ANNEX 3

"Managing Water in the Home" Section 7- Monitoring and Evaluation
(relevant for the Implementation Working Group)

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7. Monitoring and evaluating the effectiveness of alternative household water treatment and storage systems and Hazard Analysis at Critical Control Points (HACCP)

7.1 Introduction

The WHO Guidelines for Drinking-water Quality (GDWQ) are adopting the concept of Water Safety Plans and HACCP (Hazard Analysis - Critical Control Points). The WHO GDWQ have long emphasized the identification of key health-related quality constituents for which health-based guideline values are established. In addition, the GDWQ also identify and specify methods to monitor drinking water quality for constituents of health concern. However, an important development in the forthcoming revisions of the guidelines is an increased emphasis on water quality protection and control from source to consumer. Emphasis will be placed on management system to manage and monitor water quality from source to consumer according to a Water Safety Plan (WSP), to encourage stakeholder participation and mobilization, and to stress the need for communication and education about water quality and how safe water quality can be achieved. A Water Safety Plan includes: (1) risk assessment to define potential health outcomes of water supply, (2) system assessment to determine the ability of the water supply system to remove pathogens and achieve defined water quality targets, (3) process control using HACCP, and (4) process/system documentation for both steady state and incident-based (e.g., failure or fault event) management. It is recommended that HACCP for household water collection, treatment and storage be applied in the context of a Water Safety Plan that addresses source water quality, water collection, water treatment, water storage and water use.

7.2 HACCP for recommended household water storage and treatment systems

7.2.1 Household water storage

As shown in Table 18, the application of HACCP to water storage in household vessels is likely to address three hazards and their critical control points (CCPs): (1) vessel type

(appropriate versus inappropriate), (1) vessel integrity (intact, damaged, parts missing, etc.), and (3) vessel sanitation (cleaned, not cleaned and a system to monitor and document cleaning frequency). For each type of storage vessel a set of specific hazards, critical control points and other criteria for a HACCP plan can be established. For example, for household storage of water according to the CDC "Safewater" system, a preferred vessel design and alternative vessel designs that are considered suitable are provided, as are vessel designs and types considered unsafe for sanitation reasons (no cover, wide opening allowing introduction of hands and dippers, etc.) (CDC Safewater, 2000). For the solar disinfection system using sunlight for heating and UV-irradiating water (SODIS and SOLAIR), recommended or preferred vessels are identified (including vessel size and type of plastic), criteria for the integrity of the vessel are specified (e.g., absence of scratches and surface damage that would reduce light penetration), and the maximum time period of water storage is specified (to avoid degradation of the microbial quality of water and biofilm accumulation due to bacterial regrowth). These and other hazards and their critical control points can be specified for each type of water storage vessel and system.

Table 18. HACCP for Household Water Storage Vessels: Hazards and Criteria for Critical Control Points

Hazard	Vessel Type	Vessel Integrity	Vessel Sanitation
Critical Control Point(s)	Appropriate or not appropriate, based on design	Intact or not intact, based on visible damage (e.g., cracks, scratches), broken or missing parts (e.g., cap) and leaks	Sanitary or nor sanitary, based on frequency of cleaning and cleaning method

7.2.2 Household water treatment

As previously stated above, it is recommended that HACCP for household water treatment be applied in the context of a Water Safety Plan that addresses source water quality, water collection, water treatment, water storage and use. For each type of household water treatment and its application in practice, generic water safety plans can be developed and these can then be adapted to site-specific conditions and situations of their use for drinking water management. As shown in Table 19, the hazards and critical control points for household water treatment include: choice of source water and type of treatment. Also important are methods of source water collection and conditions of treated water storage and use. The HACCP program within a Water Safety Plan should identify the hazards and critical control points for all steps and activities in the overall plan from source water quality to the product at the point of consumer use. Some of the key hazards and critical control points for source water and for alternative household water treatments are summarized in Table 19. The hazards and critical control points described here are not intended to be comprehensive or complete. Instead they are intended to be representative of the important hazards (failures and deficiencies) and their critical control points for some of the key household water treatments identified and recommended in this report. Further efforts will be needed to better specify and develop

HACCP plans for these water treatment technologies on both a generic (general) as well as site-specific basis. It is important to note that HACCP plans are always best articulated on a site-specific basis, even though the key elements of the plan are often common to a particular type of commodity, technology and process train.

