevitable. For vulnerable population groups like refugees, human rights are at stake. The right to access to potable water, and the right to highest attainable standard of health are human rights. Safe water is one determinant of health, and as such closely related to the right to highest attainable standard of health. The human rights council emphasised to integrate human rights into impact assessments and to use a HRBA to implement programmes (UNHRC 15/9, Oct. 2010 §§ 8-10).
To follow this appeal on the field level, guidance on the applicability of such an approach given by research is in demand. While the needs are high and pressing in the environment of a refugee setting, decisions have to be made on one side evidence- based but on the other side human rights have to be respected, so a human rights based approach should be applied. Are these two approaches a contradiction or a useful combination? Respecting human rights is more than a moral obligation. International treaties have to be translated into action and this applies to refugee settings as well. The rights of refugees are already violated and thus the attempt should be made to progressively aim for putting the most essential rights in place again. In this sense the human rights based approach is a valuable tool to evaluate studies. It offers insight of how much this set of rights is respected and- if not, were the reasons for the incomplete implementation are.
The “do-no-harm” aspect in research can be discussed accordingly. Research with humans has to follow the “do-no-harm” aspect, anything else is considered unethical. Focusing on water quality at source rather than at point

of consumption can possibly cause harm if people do not drink the source-treated water. They might, if possible, go for untreated water because they do not like the already treated water. That means, in unfavourable conditions, the camp population might go for low- quality water with the inherent risk of getting infected with diarrhoea- causing agents.

A different way of thinking might be the combination of the evidence- based and the human rights based approach. Of course HWT effectiveness should be supported by evidence and it should not cause harm. And as a parallel line of thought, the human rights should not slip out of focus. It seems to be the most promising approach, from the perspective of the beneficiaries, and in the end as well for the implementing agency, to combine these two approaches.

In this literature study none of the reviewed publications had data on all essential aspects, which would qualify for a HRBA. On the other side, there was no 100% coverage regarding the quality data, which would, in this sense, be the evidence- based approach. But it in the end every research and implementation, which is meant to help humans has to take into consideration the needs, perceptions and rights of the people in focus.

As human rights are to be applied worldwide and for all kinds of interventions, relevant actors have an obligation to apply such approaches and to assist states to fulfil their obligations to human rights as Hammonds *et al*. (2012) concluded. While Hammonds *et al.* see this obligation on the state health sector level; this thesis is focusing on the field level, especially on refugee camps. There is a need to know to if a HRBA would be feasible in refugee camps when implementing HWT.

Studies in refugee settings

Only one of the reviewed studies was conducted in a refugee camp. Even if other settings do provide, to a certain extend, refugee-like settings, the conditions of a camp are special. A high influx of people of at least one different state and with possibly diverse cultural backgrounds as well as harsh living conditions may influence the implementation of HWT.

Research in refugee settings has major implications since one is working with people who experienced life- threatening situations, which made them come to the camp in first place. Being physically and mentally weak, in an unknown region amongst unknown people makes people vulnerable to sign in for research, which they possibly did not fully understand. As Leaning (2001) points out, the key principles of bioethics: informed consent, confidentiality, do-no-harm and benefice, have to be applied in refugee camps as in other places. Leaning continues that, even if research with refugees in camps is difficult, and the design of such a study needs probably more work, there are issues, which can only be addressed there. Failure to improve knowledge would be unethical itself as Leaning concludes.

That means that relief work does include the obligation to learn and then to improve delivering aid. There is a need for aid agencies to conduct research, respectively to cooperate with researchers, to get more insight in this particular setting of a refugee camp.

Research needed to Guide decisions

To fully adapt to a new water treatment a behaviour change is necessary. As behaviour is adopted over a long period of time, it becomes clear that a change in behaviour is not quickly done. To adhere for a certain time to a point-of-use treatment of water is more or less a question of discipline than of behaviour change. That could only be measured during a long study period, in optimal case with an evaluation some time later. Acknowledging, that 78% of the reviewed intervention studies had a study period of only six months and less, measuring acceptance or even behaviour change becomes an issue. Measuring uptake would be ideally done during the period of the intervention and later through an evaluation. Hunter (2009) argues, that the HWT studies are of short duration, which is one factor of a poor study design. He continues that, only if there are enough large, preferably blinded, randomized trials with adequate follow-up duration, then the focus should shift to uptake and sustainability of an intervention.

In Hunters comparison of HWT, ceramic filtration were much more effective than the other methods, especially in long- term. The filters had, even over a period of over 12 months, still significant health benefit, while especially disinfection interventions had little if any health benefit regarding risk for diarrhoeal disease.

Waddington *et al.* (2009) support that social networks and individual agency influence the adoption or rejection of HWT. They argue that within the social networks values, beliefs and past experience shared in the network account for behavioural mechanisms and conclude that interventions, which need behaviour change, must encounter the context in which it is applied.

Thinking of compliance and behaviour change it is clear that this is can only be achieved with high training input and monitoring. People can only comply if they understand why and what to comply to. They should know what the benefits would possibly be and if these would outweigh the shortcomings of the to date practiced water treatment.

Monitoring of several aspects is obligatory to follow the process: water quality should be observed regarding contamination, turbidity and chlorine level. Empirical data, which is aiming to shed light on perceived benefits and acceptance needs to be collected as well as weather the people would be able and willing to give part of the household income into HWT. Conduction of a local market research regarding availability and prices of HWT tools should complete the intervention.

