Protecting human health during extreme weather events:

The case for the sustainable disinfection of stored stormwater flows as a component of a resilient responses to climate change

University of Brighton

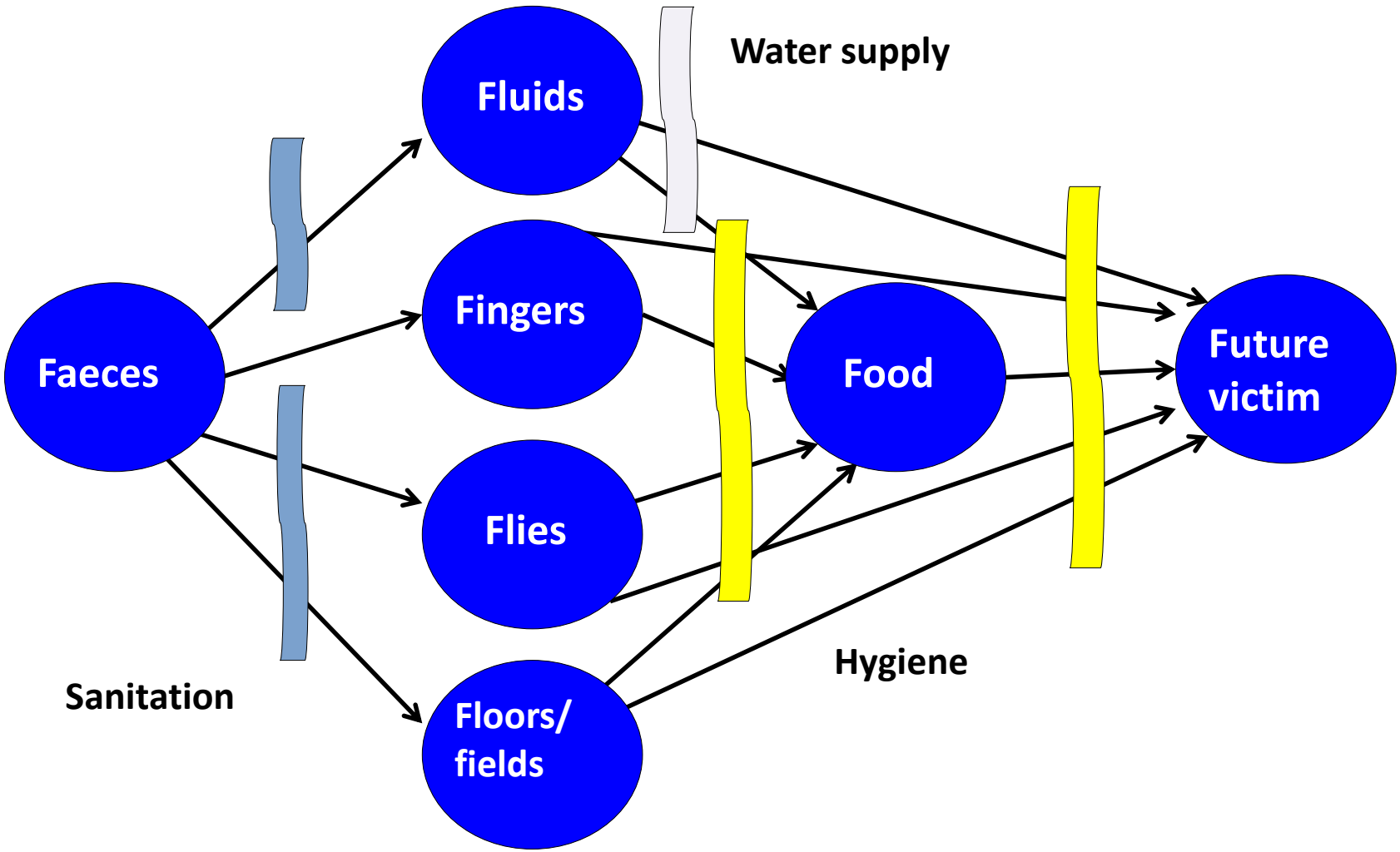
Rijksinstituut voor Volksgezondheid en Milieu
Ministerie van Volksgezondheid, Welzijn en Sport

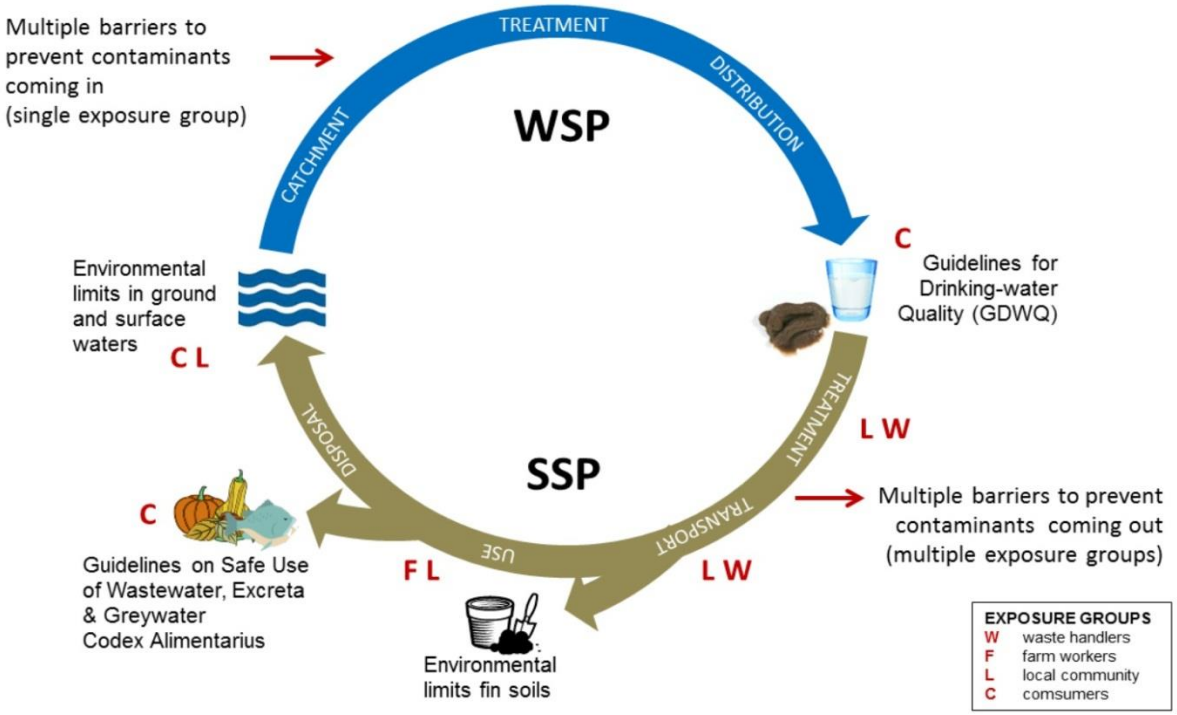
Huw Taylor
James Ebdon, Sarah Purnell,
Emanuele Sozzi and Diogo Trajano
6th April 2017