Table 19. HACCP for Household Water Treatment: Hazards and Critical Control Points

Type of Treatment	Source Water Hazards	Source Water Critical Control Point(s)	Treatment Hazards	Treatment Critical Control Points
Heating to boiling with fuel	Contaminated or uncontaminated?	Choose best available source	Inadequate temperature achieved	Heat to a visible rolling boil
Solar Radiation in clear plastic bottles (heat + UV radiation or heat only)	Contaminated or uncontaminated?Turbid? UV-absorbing solutes	Choose best available source, with low turbidity and low UV-absorbing solutes	Inadequate sunlight to achieve target temperature and UV dose	Target temperature sensor (thermometer or melting wax); elapsed exposure time (timer, clock, sun position, etc.); monitor/observe weather (sunny, part sun or cloudy)
Solar radiation (cooker or reflector) in opaque vessel (heat only)	Contaminated or uncontaminated? Turbid?	Choose best available source, with low turbidity	Inadequate sunlight to achieve target temperature	Target temperature sensor (thermometer or melting wax); elapsed exposure time (timer, clock, sun position, etc.); monitor/observe weather (sunny, part sun or cloudy)
UV irradiation	Contaminated or	Choose	No electrical	Assure a reliable

with lamps	uncontaminated? Turbid? UV-absorbing solutes?	best available source, with low turbidity and low UV-absorbing solutes	power to UV lamp; poor water quality	source of electrical power to UV lamp; assure adequate water quality (based on turbidity and UV-absorbing materials)
Settling; plain sedimentation	Contaminated or uncontaminated? Turbid?	Choose best available source, with low turbidity	Poor settling of turbidity (suspended matter)	Observe (monitor) for adequate turbidity (cloudiness) reduction
Filtration methods	Contaminated or uncontaminated? Turbid?	Choose best available source, with low turbidity	Poor filtration and turbidity reduction	Observe (monitor) for adequate turbidity (cloudiness) reduction
Chlorination or mixed oxidants from electrolysis of brine (NaCl)	Contaminated or uncontaminated? Turbid? Chlorine-demanding solutes?	Choose best available source, with low turbidity and low chlorine demand	Poor chlorination due to inadequate dose and contact time	Observe (monitor) for chlorine residual (C) and for adequate contact time (T), i.e., adequate CT
Combined chemical coagulation + chlorination systems	Contaminated or uncontaminated? Turbid? Chlorine-demanding solutes?	Choose best available source, with low turbidity and low chlorine demand	Poor treatment due to inadequate turbidity removal and chlorine dose	Observe (monitor) for turbidity (cloudiness) reduction and adequate CT (chlorine residual and contact time)

7.2.3 Summary of HACCP for household water systems

Consistent with the forthcoming WHO GDWQ, collection, treatment and storage of household water should be developed and managed according to a Water Safety Plan that includes HACCP as a management too. For household water, hazards and critical control

points can be identified for the management steps in a water safety plan that includes source water selection and protection, water collection, water treatment and water storage, including storage vessel type and its use. The approaches and examples provided here are intended to be only exemplary and not comprehensive.

SUMMARY TABLES

Table 20. Comparison of Recommended Technologies for Household Water Treatment

Criterion	Boiling with Fuel	Solar Disinfection with UV + Heat (SODIS or SOLAIR)	Solar Disinfection with Heat Only (Opaque Vessels and Solar Panels)	UV Disinfection with Lamps	Free Chlorine and Storage in an Improved Vessel ("CDC Safewater")	Chemica Coagulatic Filtration Chlorine Disinfecti
Microbial Reductions	Yes, extensive	Yes, extensive for most pathogens	Yes, extensive for most pathogens	Yes, extensive for most pathogens	Yes, extensive* for most pathogens	Yes, extensiv
Diarrheal Disease Reductions	Yes	Yes, 9-26%; two studies	None reported from epid. studies, but expected due to high temperature (55+oC)	None reported from epid. Studies, but expected due to germicidal effects	Yes, 15-48%; many studies	None reported from epic Studies ye but expect due to multiple treatment
Disinfectant Residual	No	No	No	No	Yes	Yes
Quality Requirements of Water to be Treated	No	Low turbidity (<30 NTU) for effective use; pre-treat turbid water	None	Low turbidity (<30 NTU) and low in UV-absorbing solutes,	Low turbidity (<30 NTU) and low chlorine demand for effective	None; applicable poor quali source wa