Waddington *et al.* (2009) discussed the heterogeneity across HWT studies to measure the impact on health through observing diarrhoea: risk ratio, rate ratio, prevalence ratio and odds ratios are used and a variety of different age clusters are observed. This makes direct comparison between the interventions difficult. However, the variety of measuring did not impact the effect estimates.

Observing children to measure impact on diarrhoeal disease would possibly be opportune. Especially when sticking to the age cluster of below fives since this is usually a cluster used in NGO- reporting (own experience) and it is a group the WHO is referring to in the health reports.

Owing to the examination of the papers, a potential for conflicts of interests was revealed: out of five studies using chlorination as main intervention, three received support by manufacturers of chlorination products; for the studies using a flocculation/disinfection product, five received assistance from the product manufacturers. In some studies a member of the researchers´ team was somehow involved/linked with that product manufacturer. However, in all the publications no conflicts of interest were stated.

Schmidt & Cairncross (2009) reviewed HWT studies and discussed the issue of large numbers of industry partners involved in HWT. They challenged that studies, which used commercially available products may be prone to compromise objectivity, since commercial interests may influence the publications. In their review they found zero impact across five placebo-controlled trials and addressed as well the option of publication bias and selective reporting. They concluded, that the published impact on diarrhoea reduction could be, to a certain extent, due to publication bias.

Waddington *et al*. (2009) found some evidence for publication bias in water quality interventions, and a smaller effect size for studies, which declared no conflict of interest and which had a placebo- controlled study design, which would support the issue of publication bias.

Since diarrhoea is not exclusively related to water quality the influence of personal and environmental hygiene and sanitation has to be taken into consideration as well. These factors can make a difference to study results depending on their influence. To have studies, which compare such hygiene measures with water quality interventions could probably highlight how much these different interventions influence diarrhoeal diseases.

Seven studies examined in this thesis using chlorine and flocculation/disinfection products received financial support from relevant companies. This might have had an effect on reporting. The aspect of influence on taste and smell of treated water, a clearly problematic side of these interventions, could and should have been better researched to get better insight of the perception of the consumers. In this sense, possibly unfavourable data was not published.

Limitations

Certainly there are publications, which slipped through the applied search criteria and which would have helped to find more studies and therefore the possibility to analyse more data. Examining project data of NGOs implementing HWT could probably show better, how implementing organizations apply a HRBA.

Using a different water quality guideline e.g. from UNHCR, Sphere or ICRC would have possibly given slightly different results. However, it was chosen to work with the WHO guidelines as reference and not to go into the comparison with other existing guidelines.

The data of the UNHCR was used to show the scale of the problem of endemic and epidemic diarrhoea in refugee and IDP camps. There are camps, which are not under the protection of the UNHCR, especially in natural disaster situations. It might have given a different picture including such camps as well. However, the potential of epidemics of diarrhoeal diseases and the recontamination of water is not exclusive for UNHCR- led camps.

5.2 Conclusion

Looking at source treatment it seems, that this type of treatment cannot always prevent outbreaks of diarrhoeal disease or endemic diarrhoea in camps. There is evidence, that source treatment of water does not uphold its quality to the point of consumption (Wright *et al*., 2004).
Forcing people to drink chlorinated water, which they dislike may result into mitigation practices and people fetch rather untreated and low- quality water.
Conducting research, which is looking for impact on water quality has to apply a HRBA since otherwise the perceptions, thoughts and ideas of those people, who are intended to benefit from HWT, are disrespected.
To get to know if HWT could work in camp settings, such interventions have to be conducted there. To apply a HRBA in researching HWT studies need to be re-designed applying such a human rights framework:

- With a longer intervention period
- With monitoring and gathering data for availability, accessibility, acceptance and quality
- With a follow- up of uptake
- Including local market research for availability and prices of HWT

All this is finally leading to a call for a different allocation of financial recourses to make this type of research- design possible.

5.3 Recommendations

To make an informed choice on the field level to opt for one or the other household water treatment in refugee camps, more research in refugee settings is needed. Since research in and with this already vulnerable population is a sensitive issue, a high quality approach in designing such interventions is necessary.
Data seems to suggest that filtration techniques are a suitable method to treat drinking water. The available data for uptake of filtration with ceramic filters and with biosand would favour these over the methods of chlorination, flocculation/disinfection and SODIS. Filtering methods are most likely to be used over a longer period in non- camp settings. However, there is no absolute certainty that this is the most appropriate method in refugee camps. If the uptake would be of the same dimension in a camp and to what extend this has an impact on diarrhoea remains to be seen. Giving recommendation for HWT implementation in refugee camps with the available data would not be justified. We are still in need of research to support or opt against the different HWT in this setting.

Recommendations for further research
With respect to a human rights based approach further studies should provide:

- Information on availability and price of HWT products and devices through local market research
- Findings on how much could people afford to pay for HWT to guarantee economic access
- Perceptions of the users about taste, smell, appearance of the treated water, uptake of HWT
- A complete set of data regarding water quality: baseline and reduced turbidity, pathogen reduction, chlorine level
- Results on the impact on diarrhoeal diseases

The implementation phase should be over six months and a follow- up after 12 months would shed light on uptake and acceptance with the discussed behaviour change.

