Imperial College London

The Interface between Water, Sanitation and Hygiene Engineering, Health and Behaviour Change

Engr Dr May N Sule,
PhD, AFHEA, MNSE, MWES

8th August 2020
NSE London, UK Branch
Engineering Seminar

The Nigerian Society Of Engineers

Introduction: My Background


Operations and maintenance of urban water systems


Rural sanitation


Rural water supply


Environment, sanitation, hygiene and health

2

Initial Caveat

1. These topics are not in all of our areas of engineering expertise but hopefully will appeal to many because of our collective public health interest.
2. Apologies in advance because some slides are wordy but necessary statistics!
3. Please eat your lunch in the first 20-25 minutes…

3

Content

1. Introduction
2. Two Case studies: Schistosomiasis Control and WASH improvements in Accra
   - Background
   - Methodology/Approach
   - Results/Outcomes
   - Impact/Way forward
   - Lessons learnt and possible transferable knowledge applications
3. Q and A

4

Case study 1

Schistosomiasis Control

Water Infrastructure for Schistosomiasis Endemic Regions – WISER

- Funding: £1.5 Million (GCRF, UKRI, EPSRC) – PI: Prof M Templeton
- Collaborators: Imperial College London, Natural History Museum, Addis Ababa University Ethiopia, National Institute for Medical Research, Tanzania;
- Partnered with Acting for Health on theatre/role play
- Inter-disciplinary team: water engineers, parasitologists, snail experts, synthetic biologists, anthropologists

GCRF Global Challenges Research Fund

www.wiserschisto.com
www.actingforhealth.org

UKRI Engineering and Physical Sciences Research Council

Objectives

1. Determine the effectiveness of **water treatment** processes at removing or inactivating cercariae in a rigorous and extensive manner
2. Develop and validate a rapid and cheap **biosensors** for detecting cercariae in water samples
3. Consider current **water contact behaviour** and management practices, **sanitation,** practical onsite challenges and non-technical barriers in representative **case study communities – Ethiopia and Tanzania**

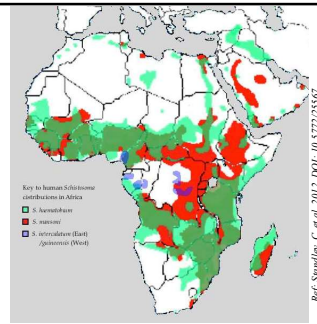
What is schistosomiasis (also known as Bilharzia)?

- **Thousands of years** old disease
- A disease cycle spread from **humans to snails and back to humans again**…a vicious cycle
- Human infection is from **skin contact with water that contains the infected snails**
- The parasites that emerge from the snails and infect humans are called **cercariae**

Picture credit: Laura Braun

What is schistosomiasis (Bilharzia)?

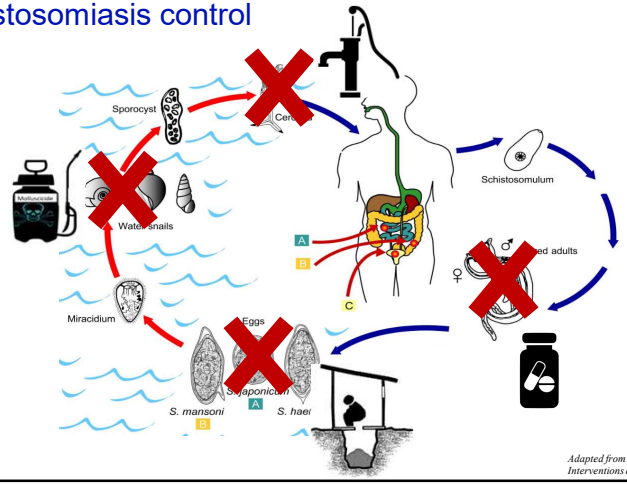
- Over **200 million people** infected; 200,000+ die each year, mostly in Africa
- **Symptoms**: bloody urine and diarrhoea, abdominal pain, enlargement of liver and spleen, inflammation & scarring of bladder
- In children, it contributes to **anaemia**, **malnutrition** and **learning difficulties**
- There is a current desire to move towards **elimination** of schistosomiasis and other neglected tropical diseases (NTDs)