Overview of the presentation

- Physicochemical treatment of wastewater and excreta – a recurring career theme
- From Brazil to Haiti to Sierra Leone
- Wastewater management for SDG6
- Climate change in Europe – changing priorities in wastewater treatment and management
- Obstacles and opportunities

The ‘F’ diagram




Multiple barriers to prevent contaminants coming in (single exposure group)
TREATMENT
DISTRIBUTION
CATCHMENT
WSP
C
Guidelines for Drinking-water Quality (GDWQ)
Environmental limits in ground and surface waters
C L
TREATMENT
L W
DISPOSAL
SSP
TRANSPORT
Multiple barriers to prevent contaminants coming out (multiple exposure groups)
C
USE
F L
L W
Guidelines on Safe Use of Wastewater, Excreta & Greywater Codex Alimentarius
Environmental limits fin soils
EXPOSURE GROUPS
W waste handlers
F farm workers
L local community
C comsumers

UPGRADING A LOW-COST PHYSICOCHEMICAL WASTEWATER TREATMENT PLANT TO SOLVE OPERATIONAL PROBLEMS

Huw D. Taylor*, Martin P. Gambrill**,
D. Duncan Mara*** and Salamão A. Silva†

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Sometimes research impact takes a while

University of Brighton

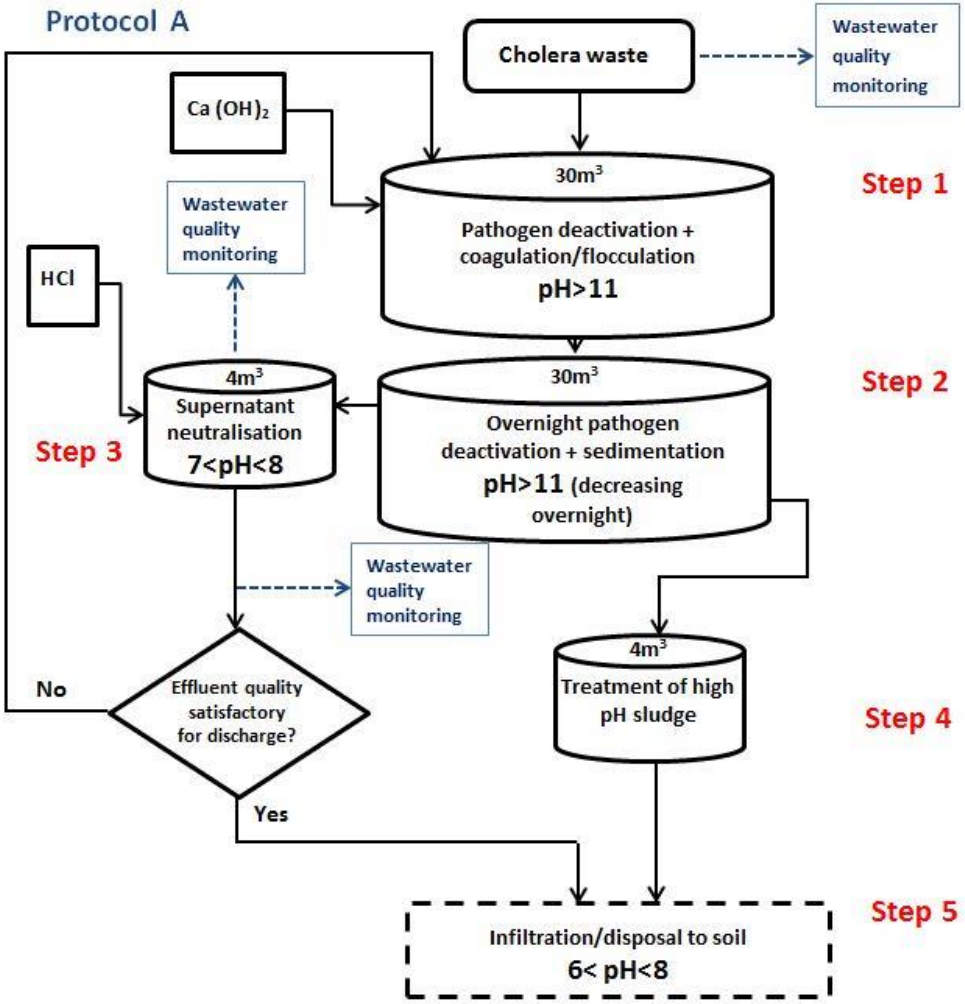
Emergency sanitation in Haiti

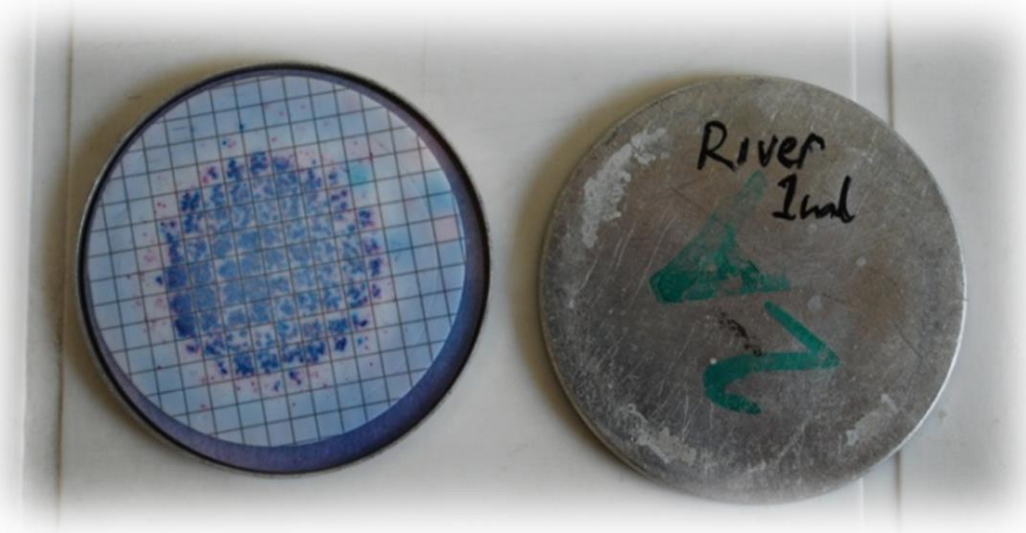
Emanuele Sozzi, Jeff Fesselet and Huw Taylor

- Ten months after the devastating earthquake of 2010, cholera appeared in Haiti for the first time in nearly a century
- The outbreak has claimed over 9,000 lives, infected 732,000 people (March 2015 figures), and continues to cause infections and deaths
- Potentially high levels of *Vibrio cholerae* in the wastewater from the Delmas Cholera Treatment Centre (CTC) in Port-au-Prince

MEDECINS SANS FRONTIERES

The treatment stages for protocol A





Urban river water versus our final effluent

Disinfectant	HTH	NaDCC	Lime
Reagent cost to treat 1 m^3 of hospital wastewater	€21.60	€14.40	€6.50

PLOS | NEGLECTED TROPICAL DISEASES

RESEARCH ARTICLE

Minimizing the Risk of Disease Transmission in Emergency Settings: Novel *In Situ* Physico-Chemical Disinfection of Pathogen-Laden Hospital Wastewaters

Emanuele Sozzi[1]*, Kerline Fabre[2], Jean-François Fesselet[3], James E. Ebdon[1], Huw Taylor[1]

1 School of Environment and Technology, University of Brighton, Brighton, United Kingdom, **2** MSF-OCA, Port-au-Prince, Haiti, **3** MSF-OCA, Amsterdam, Holland

* e.sozzi@brighton.ac.uk

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Abstract