References

1. Aiken BA, Stauber CE, Gloria M Ortiz, Sobsey MD (2011) An assessment of continued use and health impact of the concrete biosand filter in Bonao, Dominican Republic. *American Journal of Tropical Medicine and Hygiene* 85 (2), 309-317.

2. Atuyambe LM, Ediau M, Orach CG, Musenero M, Bazeyo W (2011) Land slide disaster in eastern Uganda: rapid assessment of water, sanitation and hygiene situation in Bulucheke camp, Bududa district. *Environmental Health* 10 (38), 1-13.

3. Berney M, Weilenmann H-U, Egli T (2006) Flow-cytometric study of vital cellular functions in Escherichia coli during solar disinfection (SODIS*). Microbiology* (152), 1719-1729.

4. Brown J, Sobsey MD, Loomis D (2008) Local drinking water filters reduce diarrhoeal disease in Cambodia: a randomized, controlled trial of the ceramic water purifier*. American Journal of Tropical Medicine and Hygiene* 79 (3), 394-400

5. Centre for Disease Control (1992) Famine-Affected, Refugee, and Displaced Populations: Recommendations for Public Health Issues*.* http://www.cdc.gov/mmwr/preview/mmwrhtml/00019261.htm [Accessed 31.07.2012].

6. Centre for Disease Control (2008) Household water treatment options in developing countries: Household chlorination. http://www.cdc.gov/safewater/chlorination.html [Accessed 30.07.2012].

7. Centre for Disease Control (2008) Household water treatment options in developing countries: Flocculant/disinfectant powder http://www.cdc.gov/safewater/flocculant-filtration.html [Accessed 06.01.2012].

8. Chiller TM, Mendoza CE, Lopez MB, Alvarez M, Hoekstra RM, Keswick BH, Luby SP (2006) Reducing diarrhoea in Guatemalan children: randomized controlled trial of flocculant-disinfectant for drinking water*. Bulletin of the World Health Organization* 84, 28-35.

9. Clasen T, Parra GG, Boisson S, Collin S (2005) Household-based ceramic water filters for the prevention of diarrhoea: a randomized, controlled trial of a pilot program in Colombia*. American Journal of Tropical Medicine and Hygiene* 73 (4), 790-795.

10. Clasen TF, Brown J, Collin S, Suntura O, Cairnoss S, (2004) Reducing diarrhoea through the use of household-based ceramic water filters: a randomized, controlled trial in rural Bolivia*. American Journal of Tropical Medicine and Hygiene* 70 (6), 651-657.

11. Clasen T, Saeed TF, Boisson S, Edmonson P, Shipin O, (2007) Household water treatment using sodium dichloroisocyanurate (NaDCC) tablets: a randomized, controlled trial to assess microbiological effectiveness in Bangladesh*. American Journal of Tropical Medicine and Hygiene* 76 (1), 187-192.

12. CRED (2010). Annual disaster statistical review 2009 http://www.cred.be/sites/default/files/ADSR_2009.pdf. [Accessed 26.01.2011].

13. Colindres RE, Jain S, Bowen A, Domond P, Mintz E (2007) After the flood: an evaluation of in-home drinking water treatment with combined flocculant-disinfectant following Tropical Storm Jeanne- Gonaives, Haiti, 2004*. Journal of Water and Health* 05 (3), 367-374.

14. Conroy RM, Meegan ME, Joyce T, Mc Guigan K, Barnes J (2001) Solar disinfection of drinking water protects against cholera in children under 6 years of age. *Archives of Disease in Childhood* 85, 293-295.

15. Crump JA, Otieno PO, Slutsker L, Keswick BH, Rosen DH, Hoekstra RM, Vulule JM, Luby SP (2005) Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhoea in areas with turbid source water in rural western Kenya: cluster randomized controlled trial*.* British Medical Journal (doi:10.1136/bmj.38512.618681.E0).

16. Doocy S, Burnham G (2006) Point-of-use water treatment and diarrhoea reduction in the emergency context: an effectiveness trial in Liberia*. Tropical Medicine and International Health* 11 (10), 1542-1552.

17. Du Preez M, Conroy RM, Wright JA, Moyo S, Potgieter N, Gundry S-W (2008) Short report: Use of Ceramic filtration in the prevention of diarrhoeal disease: a randomized controlled trial in rural South Africa and Zimbabwe*. American Journal of Tropical Medicine and Hygiene* 79 (5), 696-701.

18. Esrey SA, Potash JB, Roberts L, Shiff C (1991) Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization* 69 (5), 609-621.

19. Fiore MM, Minnings K, Fiore LD (2010) Assessment of biosand filter performance in rural communities in southern coastal Nicaragua: an evaluation of 199 households*. Rural and Remote Health* 10 (1483), 1-8 http://www.rrh.org.au
[Accessed: 30.11.2011]

20. Graf J, Togouet SZ, Kemke N, Niyitegeka D, Meierhofer R, Pieboji JG (2010) Health gains from solar water disinfection (SODIS): evaluation of a water quality intervention in Yaoundé, Cameroon*. Journal of water and Health* 08 (4), 779-796.
http://www.sodis.ch/methode/forschung/publikation/index#gesundheit
[Accessed: 30.11.2011]

21. Goma Epidemiology Group. *Public Health impact of the Rwandan refugee crisis: what happened in Goma, Zaire in July, 1994?* The Lancet 345 (8946), 339-344.