Ref: Standley, C. et al. 2012, DOI: 10.5772/25567

9

Schistosomiasis control



Adapted from CDC (2012) life cycle diagram; Interventions credited to: May N Sule

10

We need to reduce contact with infested water

- Provide **water for all water needs** (drinking, washing, recreational); Occupational use still a concern…paddy farmers, fishermen
- We could just dig new wells and access safe groundwater but in many cases however, we will need to **treat the infested water somehow** to make it safe
- **Behaviour change**
- **Communication of the risk** of contact with infested water is also key – engage with community

11

Research – Water treatment

1. Chlorination (Waterguard™, Aquatabs®, Bleach)

S mansoni cercariae killed with a 'CT' value of 45 mg·min/L (for pH <7.8 and temperature >20°C)

2. Sand filtration; possible Riverbank Filtration

1.2 m deep sand column filtration rate <0.5 $m^3/m^2/h$

3. Ultraviolet (UV) disinfection

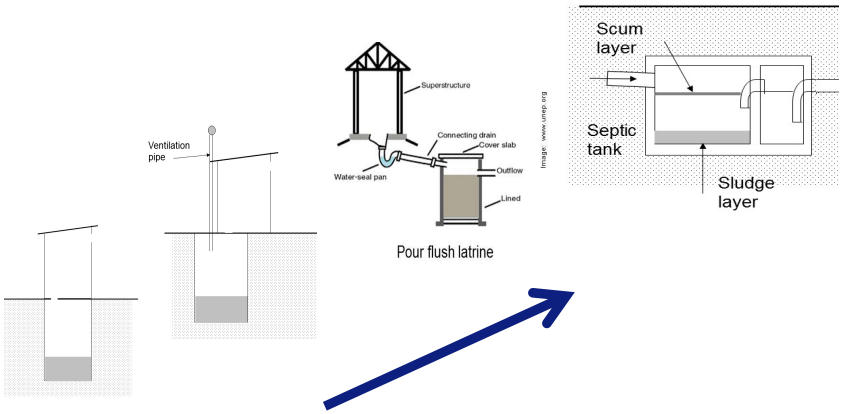
Experiments currently ongoing:
ultraviolet light emitting diodes (UV-C LEDs)

4. Storage

Analysis from previous studies show cercariae die out after 72 hours

12

The Sanitation Ladder and options



Butler and Davies (2004)

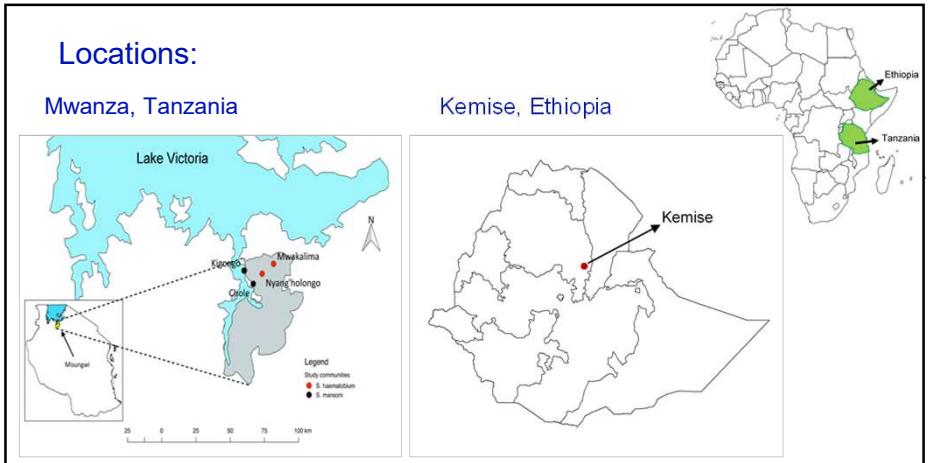
Research - Case studies

- ***Human Engineering…*** *Even if we provide people with improved/safe WASH,* ***behaviour*** *will still determine* ***uptake*** *and* ***sustainability****….*