The operation of a health care facility, such as a cholera or Ebola treatment center in an emergency setting, results in the production of pathogen-laden wastewaters that may potentially lead to onward transmission of the disease. The research presented here evaluated the design and operation of a novel treatment system, successfully used by *Médecins Sans Frontières* in Haiti to disinfect CTC wastewaters *in situ*, eliminating the need for road haulage and disposal of the waste to a poorly-managed hazardous waste facility, thereby providing an effective barrier to disease transmission through a novel but simple sanitary intervention. The physico-chemical protocols eventually successfully treated over 600 m^3 of wastewater, achieving coagulation/flocculation and disinfection by exposure to high pH (Protocol A) and low pH (Protocol B) environments, using thermotolerant coliforms as a disinfection efficacy index. In Protocol A, the addition of hydrated lime resulted in wastewater disinfection and coagulation/flocculation of suspended solids. In Protocol B, disinfection was achieved by the addition of hydrochloric acid, followed by pH neutralization and coagulation/flocculation of suspended solids using aluminum sulfate. Removal rates achieved were: COD >99%; suspended solids >90%; turbidity >90% and thermotolerant coliforms >99.9%. The proposed approach is the first known successful attempt to disinfect wastewater in a disease outbreak setting without resorting to the alternative, untested, approach of 'super chlorination' which, it has been suggested, may not consistently achieve adequate disinfection. A basic analysis of costs demonstrated a significant saving in reagent costs compared with the less reliable approach of super-chlorination. The proposed approach to *in situ* sanitation in cholera treatment centers and other disease outbreak settings represents a timely response to a UN call for onsite disinfection of wastewaters generated in such emergencies, and the 'Coalition for Cholera Prevention and Control' recently highlighted the research as meriting serious consideration and further study. Further applications of the method to other emergency settings are being actively explored by the authors through discussion with the World Health Organization with regards to the ongoing Ebola outbreak

World Health Organization

unicef

Ebola Virus Disease (EVD)

Key questions and answers concerning water, sanitation and hygiene

Introduction

Provision of water and sanitation plays an essential role in protecting human health during all disease outbreaks, including the current Ebola Virus Disease (EVD) outbreak. Good and consistently applied water, sanitation and hygiene (WASH) practices, both in health-care settings and the community will further help to prevent human-to-human transmission of EVD and many other infectious diseases.

How do people become infected with the Ebola virus?