				such as NOM, iron and sulfites	use; pre-treat turbid water	
Chemical changes in water	No, usually except deoxygenating and chemical precipitation	None or not significant	None or not significant	None or very little	Yes; may cause taste and odor and disinfection by-products	Yes, may cause tast and odor a disinfecti by-produc
Microbial regrowth potential in treated water	Yes, with storage beyond 1-2 days	Yes, with storage beyond 1-2 days	Yes, with storage beyond 1-2 days	Yes, with storage beyond 1-2 days	None to low if chlorine residual maintained	None to lo if chlorin residual maintaine
Skill level and ease of Use	Low skill, easy use	Low skill; very easy use	Low skill; easy use with training	Moderate skill, training needed for maintenance cleaning and lamp replacement	Low skill; easy use with training	Moderate training needed i adding chemicals mixing, decantin and filteri
Availability of Needed Materials	Requires a source of fuel	Requires plastic (PET) bottles and dark surface (on one side of vessel or on surface where vessel is placed	Requires black bottles of cook vessels and a solar reflector or solar cooker	Requires UV units and replacement lamps and a reliable source of electricity (power)	Requires source of free chlorine or chlorine generator and source of safe storage vessels	Requires source of t chemica mixture (coagulan and chlori disinfectan may limi availabili
Limits to Water Volume Treated	Yes, difficult to scale up above usual cooking volumes	Yes, treats 1-1.5 liters per bottle; can simultaneously treat multiple bottles	Yes, treats 1-4 liters per container; can simultaneously treat multiple vessels with multiple solar panels or solar cookers	No, units can treat several liters per minute and much, depending on lamp size and	No, easily scaled up	Yes, chemica mixture treats fixe volumes 10-20 liter repeated treatment additiona

				number and reactor volume		volumes
Performance verification requirements	Observe water for a rolling boil	Measure that target temperature is reached (thermometer or wax indicator	Measure that target temperature is reached (thermometer or wax indicator)	Must verify lamp output; may be a limitation if unit lacks a UV sensor	Measure chlorine residual or microbial quality (indicators) or both	Observe (measure turbidity reduction and measu chlorine residual
Accept-ability*	High	High to Moderate	High to Moderate	High	High to Moderate	High to moderate
Sustain-ability	High, unless fuel is scarce	High, probably	High, probably	High, probably	High	High, probably limited da
Length of Treatment Time	Minutes to tens of minutes	Hours (full sun), days (clouds), not effective if no sun	Hours (full sun), days (part sun), not effective if no sun	Seconds to minutes, depending on water volume treated and reactor design	Tens of minutes	Tens of minutes

*High is >75%; moderate is 50-75%

Table 21. Comparison of Candidate Technologies to Pre-treat Turbid Household Water

				Criterion
Effected by particle size	Yes, only settable particles removed	Yes, depends on pore size of filter; micron-submicron preferred	Somewhat; depends of medium and design; 50-99% turbidity removal possible	Somewhat; large particles reduce filter runs (remove by roughing filters or settling)

Availability of equipment and/or materials	Readily available vessels	High for local materials such as fabric or paper filters; low for membranes	High for bucket filters and local media; Medium for drum or barrel filters or cisterns; Low for more advanced filter designs	Medium if construction materials and filter sand available
Skill; ease of use	Low; very easy	Low, easy	Low for buckets; medium for drum, barrel or cistern filters	Medium; requires training to operate filter and monitor
Maintenance requirements	Low; clean settling vessel	Low for disposable filters; moderate to high for reusable filters and filter housings	Low for buckets; medium for barrel, drum & cistern filters; all require media cleaning	Medium; requires periodic cleaning and replacement of upper sand layer
Applicability to water volumes of individual households	Yes	Yes	Yes for buckets; possibly for some drum, barrel and cistern filters	Possible but unlikely; most are too large for water needs of individual family households
Cost	Low	Low for local filters; high for imported filters	Low if filter media and constriction materials are local	Low if local media and construction materials available
Acceptance	High	High for some	High, probably	Moderate, probably*
Sustainability	High	High for some	High, probably	Moderate, probably*

*Slow sand filters are often less effective, accepted and sustainable in field practice at the household level than possible in principle.