Locations:

Mwanza, Tanzania

Kemise, Ethiopia



Mixed Methods Approach

- Quantitative and Qualitative data collection methods
- Intervention: Role play (AfH), training the trainer format/ capacity building; community champions
- Baseline and post intervention surveys/Observations
- Data analysis/Results

Intended Outcome

- Research-based scientific evidence

Stakeholder Engagement

"Tell me and I will forget.
Show me and I will remember.
Involve me and I will understand.
Step back and I will act."
Chinese Proverb

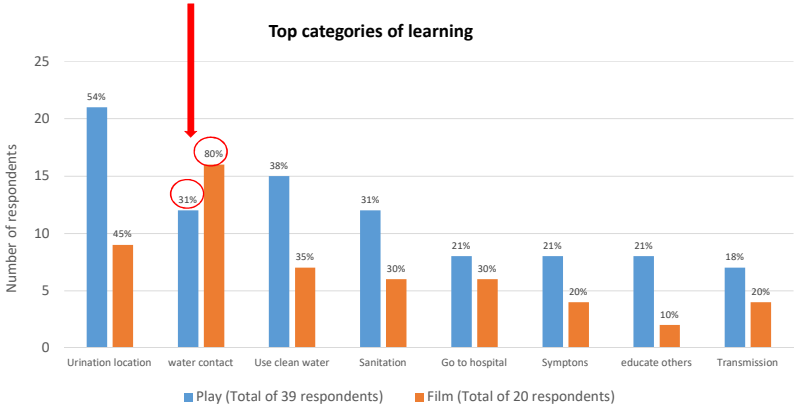
17

Learnings by cohort from AfH/trainer workshop - Tanzania

Occupation	Previously unaware of disease	Sanitation	Transmission /Prevention	Cycle of disease	Effects of disease e.g. cancer
Farmer (14)	5	1	9	2	4
Teacher (4)	0	1	4	3	1
Community Health Worker (4)	0	2	2	0	0
Village Officer (4)	1	2	3	0	0
Teenagers (4)	0	0	4	3	0
Driver (3)	0	2	2	0	0
Fish Seller/Carpenter (4)	0	1	3	0	1
TOTAL = 37	6 (11%)	9 (25%)	27 (73%)	8 (22%)	6 (17%)

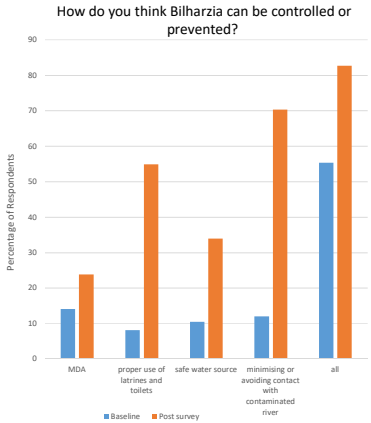
18

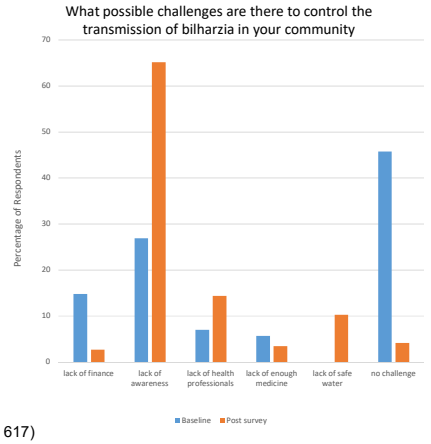
Learnings by audience in Tanzania



19

Awareness, perception and understanding - Ethiopia





(N = 617)

20

Conclusions and way forward

Potential policy/implementation implications:

- There is a wide gap in general knowledge around transmission/ prevention/ long-term morbidity; Awareness is needed
- Role play/theatre is a possible SBCC option but in combination with extended participatory community engagement, involvement and mobilisation
- Attitude and Behaviour change: General willingness to change behaviour provided the right infrastructure is in place i.e. clean water, sanitation, accessible clinics & drugs, and PPE
- Responsibility: Community, village leaders, district and regional/ national governments all have a part to play