22. Gorter AC, Sandiford P, Davey Smith G, Pauw JP (1991) Water supply, sanitation and diarrhoeal disease in Nicaragua: results from a case control study. *International Journal of Epidemiology* 20, 527-533.

23. Hammonds R, Ooms G, Vandenhole W (2012) Under the legal radar screen: global health initiatives and international human rights obligations. *BioMed Central International Health and Human Rights 12 (31), 1-19.*
http://www.biomedcentral.com/1472-698X/12/31
[Accessed: 06.05.2013]

24. Hunter PR (2009) Household water treatment in developing countries: comparing different intervention types using meta-regression. *Environmental Science & Technology 43 (23), 8991-8997.*

25. International Committee of the Red Cross, (2009). *Internal displacement in armed conflict. Facing up to the challenges*.
ICRC, Geneva.

26. Jain S, Sahanoon OK, Blanton E, Schmitz A, Wannemuehler KA, Hoekstra R, Quick RE (2010) Sodium Dichloroisocyanurate tablets for routine treatment of household drinking water in periurban Ghana: a randomized controlled trial. *American Journal of Tropical Medicine and Hygiene* 82 (1) 16-22.

27. Lantagne D, (2009) Viability of commercially available bleach for water treatment in developing countries. *American Journal of Public Health* 99 (11), 1975-1978.

28. Lantagne D, Clasen T, (2009) *Point of use water treatment in emergency response.* London School of Hygiene and Tropical Medicine, London.

29. Leaning J (2001) Ethics of research in refugee populations. *The Lancet 35, (May 5), 1432-1433.*

30. Luby SP, Agboatwalla M, Hoekstra RM, Rahbar MH, Billhimer W, Keswick B (2004) Delayed effectiveness of home-based interventions in reducing childhood diarrhoea, Karachi, Pakistan*. American Journal of Tropical Medicine and Hygiene* 71 (4), 420-427.

31. Luby SP, Mendoza C, Keswick BH, Chiller TM, Hoekstra RM (2008) Difficulties in bringing point-of-use water treatment to scale in rural Guatemala. *American Jornal of Tropical Medicine and Hygiene 78 (3), 382-387.*

32. Mäusezahl D, Christen A, Pacheco GD, Tellez FA, Iriarte M, Zapata ME, Cevallos M, Hattendorf J, Cattaneo MD, Arnold B, Smith TA, Colford Jr, JM (2009) Solar drinking water disinfection (SODIS) to reduce childhood diarrhoea in rural Bolivia: a cluster- randomized, controlled trial*. PLoS Medicine August* 6 (8), 1-13 http://www.plosmedicine.org/article/info%3Adoi%2F10.1371%2Fjournal.pmed.1000125
[Accessed: 23.11.2011]

33. Moe CL, Sobsey MD, Samsa GP, Mesolo (1991) Bacterial indicators of risk of diarrhoeal disease from drinking-water in the Philippines*. Bulletin of the World Health Organization*, 69: 305-317

34. Opryszko MC, Majeed SW, Hansen PM, Myers JA, Baba D, Thompson RE, Burnham G (2010) Water and hygiene interventions to reduce diarrhoea in rural Afghanistan: a randomized controlled study. *Journal of Water and Health* 08 (4), 687-702.

35. Prüss-Üstün A, Kay D, Fewtrell L, Bartram J (2004) Unsafe water, sanitation and hygiene. In: Ezzati M (ed.) Comparative quantification of health risks: Global and regional burden of disease attributable to selected major risk factors. World Health Organization, Geneva, pp. 1321-1352.
ISBN 9241580313.

36. Quick RE, Kimura A, Thevos A, Tembo M, Shamputa I, Hutwagner L, Mintz E (2002) Diarrhoea prevention through household-level water disinfection and safe storage in Zambia*. American Journal of Tropical Medicine and Hygiene* 66 (5), 584-589.

37. Rai BB, Pal R, Kar S, Dechen C Tsering (2010) Solar disinfection improves drinking water quality to prevent diarrhoea in under-five children in Sikkim, India. *Journal of Global Infectious Diseases* 2(3), 221-225 (doi: 10.4103/0974-777X.68532).

38. Reller ME, Mendoza CE, Lopez MB, Alvarez M, Hoekstra RM, Olson CA, Baier KG, Keswick BH, Luby SP (2003) A randomized controlled trial of household-based flocculant-disinfectant drinking water treatment for diarrhoea prevention in rural Guatemala. *American Journal of Tropical Medicine and Hygiene* 69 (4), 411-419.

39. Roberts L, Chartier Y, Chartier O, Malenga G, Toole M, Rodka H (2001) Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial. *Bulletin of the World Health Organization* 79 (4), 280-287.

40. Samaritans purse (2010) http://samaritanspurse.ca/ourwork/water/doc/WSP_Field_Note_2010_%28Cambodia%29.pdf [Accessed: 23.10.2010]

41. Schmid P, Kohler M, Meierhofer R, Luzi S, Wegelin M (2008) Does the reuse of PET bottles during solar water disinfection pose a health risk due to the migration of plasticisers and other chemicals into the water? *Water Research* (42), 5054-5060. (doi:10.1016/j.waters.2008.09.05.).