The Ebola virus spreads in the human population by human-to-human transmission through direct contact of broken skin and mucous membranes with blood or other body fluids (e.g. faeces and urine, vomit, semen and sweat) of those infected (WHO, 2014). Transmission can occur through direct contact with these body fluids, as described above, or through touching fomites (inanimate objects), such as the floor, utensils and bed linens that have recently been contaminated with infected body fluids. Transmission through intact skin has not been documented, but infection can be transmitted through penetrating injuries of the skin, such as needle-stick injuries.

What do we know about the survival of the virus in the environment?

The characteristics of the Ebola virus suggest that it is likely to be relatively fragile in the environment in comparison with the enteric viruses that commonly cause diarrhoeal disease. To date, there is no evidence for transmission of Ebola viruses via drinking-water contaminated by faeces or urine. The virus is unlikely to survive for extended periods outside of the body. Higher temperatures (room temperature or above) are likely to increase the speed at which the virus dies-off in the environment.

What are the minimum requirements for water, sanitation and hygiene in health care settings?

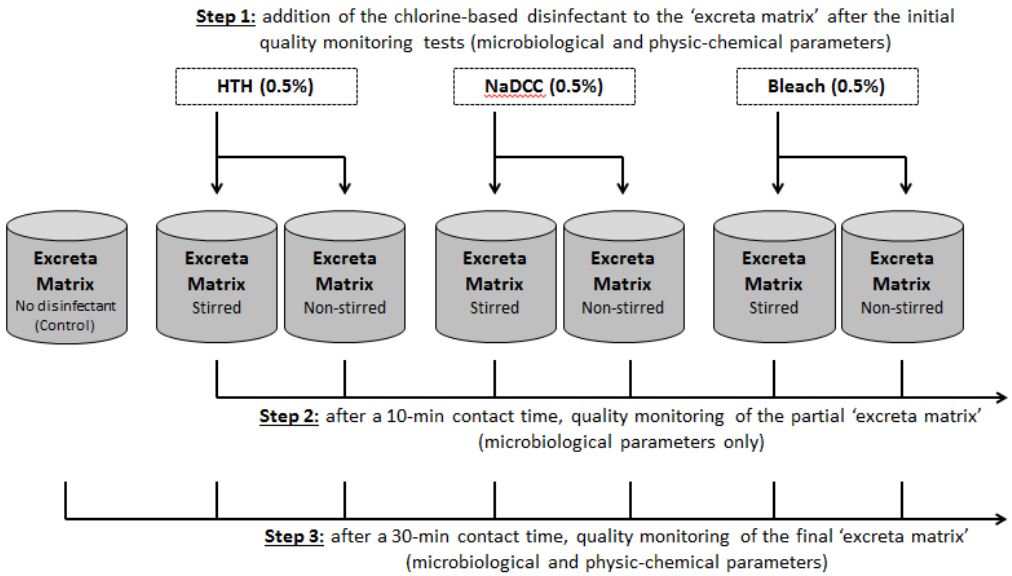
Existing recommended water, sanitation and hygiene measures in health care settings are important for providing adequate care for patients and protecting patients, staff and carers from infection risks (WHO, 2008). Of particular importance are the following actions: 1) keeping excreta (faeces and urine) separated from drinking-water sources; 2) handwashing with soap; and 3) containment of excreta such that they are effectively separated from human contact. Other important recommended measures include providing sufficient provision of drinking-water to staff, carers and patients, personal hygiene, laundry and cleaning, adequate and accessible toilets (including separate facilities for confirmed and suspected cases) and the segregation and safe disposal of health-care waste. For details refer to *Essential Environmental Health Standards in Health Care* (WHO, 2008).

What are recommended handwashing practices?

Basic hand hygiene is extremely important. This can be best achieved by handwashing with adequate quantities of clean (ideally running) water and soap or handrubbing with an alcohol-based hand rub solution. To be effective, handwashing should last 40-60 seconds and handrubbing (with an alcohol-based solution) for 20-30 seconds and the action should follow the recommended steps (WHO, 2014). Hands should be washed at all critical moments, including before and after putting on personal protective equipment (PPE), after any contact with someone infected with Ebola or their

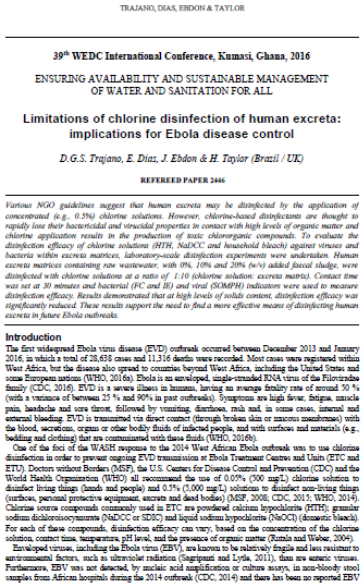
Applied Research on Disinfection to Prevent Ebola Transmission

Tufts University, with the University of Brighton and Brigham and Women's Hospital



Experiments will be repeated three times, varying the excreta matrix as follows:

Excreta Matrix 0%: raw wastewater only



TRAJANO, DIAS, EBDON & TAYLOR

39th WEDC International Conference, Kumasi, Ghana, 2016

ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL

Limitations of chlorine disinfection of human excreta: implications for Ebola disease control

D.G.S. Trajano, E. Dias, J. Ebdon & H. Taylor (Brazil / UK)

REFEREED PAPER 2446

Various NGO guidelines suggest that human excreta may be disinfected by the application of concentrated (e.g., 0.5%) chlorine solutions. However, chlorine-based disinfectants are thought to rapidly lose their bactericidal and virucidal properties in contact with high levels of organic matter and chlorine application results in the production of toxic chlororganic compounds. To evaluate the disinfection efficacy of chlorine solutions (HTH, NaDCC and household bleach) against viruses and bacteria within excreta matrices, laboratory-scale disinfection experiments were undertaken. Human excreta matrices containing raw wastewater, with 0%, 10% and 20% (w/v) added faecal sludge, were disinfected with chlorine solutions at a ratio of 1:10 (chlorine solution: excreta matrix). Contact time was set at 30 minutes and bacterial (FC and IE) and viral (SOMPH) indicators were used to measure disinfection efficacy. Results demonstrated that at high levels of solids content, disinfection efficacy was significantly reduced. These results support the need to find a more effective means of disinfecting human excreta in future Ebola outbreaks.