21

Transferable learnings/lessons

Information	• Identify stakeholders • Sensitization and mobilization, education • Health and Water sectors (+ schools)
Consult and Understand	• Open meetings and surveys • Utility/Health Service providers • Engage, Collaborate and Influence policy
Involve	• Develop user-centred engineering designs • Decision making processes • Participation/capacity building • Research and analysis

22

Case study 2

WASH improvement in Accra

23

Health impacts of poor WASH

WASH = Water, Sanitation and Hygiene

- **10% of the global disease burden** (minimum)
- **Faecal-oral infections** (e.g. diarrhoea, rotavirus, cholera)
- **4 billion** cases of **diarrhoea** each year
- **2 billion helminth infections** (STH e.g. hookworm, roundworm)
- **5 million** people are blind from **trachoma**
- 200 million people in the world are infected with **schistosomiasis**

Diseases that are easily preventable and treatable through simple, cost effective, and affordable interventions.

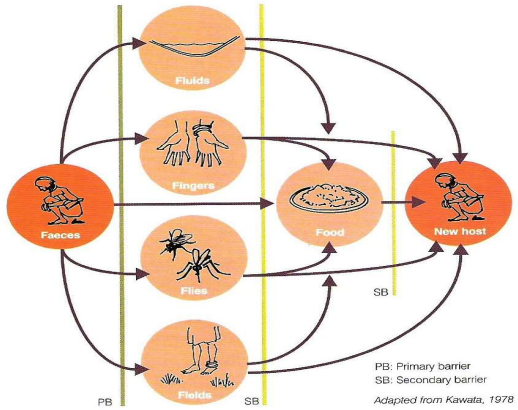
24

Diarrhoeal Disease

- Diarrhoea - passage of three or more loose or watery stools per 24 hours or an increase in stool frequency or liquidity
- A leading cause of **childhood mortality and morbidity**
- Globally, contributed to **15% of all under-5 deaths** (~2.5 million deaths each year) – 2nd leading cause of death
- Developing countries/economically disadvantaged regions carry the highest burden (**four-fifths of under-5 mortality** occur in Sub-Saharan Africa and south Asia)
- (WHO) (2016): **73.1 deaths per 1000** live births for under-5 mortality rate in low-income countries, nearly **14 times** the average rate in high-income countries
- One gram of human faeces can contain 10,000,000 viruses, 1,000,000 bacteria, 1,000 parasite cysts and 100 parasite eggs.

25

Transmission of diseases from faeces: F-diagram

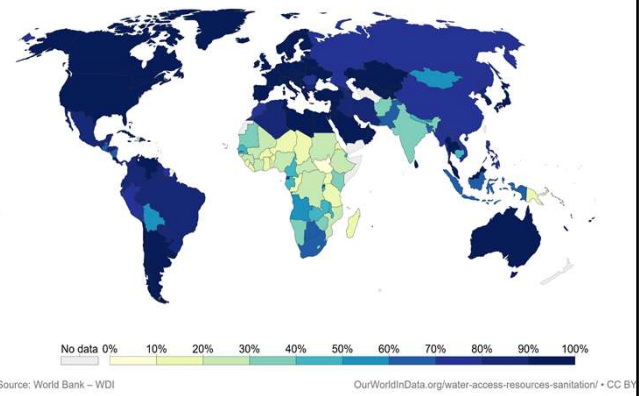


Credit : Oliver Cumming, LSHTM

26

Sanitation crisis

- Access to improved water supply – 77% in 1990, 89% in 2010, 92% access in 2015
- Not so for improved sanitation – 34% still lack access; at the current rate, the SDG goal of 77% access will only be achieved in 2049!



Share of population with improved sanitation facilities, 2015

Improved sanitation facilities include flush/pour flush (to piped sewer system, septic tank, pit latrine), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet.