42. Schmidt W-P, Cairncross S (2009) Household water treatment in poor populations: is there enough evidence for scaling up now? *Environmental Science and Technology* 43 (4), 986-992. (doi: 10.1021/es802232w).

43. Sobsey MD (2002) Managing water in the home: accelerated health gains from improved water supply. *World Health Organization, Geneva* http://www.emro.who.int/ceha/pdf/Doc-managing.pdf [Accessed: 15.12.2011]

44. Stauber CE, Ortiz GM, Loomis DP, Sobsey MD (2009) A randomized controlled trial of the concrete biosand filter and its impact on diarrhoeal disease in Bonao, Dominican Republic. *American Journal of Tropical Medicine and Hygiene* 80 (2) 286-293.

45. Tiwari SSK, Schmidt WP, Darby J, Karuiki ZG, Jenkins MW (2009) Intermittent slow sand filtration for preventing diarrhoea among children in Kenyan households using unimproved water sources: randomized controlled trial. *Tropical Medicine and International Health* 14 (11) 1374-1382.

46. Toole MJ, Waldmann RJ (1997) The public health aspects of complex emergencies and refugee situations. *Annual Review of Public Health* 18, 283-312.

47. United Nations (1948) *Universal Declaration of Human Rights* http://daccess-ods.un.org/TMP/6585385.79940796.html [Accessed 27.12.2012].

48. United Nations (2001) *Fact sheet N° 27: Seventeen frequently asked questions about United Nations special rapporteurs.* United Nations, Geneva.

49. United Nations Children´s Fund (2009) *Diarrhoea: Why children are still dying and what can be done.* United Nations Children´s Fund ISBN 978 92 806 4462 3

50. United Nations General Assembly 2010. Resolution 64/292. *The human right to water and sanitation.* http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/64/292 [Accessed 15.01.2013].

51. United Nations General Assembly of the Human Rights Council 2010. *Human rights and access to safe drinking water and sanitation.* daccess-ddsny.un.org/doc/UNDOC/GEN/G10/166/33/PDF/G1016633.pdf?OpenElement [Accessed 15.01.2013].

52. United Nations High Commissioner for Human Rights (2012) *Briefing notes 27 January. UNHCR employs alternative strategies in managing the Dadaab camps*. http://www.unhcr.org/4f22a26c6.html [Accessed 03.05.2012].

53. United Nations High Commissioner for Human Rights (2011b) *Statistical yearbook 2010.* United Nations, Geneva, pp. 15-30. http://www.unhcr.org/cgi-bin/texis/vtx/home/opendocPDFViewer.html?docid=4ef9c7849&query=statistical%20yearbook%202010 [Accessed 12.07.2012].

54. United Nations High Commissioner for Human Rights (2010) *Human rights and access to safe drinking water and sanitation.* Human Rights Council, 15th session http://daccess-ods.un.org/TMP/6941715.47889709.html [Accessed 24.12.2012].

55. United Nations High Commissioner for Human Rights (2008) *Standards and indicators report.* http://www.unhcr.org/pages/4a0183436.html [Accessed 03.05.2012].

56. United Nations High Commissioner for Human Rights (2007) *Programme overview fact sheets. Refugee Public Health 2007*
http://www.unhcr.org/4b4dcfea9.html
[Accessed 06.12.2011].

57. United Nations High Commissioner for Human Rights (1966) *International Covenant on Economic, Social and Cultural Rights General Assembly Resolution*
http://www2.ohchr.org/english/law/cescr.htm#art12
[Accessed 31.08.2012].

58. United Nations High Commissioner for Refugees (2011a) *UNHCR global trends 2010*.
UNHCR, Geneva
http://www.unhcr.org/4dfa11499.html
[Accessed 03.04.2012].

59. United Nations High Commissioner for Refugees (2011c) *The role of host countries: the cost of hosting refugees:* Standing committee, 51th meeting
http://www.unhcr.org/cgi-bin/texis/vtx/home/opendocPDFViewer.html?docid=4de4f7959&query=hosting%20refugees
[Accessed 15.01.2013].

60. Waddington H, Snistveit B, White H, Fewtrell L (2009) (ed.) Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries. *International Initiative for Impact Evaluation (3ie).*

61. Wright J, Gundry S, Conroy R (2004) Household drinking water in developing countries: a systematic review of microbial contamination between source and point-of-use.
Journal of Tropical Medicine and International Health 9 (1), 106-117.

62. World Health Organization (2013) Fact sheet N° 330:
http://www.who.int/mediacentre/factsheets/fs330/en/
[Accessed 28.05.2013].

63. World Health Organization (2011a) *Guidelines for drinking-water quality 4th edition.* World Health Organization, Geneva.
ISBN 978 92 4 1548151

64. World Health Organization (2011b) *Human rights and gender equality in health sector strategies: how to assess policy coherence*.
World Health Organization, Geneva.
ISBN 978 92 4 156408 3

65. World Health Organization (2011c) *Evaluating household water treatment options: Health-based targets and microbiological performance specifications*.
World Health Organization, Geneva.
ISBN 978 92 4 154822 9

67. World Health Organization (2011d) Country statistics website
http://apps.who.int/ghodata/?vid=8500&theme=country
[Accessed 11.12.2012].