Introduction

The first widespread Ebola virus disease (EVD) outbreak occurred between December 2013 and January 2016, in which a total of 28,638 cases and 11,316 deaths were recorded. Most cases were registered within West Africa, but the disease also spread to countries beyond West Africa, including the United States and some European nations (WHO, 2016a). Ebola is an enveloped, single-stranded RNA virus of the Filoviridae family (CDC, 2016). EVD is a severe illness in humans, having an average fatality rate of around 50 % (with a variance of between 25 % and 90% in past outbreaks). Symptoms are high fever, fatigue, muscle pain, headache and sore throat, followed by vomiting, diarrhoea, rash and, in some cases, internal and external bleeding. EVD is transmitted via direct contact (through broken skin or mucous membranes) with the blood, secretions, organs or other bodily fluids of infected people, and with surfaces and materials (e.g., bedding and clothing) that are contaminated with these fluids (WHO, 2016b).

One of the foci of the WASH response to the 2014 West African Ebola outbreak was to use chlorine disinfection in order to prevent ongoing EVD transmission at Ebola Treatment Centres and Units (ETC and ETU). Doctors without Borders (MSF), the U.S. Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) all recommend the use of 0.05% (500 mg/L) chlorine solution to disinfect living things (hands and people) and 0.5% (5,000 mg/L) solutions to disinfect non-living things (surfaces, personal protective equipment, excreta and dead bodies) (MSF, 2008; CDC, 2015; WHO, 2014). Chlorine source compounds commonly used in ETC are powdered calcium hypochlorite (HTH), granular sodium dichloroisocyanurate (NaDCC or SDIC) and liquid sodium hypochlorite (NaOCl) (domestic bleach). For each of these compounds, disinfection efficacy can vary, based on the concentration of the chlorine solution, contact time, temperature, pH level, and the presence of organic matter (Rutala and Weber, 2004).

Enveloped viruses, including the Ebola virus (EBV), are known to be relatively fragile and less resistant to environmental factors, such as ultraviolet radiation (Sagripanti and Lytle, 2011), than are aseptic viruses. Furthermore, EBV was detected, by nucleic acid amplification or culture assays, in non-bloody stool samples from African hospitals during the 2014 outbreak (CDC, 2014) and there has been no reported EBV

Laboratory experiments

- Three chlorine-based 0.5% solutions: HTH, NaDCC and domestic bleach
- Three hydrated lime $Ca(OH)_2$ based suspensions: 10%, 20% and 30%
- Three excreta matrices: 0, 10% and 20% v/w wastewater+ faecal sludge

Wastewater

Faecal sludge

Disinfectants

Bucket scale excreta disinfection

WASH response during Ebola outbreak (excreta disinfection)

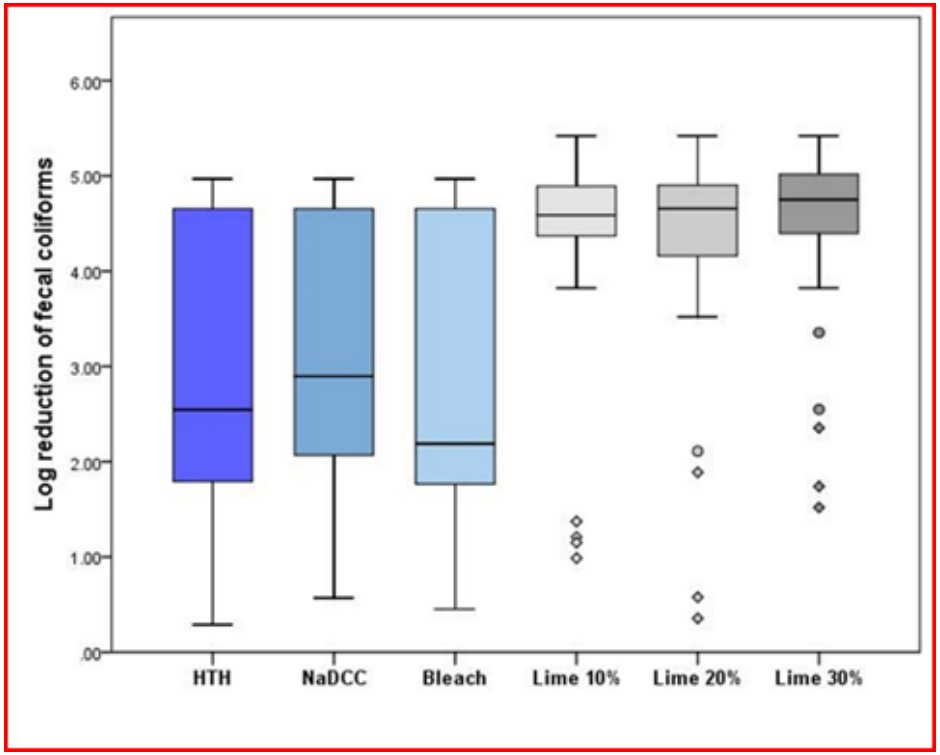
Current recommendation

- WHO, US CDC, MSF
- Chemical disinfection
- Super-chlorination
- Bucket disinfection
- Contact time 10 and 30 minutes