27

Current global sanitation data

- Unsafe sanitation is responsible for 775,000 deaths each year
- 5% of deaths in low-income countries result from unsafe sanitation
- 2.4 billion people i.e. one-third of the world, does not have access to improved sanitation
- 4.5 billion people (60% of the world) do not have access to safely managed sanitation
- 15% of the world still practice open defecation
- 40% of the world does not have access to basic handwashing facilities
- Unsafe sanitation has a significant impact on childhood stunting

28

Framework for WASH sector improvements in data-poor environments, applied to Accra, Ghana

- Funding: DFID (~ 15% of £4.915 million, as part of Future Proofing African Cities for Sustainable Growth project, grant number 203830); The Ecological Sequestration Trust; Cities Alliance – cities without slums; Imperial PI - Prof Nilay Shah
- Collaborators: Imperial College London, Institute for Integrated Economic Research (IIER), Centre for Remote Sensing and Geographic Information Services, University of Ghana
- Partner: Greater Accra Metropolitan Area (GAMA) authority

Department for International Development

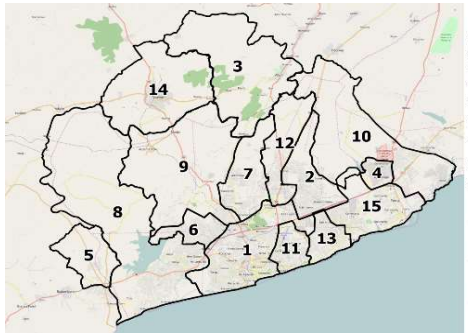
29

Objectives

1. Develop a **data integration framework** on WASH data in GAMA
2. Create a **material flow analysis** to aid data-based policy and infrastructure development for the WASH sector
3. Provide a **robust quantitative mapping** of the **complete anthropogenic WASH flow-cycle**
4. Integrate various available sources using a **process-chain bottom-up engineering approach** to improve the quality of WASH planning

30

Location: Greater Accra Metropolitan Area (GAMA)



1. Accra Metropolitan
2. Adentan
3. Akwapim South
4. Ashaiman
5. Awutu Senya East
6. Ga Central
7. Ga East
8. Ga South
9. Ga West
10. Kpone Katamanso
11. La Dade Kotopon
12. La Nkwantanang Madina
13. Ledzokuku Krowor
14. Nsawam Adoagyiri
15. Tema Metropolitan

Boundaries of GAMA administrative regions from 2012 onwards

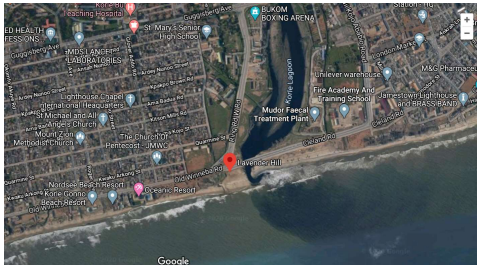
31

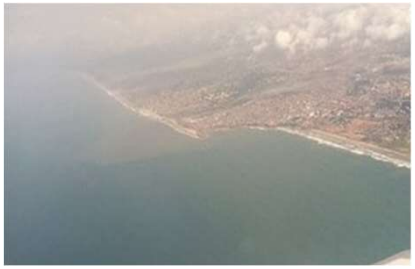
Greater Accra Metropolitan Area (GAMA)

- Over **50%** of Ghanaians live in cities
- **51%** of urban residents live in slums
- Accra's population of **4 million** will likely **double** in **5** years
- No basic services thereby impacting the city's sanitation and drainage
- Neighbourhoods vulnerable to destructive flooding
- Sewage dump sites – Lavendar Hill!