68. World Health Organization (2008) *Guidelines for drinking-water quality 3rd edition*
ISBN 978 92 4 154761 1

69. World Health Organization (2005) *Communicable disease control in emergencies. A field manual.* World Health Organization, Geneva.
ISBN 92 4 154616 6

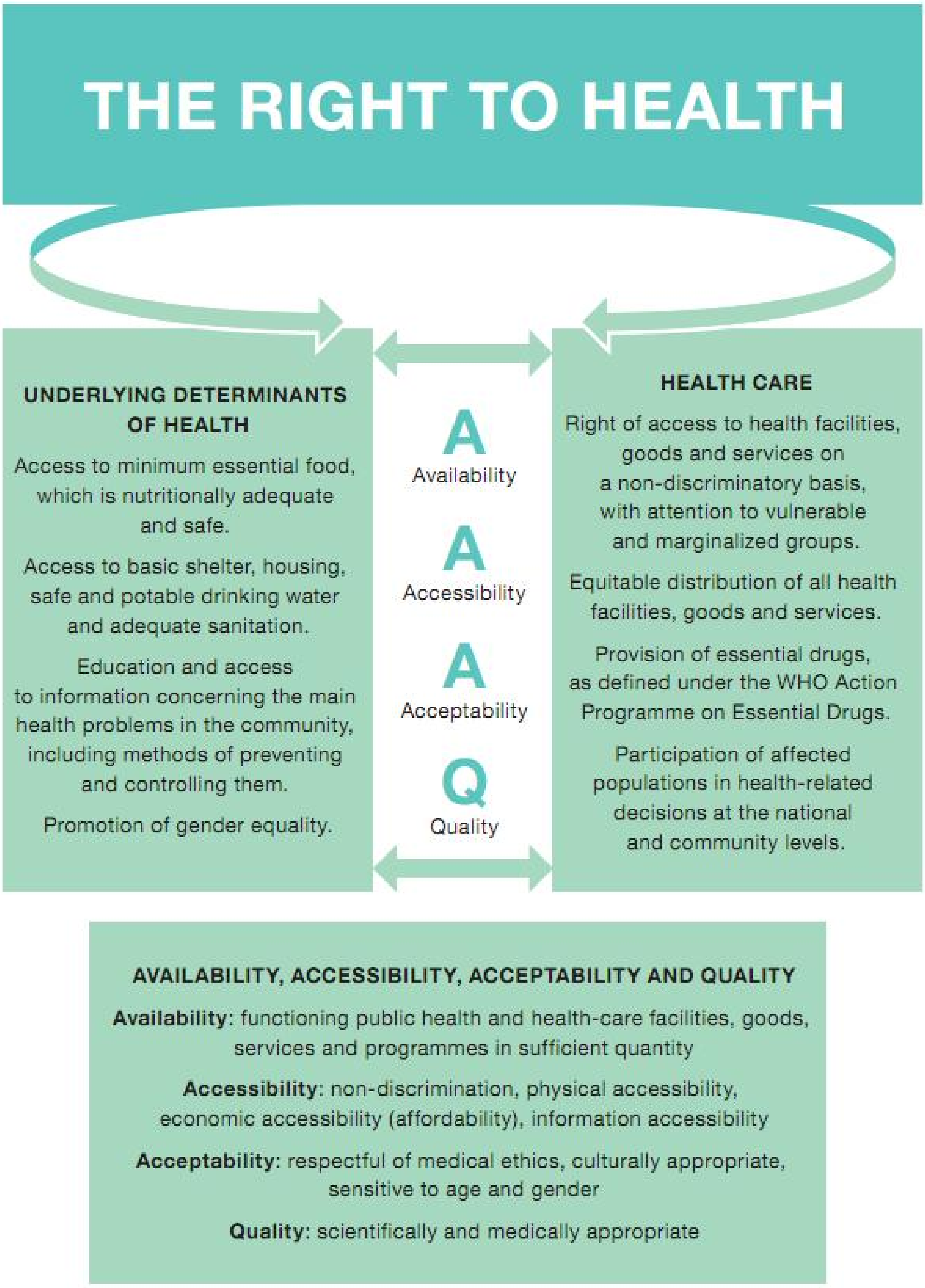
70. World Health Organization (2004). *Serious childhood problems in countries with limited resources. Background book on management of the child with a serious infection or severe malnutrition.*
World Health Organization, Geneva.
ISBN 92 4 156269 2

71. World Health Organization (2002a) *25 questions and answers on Health and Human Rights*. World Health Organization, Geneva.
ISBN 92 4 154569 0

72. World Health Organization (2002b) *Environmental health in emergencies and disasters. A practical guide.*
World Health Organization, Geneva.
ISBN 92 4 154541 0

73. World Health Organization (1978) *Declaration of Alma-Ata*.
International Conference on primary health care, Alma-Ata, USSR, 6-12- September 1978
http://www.who.int/publications/almaata_declaration_en.pdf
[Accessed 24.12.2012].