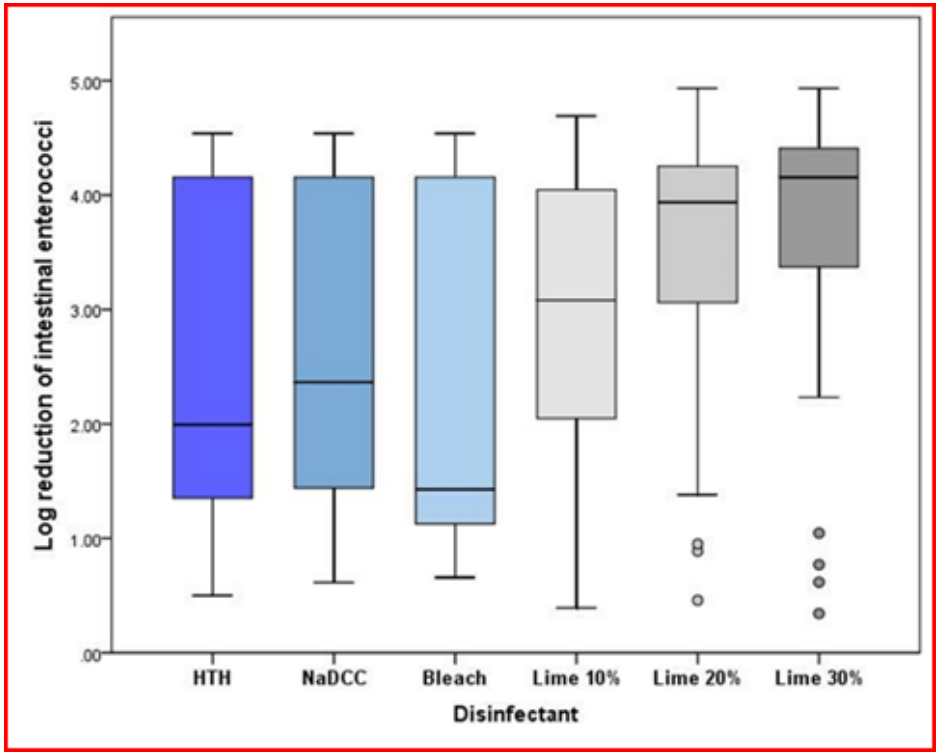
Proposed recommendation

- WHO/UNICEF 2014 Ebola Q&A
- Physio-chemical disinfection
- Hydrated lime $Ca(OH)_2$ = High pH 12-13
- Bucket disinfection
- Contact time 30 minutes

RESULTS: **Log reduction of bacteria indicator microorganisms in all excreta matrices after disinfection (pooled data).**



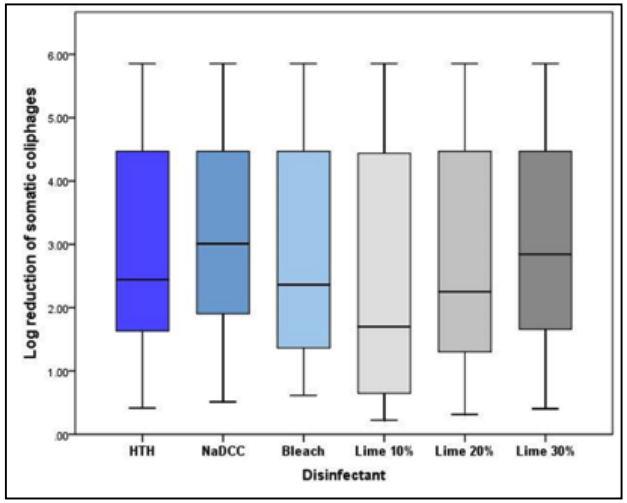
Faecal coliforms



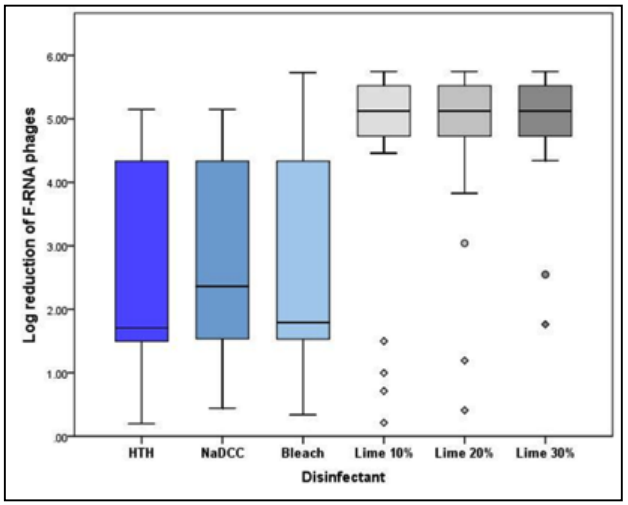
Intestinal enterococci

RESULTS:

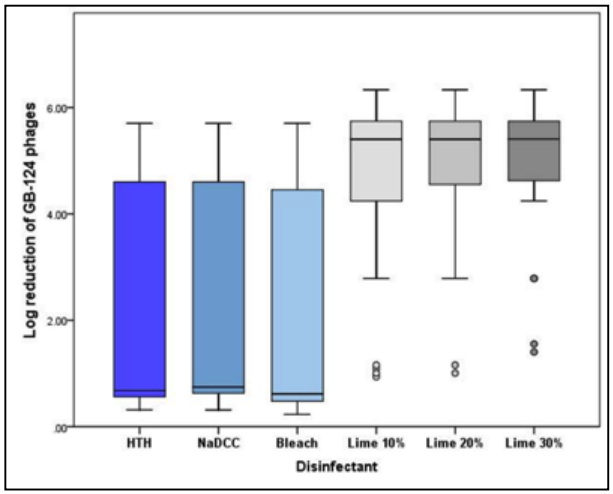
Log reduction of viral indicator microorganisms in all excreta matrices after disinfection