32

Lavendar Hill site





Pic credit: Engineering for Change

Lavendar Hill site

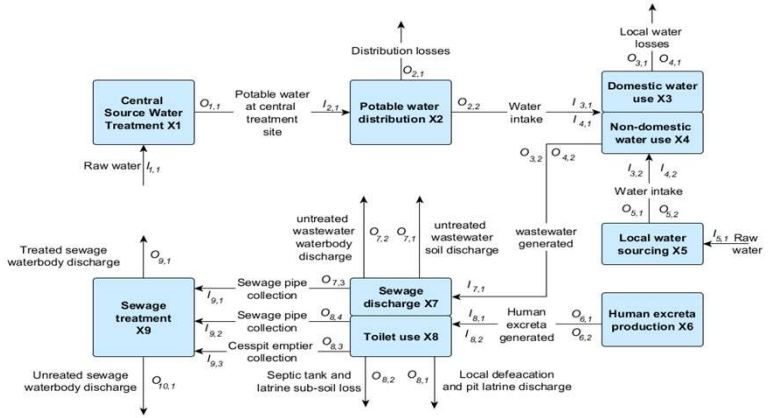
Pic credit: Kojo Emmanuel

Pic credit: Prince Elisha Nsiah-Asamoah & Dr. David Ackah

Lavendar Hill site

Pic credit: Prince Elisha Nsiah-Asamoah & Dr. David Ackah

Framework development and data generation



Water treatment plants

Treatment plant sites	Water source	Technology*	Year of opening	Year of expansion	Capacity in 2010 (m^3 day^{-1})	Capacity in 2015 (m^3 day^{-1})
Weija	Weija lake	Conventional chemical water treatment	1951	1978, 1984, 2002, 2009	245,484	245,484
Kpong	Volta river	Conventional chemical water treatment	1963	1965, 1995, 2015	220,454	434,454
Teshie	Sea	Desalination	2015	-	-	60,000

*Conventional technologies are defined following the American Water Works Association (AWWA) guidelines

37

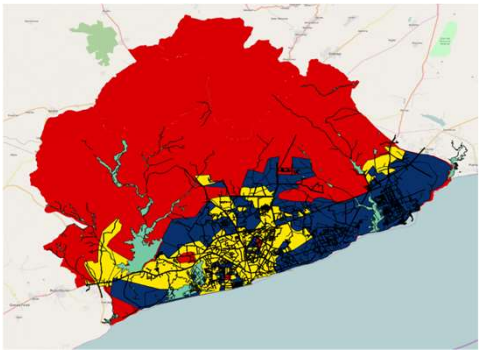
Existing wastewater treatment plants

Site	Year of opening	Capacity (m^3/day)	Comments
Slamson Ghana Korle Lagoon cesspit treatment	2013	400	DANIDA funded
University of Ghana Legon Sewerage	2011	6424	12% of design capacity is operational
Jamestown/Korle Lagoon sewerage plant	2000	16,120	broke down in 2004 due to a malfunctioning intake pump
TEMA septage central sewer	1997	20,000	broke down in 2000
La Palm Royal Beach Hotel, Golden Tulip Hotel, and Nestle Ghana, +others	various	862	privately owned

Total wastewater treatment capacity as at 2016 = 18%

38

Water distribution



Zones in GAMA supplied by pipe and rationing scheme as of August 2015. Areas with no access to pipe supply (red), areas with continuous pipe supply (blue), areas with rationed supply (yellow), water bodies (turquoise), and the pipe network (dark lines). Source of data: Ghana Water Company Limited (GWCL), map data © OpenStreetMap contributors

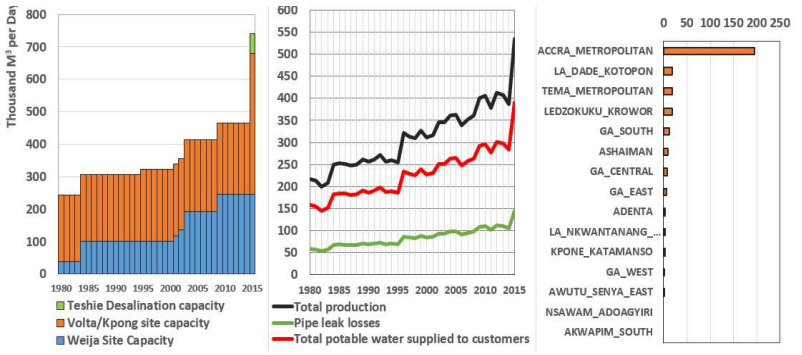
39

Water consumption in litres per capita per day by income

Sourcing condition	Source type	Low income	Medium income	High income
Continuous Piped Water Access	Piped water source	66	90	138
Good intermittent Piped Water Access (80%+ time available)	Piped water source	56	83	110
	Secondary source	0	0	28
Poor intermittent Piped Water Access (<50% time available)	Piped water source	43	54	75
	Secondary source	0	0	15
No Piped Water Access / decentralised source	Secondary decentralised source	32	53	53