Annex 1: Figure "The Right To Health"



Source: WHO, 2011b, p. 18

Annex 2: data extraction sheet

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
44) Stauber *et al.* (2009) Biosand filtration	Rural and peri-urban Dominican Republic	154 HH	6 months	31.3% <1 MPN 30.4% 1-10 MPN 26.1% 11-100 MPN 48% reduction *E. coli*	Not applicable	No data	47 % reduction in all ages, children 2-4 years 64% reduction	No data	No data	No data	No data
1) Aiken *et al.* (2011) Evaluation of biosand implement.	Rural and peri-urban Dominican Republic	328 HH	8 weeks evaluation, filters 1 year in use		Not applicable			No data	No data	No data	27 discontinued
		152 from study of Stauber (2009)		88% reduction of *E coli*		Average turbidity reduced by 29.5% (1.1 to 0.6 NTU)	61% reduction in all ages				91% of filters still in use
	176 non-rct										90% of filters still in use
19) Fiore *et al.* (2010) Evaluation of biosand implementation	Rural Nicaragua	199 HH	3 weeks, filters in average 1 year in use	0 CFU (3%) <19 CFU (17%) medium filter efficiency 80%, overall 48%	Not applicable	No data	10% of HH had diarrhoea the previous week	60 USD exclusive delivery	yes	Filtered water tastes better: 97%	77% still in use, 99% content with the filter

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
45) Tiwari *et al.* (2009) Biosand filtration	Rural Kenya	59 HH	6 months	Mean faecal coliform reduction 94.4%	Not applicable	No data	51% reduction for age <5 years	22USD production, post-study sale for 4.86 USD	Yes	Taste and smell improved	Post-trial purchase 90% in intervention- and 69% in control-group
10) Clasen *et al.* (2004) Ceramic filtration	Rural Bolivia	50 HH	6 months	100% had 0 TTC	Not applicable	No data	72% reduction for <5 years age	25 USD, people willing to pay 9.25 USD	No data	No data	72% filters in use, 100% said they liked the filter
9) Clasen *et al.* (2005) Ceramic filtration	Urban and rural Colombia (3 sites)	140 HH	6 months	Overall reduction 75.2%	Not applicable	No data	Overall reduction 60%	No data	No data	No data	No data
	Curvarado (most remote place)	49 HH		Mean reduction 64.4%			13% reduction all age, no for <5 years age				
	Dabeiba (town)	51 HH		Mean reduction 79.1%			51% reduct all age, 40% reduction for <5 years age				
	Cartagenita (rural community)	40 HH		100% 0 TTC			79% reduct all age, 81% reduction for <5 years age				

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
17) Du Preez *et al.* (2008) Ceramic filtration	Rural Zimbabwe and Republic of South Africa	115 HH	6 months	0 *E. coli:* In RSA 73.9% In Zimbabwe 42.9%	Not applicable	No data	80% reduction for children 24-36 months age	60 USD for a system	No	No data	No data
4) Brown *et al.* (2008) Ceramic filtration	Rural Cambodia	180 HH	18 weeks	Both filters 96% reduction of *E. coli*	Not applicable	Baseline 11 NTU		8-10 USD	Yes	No data	98% of filters in use at all visits, 100% said they used it for all household drinking water
CWP				40% <1 *E. coli* 59% <10 *E. coli*		3.1 NTU	42% mean reduction for <5 years age				
CWP-Fe				37% <1 *E. coli* 62% <10 *E. coli*		3.1 NTU	35% mean reduction for <5 years age				
26) Jain *et al.* (2010) Chlorination NaDCCC vs safe storage	Periurban Ghana	240 HH	12 weeks	8% positive for *E. coli* (0-292 MPN)	74-89% of HH >/= 0.2mg/l	No data	No significant reduction for <5 years age	No data	No data	Better taste: 16%	Easy to use: 21% Adherence to treatment seen as acceptance

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
11) Clasen et al. (2007) Chlorination (NaDCC tablets)	Urban slums Dhaka, Bangladesh	100 HH	16 weeks	62% 0 TTC 23% 1-10 TTC	0.1-1mg/l: 9.6% 1.5mg/l: 16% 2.0mg/l: 21% 3.0mg/l: 16% exceeding 5.0mg/l: 11.7%	Baseline <5 NTU (94% of samples), max 12 NTU	No data	No data	No data	No data	No data, detectable free chlorine seen as indicator for consistent use

Studies	Study setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
30) Luby *et al.* (2004) Chlorination (Bleach)	Squatter settlements in Karachi, Pakistan		18 months	No data	No data	No data	Measured in age group up to 15 years	No data	yes	No data	No data
Year 2000		226 HH									
Improved vessel+bleach+fridge		46 HH					73% reduction				
Improved vessel+bleach		30 HH					Not significant				
Year 2001		278 HH					Overall reduction bleach+improved vessel: 71%				
Improved vessel+bleach+fridge		51 HH					73% reduction				
Improved vessel+bleach		29 HH					69% reduction				
Local vessel+bleach+fridge		47 HH					19% reduction				
Local vessel+bleach		28 HH					15 % reduction				

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
36) Quick et al. (2002) sodium hypochlorite/ safe storage	Kitwe, rural Zambia	260 HH	12 weeks	69% free of E. coli	>/= 0.2mg: 55-80.5%	No data	48% risk reduction all ages	no data	yes	No data	95% said water treatment prevents diarrhoea
34) Opryszko *et al.* (2010) Chlorination + evaluation after 12 months	Rural Afghanistan	328 HH 288 HH for follow-up	12 months intervention, 4 weeks follow-up	No data	No data	No data	No reduct. For <5 years, 39% overall age reduction	No data	Yes	No data	82% reported having used chlorine the previous 2 weeks
15) Crump *et al.* (2005) Chlorination	Rural Kenya	605 HH	20 weeks						yes		non-health benefits are used as indicators for acceptance
Chlorine-arm				78% < 1 CFU	85% > 0.1mg/l, (in unannounced visits: 61%)	Baseline 100-1000 NTU After treatment 55 NTU	17% reduct. For < 2 years			Looks better 77% Pref. trd.water 99%	
Flocc/ disinfect.-arm				82% < 1 CFU	86% > 0.1mg/l, (in unannounced visits 44%)	Baseline 100-1000 NTU, after treatment 8 NTU	25% reduct. For < 2 years			Looks better 100% Pref. trd.water 100%	