Somatic coliphages



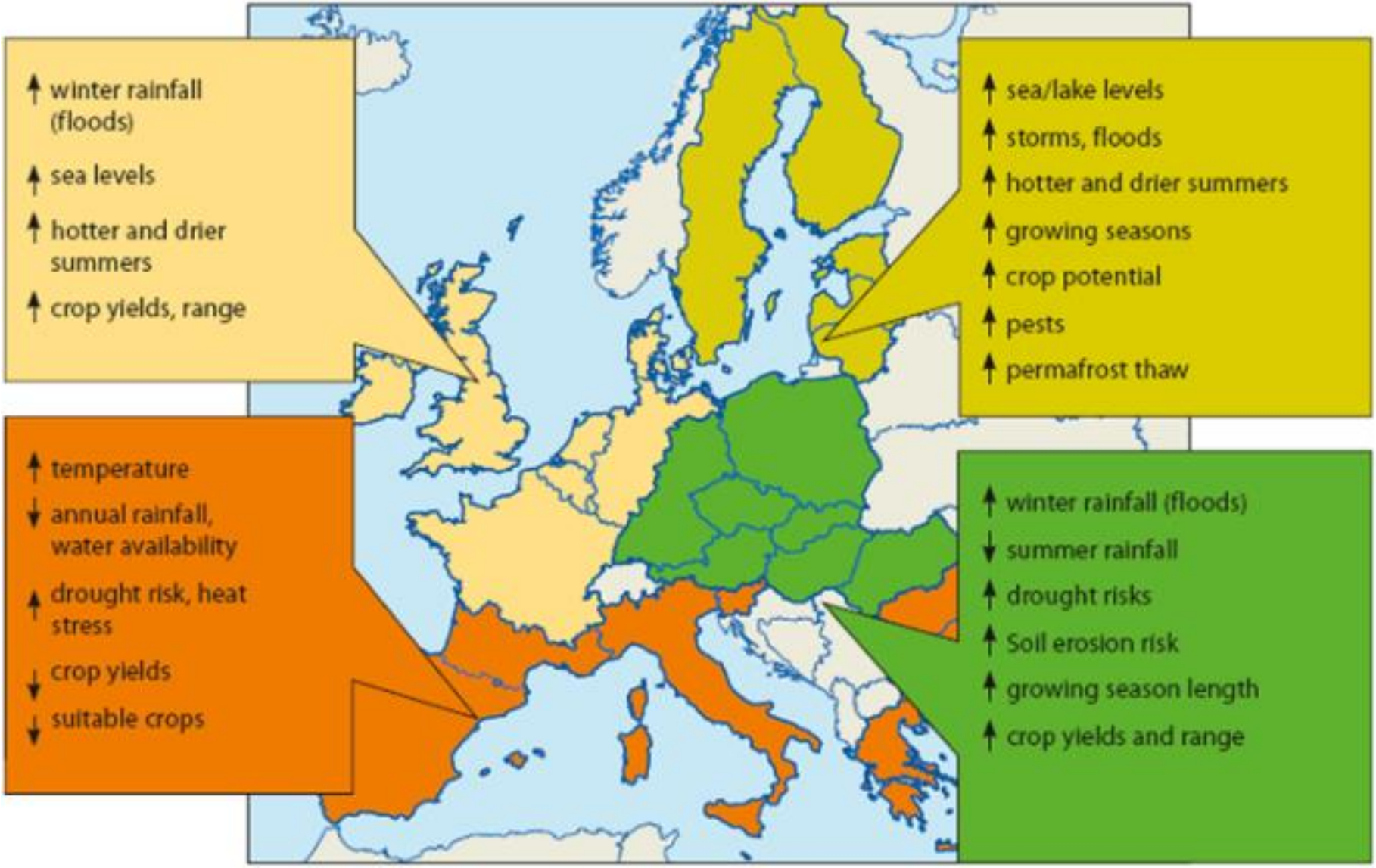
F-specific (MS-2) phages

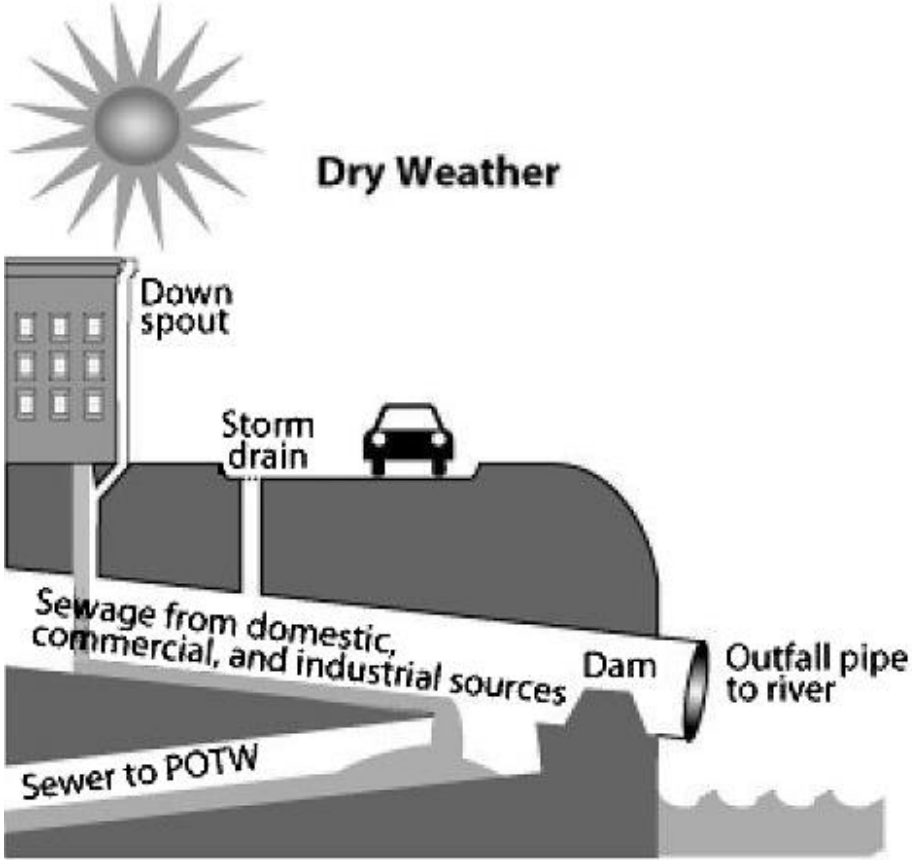


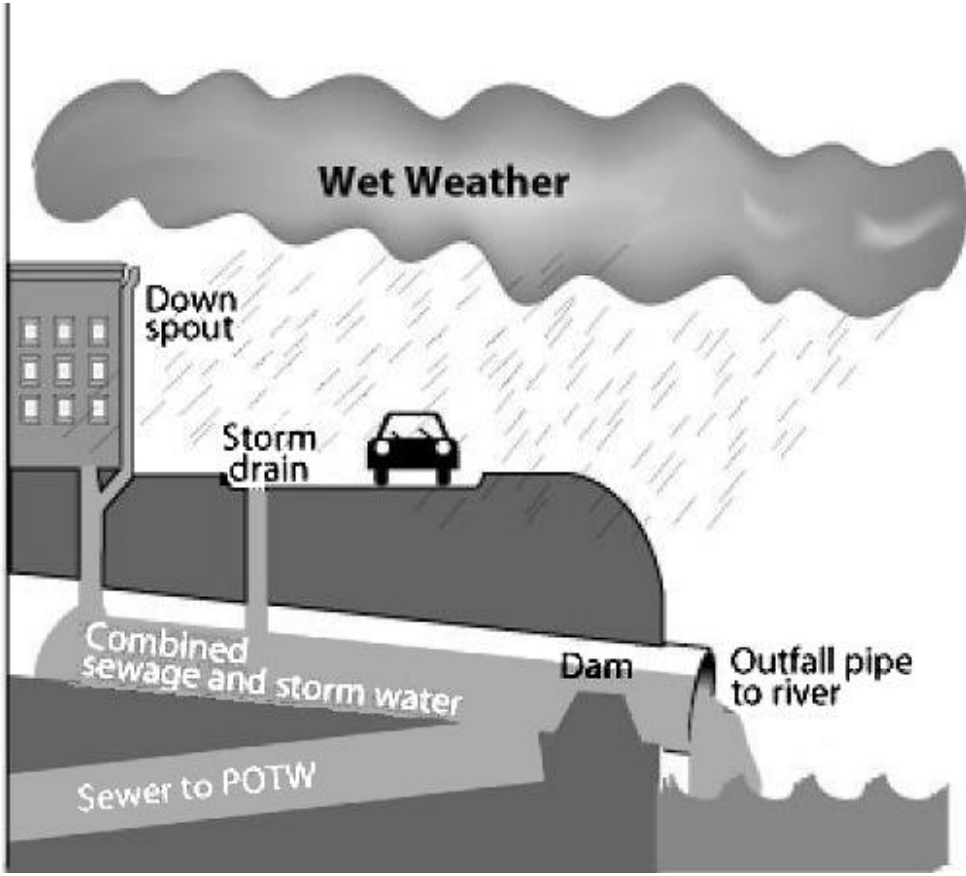
Bacteroides fragilis (GB124) phages

Conclusions from recent lime disinfection studies

- Super-chlorination seems to be effective only during the disinfection of pure wastewater
- Hydrated lime suspensions seems to be more effective than chlorine solutions
- Somatic coliphages (viral indicators) were the most resistant microorganisms
- Increasing the concentration of hydrated lime solutions improves the efficacy of the disinfection processes.
- Lime suspension (30%); mixed; 30 minutes contact time = most effective combination


↑ winter rainfall (floods)
↑ sea levels
↑ hotter and drier summers
↑ crop yields, range
↑ sea/lake levels
↑ storms, floods
↑ hotter and drier summers
↑ growing seasons
↑ crop potential
↑ pests
↑ permafrost thaw
↑ temperature
↓ annual rainfall, water availability
↑ drought risk, heat stress
↓ crop yields
↓ suitable crops
↑ winter rainfall (floods)
↓ summer rainfall
↑ drought risks
↑ Soil erosion risk
↑ growing season length
↑ crop yields and range


Dry Weather
Down spout
Storm drain
Sewage from domestic, commercial, and industrial sources
Dam
Outfall pipe to river
Sewer to POTW


Wet Weather
Down spout
Storm drain
Combined sewage and storm water
Dam
Outfall pipe to river
Sewer to POTW

QMRA: Quantitative microbial risk assessment

Human health and stormwaters

- A critical control point for waterborne disease?
- An integrated safety planning approach to the water cycle
- The need to investigate options in response to climate change – a QMRA approach

Thank you for listening

University of Brighton

h.d.taylor@brighton.ac.uk

THE BODY SHOP FOUNDATION

USAID FROM THE AMERICAN PEOPLE

Applied Research on Disinfection to Prevent Ebola Transmission
Tufts University, with the University of Brighton and Brigham and Women's Hospital