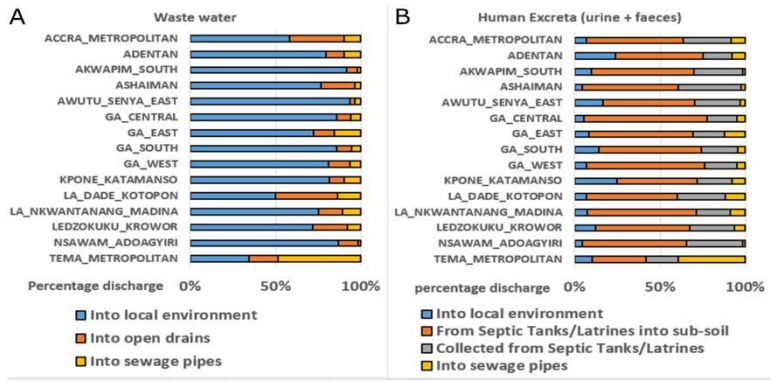
40

Centrally supplied water in GAMA



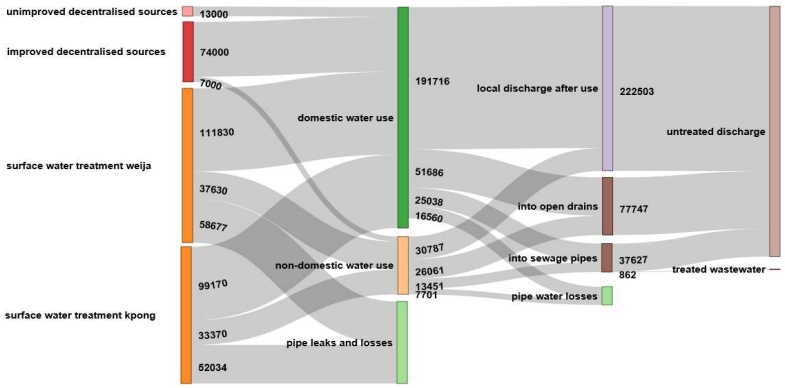
41

Wastewater and human excreta generation per municipality



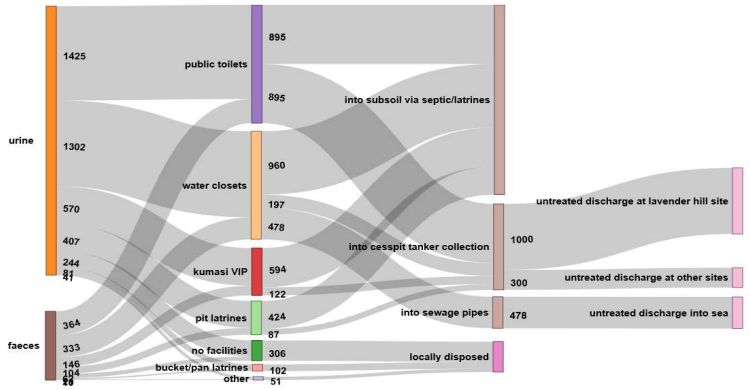
42

Water intake to wastewater discharge in cubic meter per day



43

Human faecal sludge (excreta) discharge



Modified “Shit Flow Diagram, SFD”

44

Breakdown of Results/Outcome

- 96% of the population had access to improved safe water if sachet and bottled water are included, but only 67% if excluded
- 66% of 338,000 m^3/day of generated wastewater is unsafely disposed locally (<5% of households connected to sewer system)
- 23% of generated wastewater enters open drains; 11% into sewage pipes
- Total treated wastewater was <0.5% in 2014 because only 18% of the 43000 m^3/day treatment capacity was operational for sewer system
- Total human excreta estimated as 5110 m^3 (4070 m^3 of urine and 1040 m^3 of faeces generated per day)
- 9% or 468 m^3 per day of human excreta directly discharged into the environment via open defecation or bucket/pan latrines
- 1298 m^3 of excreta is collected via cesspit-emptier services and primarily emptied untreated at the 'Lavender Hill' site into the sea