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
38) Reller *et al.* (2003) Flocculation/ disinfection	Rural Guatemala	492 HH	12 months			Control group 5.1 NTU		No data	No data		
Flocculation/ disinfection		102 HH		40% <1 *E. coli*	27% effective level, unannounced visits: 27% chlorine >0.1mg/	Mean 3 NTU	24% reduction all age, no reduction </= 12 months			Water good/ very good: 87%	77% it is worth the time
Flocc/ disinfect. + vessel		97 HH		57% <1 *E. coli*	34% effective level in unannounced visits: 34% chlorine >0.1mg/l	Mean 2.7 NTU	29% reduction all age, 21% reduction For </= 12 months			Water good/very good: 88%	89% it is worth the time
Bleach		97 HH		51% <1 *E. coli*	36% effective level in unannounced visits: 36% chlorine>0.1 mg/l	Mean 4.2 NTU	25% reduction all age, 13% reduction</= 12 months			Water good/ very good: 88%	100% it is worth the time
Bleach + vessel		100 HH		61% <1 *E. coli*	44% effective level in unannounced visits: 44% chlorine >0.1mg/l		12% reduction all age, 3% reduction </= 12 months			Water good/ very good: 86%	94% it is worth the time

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
8) Chiller *et al.* (2006) Flocculation/ disinfection	Rural Guatemala	514 HH	13 weeks		85% > 0.1mg/l	No data	39% reduction in prevalence for <5 years	No data	No data	No data	No data
31) Luby et al. (2008) assessment of flocculation/disinfection uptake	Rural Guatemala	514 HH		No data	1.5% of HH had detectable chlorine level	No data	No data	0.14 USD; would buy if price was half: 93%	yes	Tastes better: 84%	5% of HH met criteria for repeated use
16) Doocy & Burnham (2006) Flocculation/ disinfection	2 camps in Liberia	400 HH	12 weeks	No data	85% met or exceeded Sphere standard (0.5-1.0mg/l)	No data	83% reduct. In prevalence for all ages, 90% reduct. In incidence for all ages	estim. Consum. Cost/year 11,01 USD	No data	No data	95% compliance rate (residual chlorine in unannounced visits)
	Morris Farm	200 HH									
	Last Displaced Camp	200 HH									

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
13) Colindres *et al.* (2007) Flocculation/ disinfection	Rural Haiti	100 HH	KAP-study after emergency intervention	No data	40.9% had 0.2-2mg/l	No data	No data	No data, people would pay 0.027 USD	irregular distribution	Taste, smells, looks better: 97%,	<25% said they used PUR more than 5 times over a period of 2-4 weeks
32) Mäusezahl *et al*. (2009) SODIS	Rural Bolivia	425HH	1 year	No data	Not applicable	No data	19% reduction in children <5 years	No data	No data	No data	Mean user rate acc to field worker: 32.1%, participants reported 80% compliance
20) Graf *et al.* (2010) SODIS	Slum area in Yaoundé, Cameroon	291 HH for implementation, 671 HH for evaluation	Ca. 10 months	No data	Not applicable	No data	33.7% reduction for < 5 years	No data	No data	No data	Users: Regular: 45.8%, Irregular: 19%, Non: 35%
37) Rai *et al.* (2010) SODIS	Sikkim, India, urban slum	102 HH	6 months	No data	Not applicable	No data	76% reduction For <5 years	No data	No data	No data	No data

Studies	Setting	Study population	Study duration	Water contamination	Chlorine concentration	Turbidity	Effect on diarrhoea	Costs	Locally available/ producable	Non-health benefits	Acceptance
14) Conroy *et al.* (2001) SODIS Cholera outbreak observation	Rural Kenya	131 HH	8 weeks	No data	Not applicable	No data	88% reduct. Of cholera in <6 years	No data	No data	No data	No data

Comparison of household water treatment methods in low-and-middle-income countries under the perspective of a human rights based approach and their applicability in camps for displaced populations

A thesis submitted as partial fulfilment of the requirement for the degree of

Master in International Health

by

Sonja Nientiet

Germany

Declaration:

Where other peoples work has been used (either from printed sources, online publications or any other source) this has been fully acknowledged and referenced in accordance with the departmental requirements.

This thesis "Comparison of household water treatment methods in low-and-middle-income countries under the perspective of a Human Rights based approach and their applicability in camps for displaced populations"

is my own work

This thesis contains 10,459 words

Signature and date

29.05.2013
..................Sonja Nientiet............................
Sonja Nientiet

Master in International Health (MIH)
September 2009 to August 2013
Royal Tropical Institute (KIT)
In cooperation with the Vrije Universiteit Amsterdam
Amsterdam, The Netherlands