45

Limitations of study

- Data for the parameter on leakage in the pipe system was found to be limited with only rough estimates of pipe loss values based on the difference between the quantity of water sold and water treated;
- Water use in non-domestic sectors had only indirect estimates available from the GWCL. Data could be generated by carrying out company water use surveys, and by expanding water metering and meter maintenance within GWCL systems
- Availability of more recent household data than 2010 to provide for a more up to data analysis. In particular, figures on household use of non-drinking and drinking water sources, toilets types, and liquid waste discharge were not available; but literature data was verifiable to a good level
- Interpretation of key indicators, such as access to improved sources of water, as these depend on definitions, e.g. which sources are included or excluded

46

Way Forward and impact on GAMA

- Government went into public private partnership (PPP) with Sewerage Systems Ghana Limited SSGL
- SSGL has built two new faecal treatment plants (Lavender Hill Faecal Treatment Plant – near the Korle Lagoon and the Kotoku Faecal Treatment Plant – Adjen Kotoku)
- The new Lavendar faecal waste treatment plant at Jamestown is just a few metres from the infamous dumpsite; Old dumpsite totally decommissioned (no more dumping waste)
- Cesspit emptiers, owned by mostly individuals and some assemblies, arrive every 10 minutes to empty their contents
- The receiving bay of the plant takes a maximum of eight trucks at a time and it takes not more than 10 minutes to empty and clean the trucks
- Rehabilitated Mudor Waste Water Treatment Plant also at Jamestown (last year)
- By-products of the treatment process used as bio char (charcoal from liquid waste)

47

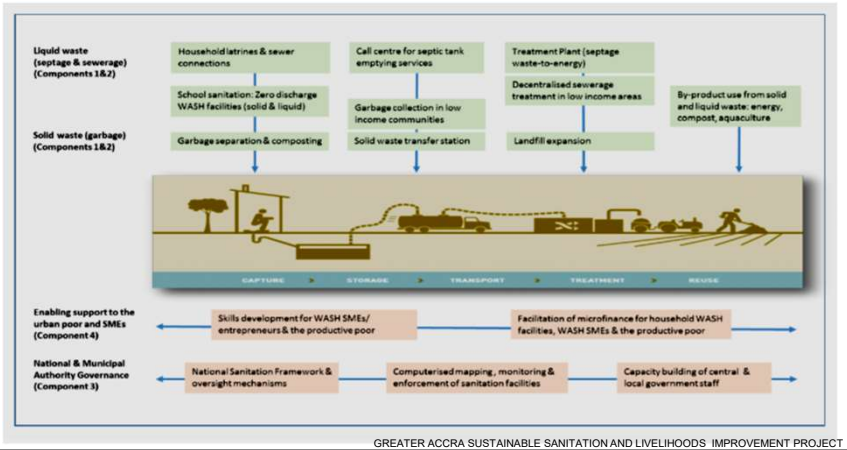
Now…

Pic credit: Edmund Smith-Asante

Pic credit: Reuters news

48

Integrated approach providing support across sanitation value chain



GREATER ACCRA SUSTAINABLE SANITATION AND LIVELIHOODS IMPROVEMENT PROJECT

Transferable learnings/lessons

- Political will
- Right positive attitude to accept and use recommendations
- Proper structure in place (Public-private partnerships, PPP)
- Capacity building
- Behavioural change
- Stakeholder engagement
- Enforcement of new rules

YES…

…We may not get things right initially but with the right attitude, there is always room for progress.

Acknowledgements

GCRF Global Challenges Research Fund
ROYAL ACADEMY OF ENGINEERING
Department for International Development
UKaid from the British people
UKRI Engineering and Physical Sciences Research Council
Cities Alliance Cities Without Slums
ecological sequestration trust
University of Ghana - Legon
Imperial College London
National Institute for Medical Research
Acting for Health
Addis Ababa University
Natural History Museum

Questions???

Twitter: @May_Sule